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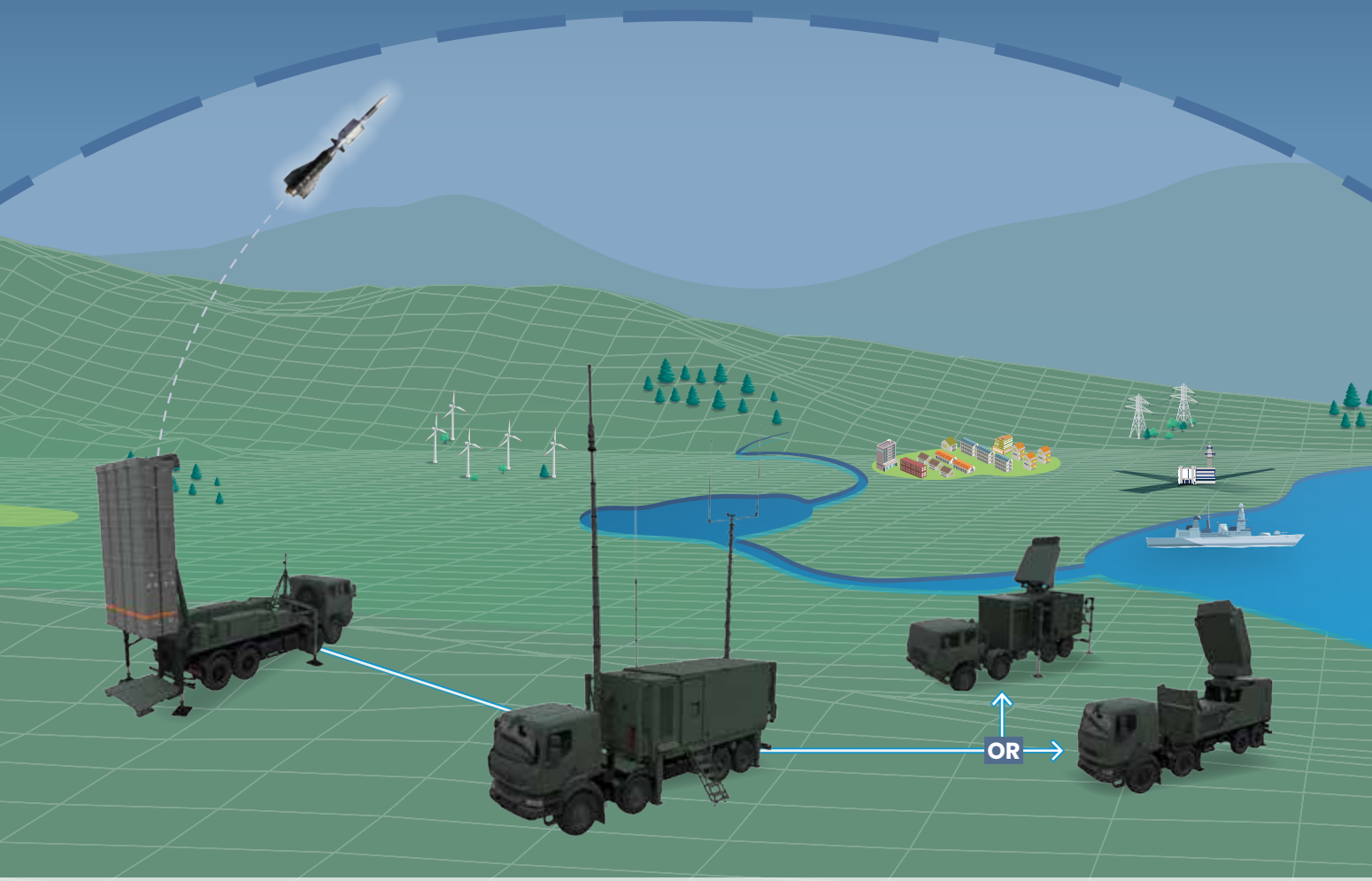

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Prepare for foreseen consequences

As things seem to be heading in the direction of a peace agreement to end (or at least pause) the War in Ukraine, it is worth taking stock of the strategic big picture in Ukraine, and examining how things may look to the recently incumbent Trump administration.

Looking back, Russia has managed to make some significant territorial gains in 2024, at least by the standards of this war, which has been characterised by static and positional fighting for its majority. Yet while Russia's gains were not inconsiderable given the circumstances, neither are they particularly significant in strategic terms.

Added to this, while Ukraine has faced severe manpower and equipment shortages, and its prospects for meaningful counteroffensive efforts still seem bleak, none of the most dire predictions of 2024 came to pass. Ukraine's frontlines did not collapse, Russia did not manage to capitalise on the relative lack of capacity of Ukraine's air defences at the start of 2024 to secure wider air superiority, and indeed the number of bombs fitted with UMPK glide/guidance kits was reported to have dropped over late 2024/early 2025. Perhaps somewhat surprisingly, Ukraine has even managed to maintain a foothold in Kursk. While Russian and North Korean forces have chipped away at this gradually, Ukraine presently retains roughly 40% of the territory it originally captured.

For the US, and perhaps in particular for President Trump, the cause for immediate alarm would seem to be minor. Indeed, in some ways, the War in Ukraine (and associated sanctions) has yielded certain outcomes beneficial to the US – some concrete, others only when viewed through a zero-sum transactional mindset. Yet all seem at risk of generating longer-term negative consequences for US interests downstream.

For starters, the war has shaken many European countries out of their pre-war torpor and kicked off a wave of military modernisation and re-armament programmes. Where in 2021, only six members met the NATO spending target of 2% of GDP on defence, by 2024 that figure became 23 members.

Granted, in some cases the 2% target appears to have been achieved through some creative accounting, such as including value added tax (which is typically reimbursed), or the inclusion of police units, military pensions, intelligence-gathering, or the costs of overseas stabilisation or peacekeeping missions, into the spending figures, along with various other tricks. Nonetheless, the overall increase in the number of procurement programmes for many kinds of military hardware does at least serve as an imperfect indicator that many European countries have started to take military modernisation more seriously and are broadly going down the right track.

However, along with this spending boost and amid sluggish economic growth, senior figures at the European level have begun to question the fairness of the current trans-Atlantic defence-industrial relationship, perhaps most notably Mario Draghi, serving as the EU rapporteur for competitiveness. European figures will have been observing with trepidation Trump's recent imposition of a 10% tariff on China, and (for now) pausing his threat to levy a 25% tariff on Canada and Mexico. With the spectre of trade war hanging over the world, European leaders will seek to maintain stability, perhaps even at the cost of distancing themselves from the US.

Secondly, Europe has broadly divested from Russian oil and gas; at least for the most part – flows from the Turkstream pipeline, off-the-books ship-to-ship transfers, and imports of petroleum by-products originating from Russia but processed elsewhere (such as India), are understood to be ongoing. This divestment has directly benefitted the US hydrocarbon industry, which has been able to sell liquefied natural gas (LNG) to Europe at significantly higher prices than those previously paid for Russian gas.

Here, it should be noted that the resulting economic impact from energy price increases has become an ongoing political source of tension in Germany in particular, whose economy previously relied heavily on cheap Russian gas. This has been especially notable among far-right/left extremist German parties such as the AFD and the BSW, who see the US as getting rich off Germany's misfortune, and for whom the issue is rhetorically both a strong source of anti-American sentiment, and a driver for rapprochement with Russia.

Their broad message appears to be resonating with many Germans, with AFD polling at 22% at the time of writing, and on track to take second place in Germany's Federal Election on 23 February 2025. This limits the prospects for Friedrich Merz' CDU/CSU, which is polling at 30%, and will need coalition partners to form a majority. Previously, the CDU/CSU held the policy of maintaining a cordon sanitaire around the AFD, which would have meant in this election that the only realistic options for coalition partners look to be the SPD (16%) and Greens (13%), both of whom were members of the last government. However, this looks to be in the process of crumbling – as demonstrated on 29 January 2025 when CDU leader Friedrich Merz relied on AFD votes to get an anti-immigration motion through Germany's parliament. As such, it is plausible that Germany's future governing coalition could contain a fairly strong anti-American component, creating a divide between the US and a key strategic ally.

Finally, the war has severely degraded Russian economic, military, and overall state capacity; arguably decreasing the strategic threat posed by Russia to the US, and limited its capacity to cause trouble outside Ukraine. At the same time, this has pushed Russia closer to both China and Iran, and precipitated the rapid collapse of the Assad regime in Syria. All are likely to result in headaches for the US down the road.

Mark Cazalet

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Cover Photo: A medium-range ballistic missile (MRBM) target is launched from Makaha Ridge, part of the Pacific Missile Range Facility (PMRF) in Kauai, Hawaii, during Flight Test Aegis Weapon System 31 Event 1a (FTM-31 E1a) on 30 March 2023.
[Missile Defence Agency/Mark Wright]

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Danes strengthen defence plans for High North in wake of Trump's avarice for Greenland

(pf) The political parties behind the Danish Defence Agreement have settled on a new accord regarding security in the Arctic and North Atlantic region, the Danish Ministry of Defence (MoD) announced on 27 January 2025.

This first agreement contains initiatives with financial commitments of a value of approximately DKK 14.6 billion (EUR 1.96 billion) and the parties have agreed on the need for a second agreement on this issue to be concluded in the first half of 2025, the MoD added.

[Danish MoD]

The agreement to bolster the High North no doubt responds to the effects of global warning on the region, which could become easier to navigate and exploit and thus become the subject of geopolitical competition. However, the Danish move also comes in the wake of US President Donald Trump's attempts to strong-arm Denmark – a NATO ally – into allowing the United States to acquire Greenland: a self-governing country within the Kingdom of Denmark (which also includes metropolitan Denmark and the Faroe Islands).

The Danish Defence Agreement came into being on 28 June 2023, when the Danish government (consisting of the Social Democratic Party, the Liberal Party and the Moderates), together with the Green Left, the Denmark Democrats, the Liberal Alliance, the Conservative Party, the Social Liberal Party, the Danish People's Party and the New Right, agreed on the overall framework for Danish defence and security from 2024 through to 2033.

The parties behind the new agreement announced on 27 January aim to improve capabilities for surveillance and maintaining sovereignty in the Arctic and North Atlantic. At the same time, supporting NATO efforts in the High North is recognised as essential to strengthening regional security and defence overall.

Among other measures, the new agreement includes the following initiatives:

- three new Arctic naval vessels to ensure that tasks around Greenland can be carried out more effectively and with greater flexibility. The ships will be able to carry other capabilities with them such as helicopters and unmanned aerial vehicles (UAVs);
- two long-range UAVs with the ability to conduct surveillance over large areas at great distances and provide detailed surveillance;
- satellite capacity and ground-based sensors to strengthen situational awareness and intelligence by identifying and surveying activities in areas such as the Arctic and North Atlantic;
- increased access and availability for young Greenlanders to "acquire important skills allowing them to take responsibility for preparedness".

Trump returned to his first-term ambition to acquire Greenland – along with the Panama Canal and Canada – in a 7 January 2025 new conference at his Mar-a-Lago estate in Palm Beach, Florida. When asked at the time, he disturbingly refused to rule out using military force to pursue those ambitions.

While the Danish response to this was just as affronted as the first time round, this time the Danes are taking the issue much more seriously.

In mid-January the newly installed President Trump had a 45-minute phone conversation with Danish Prime Minister Mette Frederiksen that was reported by a source who witnessed it as "horrendous". The source told the *Financial Times* that Trump became aggressive when he was told that Greenland was not for sale and threatened to impose punitive tariffs on Denmark if it refused to give Greenland up.

UK steps up efforts to head off Russian interference with critical undersea infrastructure

(pf) The UK's Royal Navy (RN) has been stepping up its efforts to counter suspected Russian interference with the critical undersea infrastructure around the British Isles, with UK Defence Secretary John Healey acknowledging that he has changed the RN's rules of engagement to facilitate a more robust response.

In a statement to the UK House of Commons on 22 January 2025, Healey noted that the Russian ship *Yantar* entered the UK Exclusive Economic Zone about 45 nautical miles off the British coast on 20 January and had been monitored by the RN before moving into the North Sea.

"Let me be clear: this is a Russian spy ship used for gathering intelligence and mapping the UK's critical underwater infrastructure," said Healey. "For the last two days the Royal Navy has deployed HMS *Somerset* [a Type 23 frigate] and HMS *Tyne*

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[a River-class offshore patrol vessel] to monitor the vessel every minute through our waters. And I changed the Royal Navy's rules of engagement so that our warships can get closer and better track the *Yantar*," he added.

Healey noted, however, that this was the second time that *Yantar* had entered British waters in recent months.

"In November the ship was also closely watched and detected loitering over UK critical undersea infrastructure," said Healey, adding, "To deter any potential threat I took measured steps then as part of a clear and direct response to the Russian vessel. RAF maritime patrol aircraft, alongside HMS *Cattistock* [a Hunt-class mine countermeasures vessel], HMS *Tyne* and RFA Proteus [a survey and surveillance ship], were deployed to shadow *Yantar*'s every movement.

"Today," Healey continued, "I also want to confirm to the House that I authorised a Royal Navy submarine – strictly as a deterrent measure – to surface close to *Yantar* to make clear that we had been covertly monitoring its every move. The ship then left UK waters – without further loitering – and sailed down to the Mediterranean."

Healey stated that he wanted Russian President Vladimir Putin "to hear this message: we see you; we know what you are doing; and we will not shy away from robust action to protect this country. And with our NATO allies we are strengthening our response to ensure that Russian ships and aircraft cannot operate in secrecy near the UK or near NATO territory."

The UK Ministry of Defence (MoD) announced on 6 January 2025 that the UK-led multinational Joint Expeditionary Force (JEF) had activated an advanced reaction system to track potential threats to undersea infrastructure and monitor Russia's 'shadow fleet' of sanctions-busting tankers in response to reported damage to a major undersea cable in the Baltic Sea.

The operation, activated around the start of the year and named 'Nordic Warden', harnesses artificial intelligence (AI) to assess data from a range of sources, including the Automatic Identification System (AIS) that ships use to broadcast their position, to calculate the risk posed by each vessel entering areas of interest.

The activation of 'Nordic Warden' came in response to reported damage caused on 25 December 2024 to the Estlink2 cable, which carries electricity from Finland to Estonia. The Finnish authorities suggested at the time that the damage may have been caused by the tanker *Eagle S*, which forms part of Russia's shadow fleet of vessels it uses to attempt to bypass international sanctions.

Latvian MoD orders 42 ASCOD IFVs from GDELS-Santa Bárbara Sistemas

(mc/pf) The Latvian Ministry of Defence (MoD) has awarded General Dynamics European Land Systems-Santa Bárbara Sistemas (GDELS-SBS) a contract for the delivery of an initial batch of 42 ASCOD infantry fighting vehicles (IFVs), the company announced on 30 January 2025.

[Latvian National Armed Forces]

The initial contract is valued at approximately EUR 373 million and includes a logistics support package. In response to questions from *ESD*, GDELS representatives revealed that the first vehicle would be delivered in summer of 2026 and that "all the rest of the batch will be delivered within 2027".

The IFVs to be delivered will be the latest iteration of GDELS' ASCOD family of tracked vehicles and will include features specific to Latvian requirements. While GDELS declined to confirm certain details regarding specific subsystems on Latvia's chosen ASCOD configuration, a representative stated that the version pictured on Latvian trials would be "pretty close to that configuration", while noting that "there will be some tendered options to be confirmed by the customer".

Taken at face value, this would suggest that Latvia has opted for the most recent iteration of the ASCOD tracked platform, fitted with Soucy composite rubber tracks (CRTs) and an Elbit Systems UT30 Mk2 unmanned turret armed with a Mk44 Bushmaster II 30 mm automatic cannon.

Alongside this, a photo of a scale model of ASCOD was shared on X/Twitter by Latvian Defence Minister Andris Spruds, along with photos of the contract signing ceremony. Notably, the model in question was equipped with the Elbit Systems Iron Fist hard-kill active protection system (APS). This hints at some of the 'options' to which the GDELS representative may have been alluding.

When *ESD* asked whether an anti-tank guided missile was part of the turret package, the GDELS representative stated, "It is an option that the Latvian Army considers to be integrated in the turret, yes", but did not confirm whether a specific missile had been selected.

As for the tracked platforms themselves, the GDELS representative confirmed to *ESD* that these would be produced at the GDELS-Santa Bárbara Sistemas facilities in Spain.

With regard to notable changes for Latvia's configuration of the ASCOD platform specifically, the GDELS representative noted that this included an "open electronic architecture that allows now the seamless integration of different equipment, so will integrate the latest C4I system".

The Latvian Land Forces currently operate an AFV force consisting of around 170 ex-British Army Combat Vehicle Reconnaissance (Tracked) variants, which the ASCOD IFVs will replace, plus a growing fleet of Patria 6×6s, of which 256 have been ordered under the Common Armoured Vehicle System (CAVS) framework agreement.

UK announces GBP 4.5 million boost for Ukraine in 2025 as Starmer visits Kyiv

(pf) In 2025 the UK government will give more military support to Ukraine than ever before, the UK Ministry of Defence (MoD) asserted on 16 January 2025.

GBP 3 billion (EUR 3.55 billion) has already been committed for lethal aid, while the first GBP 1.5 billion from a GBP 2.26 billion loan as part of the G7 Extraordinary Revenue Acceleration (ERA) scheme set to be released for major procurement projects, said the MoD. The loan will be repaid using the extraordinary profits on immobilised Russian sovereign assets.

The MoD statement was issued the same day UK Prime Minister Sir Keir Starmer made his first state visit to Kyiv, where he told Ukrainian President Volodymyr Zelenskyy, "We are with you not just today, for this year or the next, but for 100 years – long after this terrible war is over and Ukraine is free and thriving once again."

[V Zelenskyy X account]

The GBP 4.5 billion boost for Ukraine in 2025 will see the UK procure hundreds more air defence systems, first-person-view drones and essential equipment support to sustain Ukrainian forces on the front line.

Starmer also told Zelenskyy that nothing is off the table when it comes to the UK's training offer for Ukraine in 2025, with the UK MoD noting that the UK will expand its offer to train members of Ukraine's armed forces, building on the success of Operation 'Interflex' that trained more than 51,000 Ukrainian recruits over the last two years. Ukrainian officer cadets will be trained at the Royal Military Academy Sandhurst, helping to develop Ukraine's future military leaders. British officer cadets will also be able to attend training colleges in Ukraine, learning first hand from the Ukrainian armed forces about their fight on the battlefield.

During Starmer's visit to Kyiv it was also disclosed that a new UK-designed air defence system called Gravehawk has been rapidly developed to meet Ukrainian battlefield requirements, jointly funded by the UK and Denmark. Little is known about this system, but the MoD described it as an "innovative system, which is the size of a shipping container, [that] is able to retrofit air-to-air missiles for ground-based air defence, meaning it can use Ukrainian missiles already in their armed forces' possession".

Two Gravehawk prototypes were tested in Ukraine in September 2024 and a further 15 will follow this year, the MoD said.

Rolls-Royce secures largest ever contract with UK MoD to support Royal Navy's submarines

(pf) In signing the landmark GBP 9 billion (EUR 10.7 billion) Unity contract, which covers all aspects of research and technology, design, manufacture and in-service support of the nuclear reactors that power the UK Royal Navy's current and future fleet of submarines, Rolls-Royce has secured the largest ever contract with the UK Ministry of Defence (MoD) in its history.

[Crown Copyright]

The deal was announced on 24 January 2025 by UK Defence Secretary John Healey during a visit to Rolls-Royce's nuclear reactor production facility in Derby.

Alongside creating and maintaining 5,000 long-term UK jobs, the agreement also "streamlines previous contracts and incentivises more efficient delivery, resulting in better value for money for the taxpayer through savings of more than GBP 400 million over the eight-year contract", the MoD stated in a press release.

"As part of our national endeavour to maintain a continuous at-sea deterrent, this agreement will help streamline decision-making and foster the kind of close partnership between industry and government that is essential to our success," the UK MoD added.

The agreement reinforces the UK government's commitment to the 'triple-lock' on the UK nuclear deterrent, which covers: the building four new Dreadnaught-class nuclear-powered ballistic missile submarines (SSBNs) in Barrow-in-Furness to replace the current Vanguard-class SSBNs; maintaining the UK's continuous at-sea deterrent with the Vanguard class; and delivering all future upgrades needed for those submarines.

Rolls-Royce designs, builds and maintains all of the nuclear reactors that power the Royal Navy's fleet of nuclear-powered attack and ballistic missile submarines. The eight-year Unity contract will provide full support of the Royal Navy's in-service submarine fleet throughout the period, continued support of the build and commission of the Dreadnought-class SSBNs and supports the beginning of previously announced nuclear-powered submarine plans under the strategic SSN-AUKUS contracts agreed with the United States and Australia.

First RCH 155 wheeled SPH for Ukraine rolled out in Kassel

(gh) In front of a high-ranking audience headed by German Defence Minister Boris Pistorius and Ukrainian Ambassador Oleksii Makeiev, KNDS presented the first RCH 155 wheeled self-propelled howitzer (SPH) for Ukraine at the company's production site in Kassel on 13 January 2025.

The combat vehicle was symbolically handed over by KNDS CEO Ralf Ketzel. The RCH 155 wheeled SPH is a combination of the best of two worlds, Pistorius said: the tried-and-tested drive module of the GTK Boxer and the powerful weapon system of the KNDS Panzerhaubitze 2000 (PzH 2000) tracked 155 mm SPH. Ukraine will thus become the sixth Boxer user after Germany, the Netherlands, Lithuania, Australia and the United Kingdom. Ukraine will be the first user of the Boxer SPH ahead of Germany and the UK, which also intend to purchase the vehicle.

In 2022 Ukraine ordered 18 RCH 155 SPHs, financed by funds from the German government's modernisation initiative. One year later the order was extended by 36 to 54 units. When asked, Pistorius quoted an investment sum of EUR 890 million. The deliveries will extend beyond 2027.

The SPH that has now been handed over will initially be used for training in Germany. As Ketzel explained, together with the Boxer RCH 155, digital fire control systems will be delivered in the Dingo 1 protected transport vehicle and the Boxer RCT30 armoured personnel carrier, which together form the basis of the training. The training is to be carried out in March/April 2025, partly at KNDS and partly at the German artillery school in Idar-Oberstein, and will last around two months. Only then can the system be handed over to the troops in Ukraine. Six more systems are to follow this year. The number of fire control systems integrated on Dingo 1s and Boxer RCT 30s has not been disclosed.

[Bundeswehr]

In total, Ukraine will receive enough systems to equip three artillery battalions, Pistorius noted, meaning that the RCH 155 and associated vehicles will make a significant contribution to the development of the Ukrainian armed forces' capabilities. Pistorius also referred to the deliveries of PzH 2000s; in addition to 11 SPHs from other countries, Germany has handed Ukraine 14 PzH 2000s from Bundeswehr stocks and financed 11 more from industrial stocks, which has increased the firepower of Ukrainian artillery units over the shorter term. Another 18 newly built PzH 2000s are to follow by mid-2027, giving a total of 54 such SPHs, with which a further three artillery battalions can be equipped.

Germany takes final step to full membership of CAVS programme

(pf) Germany has officially joined the Common Armoured Vehicle System (CAVS) Framework Agreement, becoming the fourth country to do so after Finland, Latvia and Sweden, Patria announced on 30 January 2025.

[Patria]

Joining the Framework Agreement, which allows Germany to make serial procurements of CAVS vehicles based on the Patria 6×6, completes a journey that Germany began in 2022, when it signed a statement of intent regarding CAVS. Germany then joined the CAVS Technical Arrangement in 2023 and the programme's research and development agreement in 2024.

Within the CAVS programme the 6×6 armoured vehicle system development is led by Patria, but the vast majority of ordered vehicles are supplied by utilising the member nations' local industrial capabilities, with every new nation inherently reinforcing the security of supply for the whole collaborative programme.

The Bundeswehr intends to procure the Patria 6×6 armoured personnel carrier, which is the basis for CAVS, to replace almost a thousand Fuchs armoured transport vehicles. Germany also intends to procure a CAVS heavy mortar variant armed with Patria's turreted semi-automatic 120 mm NEMO (NEw MOrtar) system.

Patria has already received orders for over 800 Patria 6×6 vehicles and has delivered more than 200.

Turkish MND announces steel has been cut on future carrier, AAW destroyer and submarine programmes

(pf) The Turkish Ministry of National Defence (MND) has simultaneously initiated three major naval programmes.

[Turkish MND]

During its weekly press conference on 2 January 2025 the MND announced steel-cutting ceremonies for the MUGEM (Milli Uçak Gemisi – National Aircraft Carrier), TF-2000 anti-air warfare (AAW) destroyer and MILDEN (Milli Denizaltı – National Submarine) programmes.

The steel-cutting steel ceremonies for the MUGEM and TF-2000 programmes were conducted in Istanbul Naval Shipyard, while the ceremony for the MILDEN programme was held at the Gölcük Naval Shipyard.

Unveiled publicly in February 2024, the MUGEM programme will produce an aircraft carrier that is 285 m long with a displacement of 60,000 tons and the capacity to accommodate 50 manned and unmanned aircraft (20 on deck and 30 in the hangar). The ship is set to feature three runways – two for take-offs and one for landings – and will initially feature a 'ski-ramp' design. Subsequently, however, an indigenous catapult system is expected to replace the ski-ramp. Aircraft slated for service on the future Turkish carrier include the Turkish Aerospace Anka-3 and Baykar Bayraktar Kizilelma jet unmanned combat air vehicles (UCAVs) as well as Baykar Bayraktar TB3 UCAVs, various rotary-wing aircraft and possibly navalised Turkish Aerospace Hürjet light combat aircraft.

The TF-2000 AAW destroyer project, meanwhile, is the final phase of Turkey's MILGEM programme and was initiated in July 2017. With an overall length of 149 m, the TF-2000 destroyers will be the largest ships built under the MILGEM programme, which has so far led to the construction of corvettes and frigates. The destroyers will feature Turkish designed weapons that will include surface-to-air missiles intended to counter a wide variety of airborne threats, including ballistic missiles.

Turkey's ambitious MILDEN national submarine programme was initiated in March 2012 and is intended to deliver submarines to the Turkish Navy by the mid-2030s. The boats will be more than 80 m long, have a surface displacement of around 2,700 tons and will feature an air-independent propulsion (AIP) system to facilitate stealthy operations and extend operational endurance. MILDEN submarines will be armed with weapons that will include the Akya heavyweight torpedo and Atmaca anti-ship missile produced by Turkish company Roketsan as well as the Gezgin land attack cruise missile, which is currently under development.

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Armour remains vital and 'recce strike complex' is essential, asserts head of British Army

(pf) While bomb-laden unmanned aerial vehicles (UAVs) and loitering munitions have certainly presented a new threat on the battlefields of Ukraine in recent years, the role of heavy armour still remains vital, while development of an overall 'recce strike complex' is essential, the head of the British Army has asserted.

Speaking on 21 January at Defence iQ's 2025 International Armoured Vehicles (IAV 2025) conference, held at the Farnborough International Exhibition Centre, British Army Chief of the General Staff (CGS) General Sir Roly Walker asserted that, while "there are lots of dead tanks littering Ukraine, the tank is not dead" and that armour "remains critical" as a battle-winning asset.

Gen Walker noted that both Russian and Ukrainian forces "have arguably shifted from where the weighting of their lethality is in the business of close combat to an integrated recce strike system operating over ever-increasing ranges, and it's proving to be extraordinarily effective in the hands of competent and creative operators".

This, the CGS asserted, is a vital lesson in the effective application of modern technology, such as networking and the use of artificial intelligence (AI), that can speed up the 'observe, orient, decide, act' (OODA) loop and "reduce the cognitive burden of sensing and shooting faster.

"The armoured vehicle, the attack helicopter, the underground bunker, all the fast-moving assault section, are all now becoming effectively nodes on a highly dispersed and distributed network that is the foundation of modern all-domain fighting power," he said.

One consequence of this, noted Gen Walker, is that Ukrainian forces, who arguably cannot sustain losses to match the Russians' 'meatgrinder' approach to the war in Ukraine, in which personnel losses are of little consequence, are placing a premium "on developing more attritable and consumable technologies, which sharpens up their lethality even more and generates combat mass".

The CGS emphasised that "to fight and win on and from the land it is still true that you must be able to seize and hold ground. It follows, therefore, that our land forces must be able to close with and kill the enemy in the most dangerous and difficult circumstances. And the front lines of modern battlefields show you what that looks like and feels like in the close fight – and it is utterly terrifying for the soldiers that have to work there. Without armour, you are just not in the business of fighting and winning in the most dangerous and difficult circumstances.

"We will need armoured vehicles to fight from, no question," said Gen Walker. "And we will face armoured vehicles en masse, no question, but I'm with the Ukrainian way when it comes to the balance of the survivable, the attritable and the consumable platforms within that system. And that is exactly what we are doing."

"My contention," the CGS explained, "is that there are now many more arms to combine in that battle, such as the uncrewed air systems, the electronic warfare systems, as well as the information systems, and much more can be done to kill the enemy from distance and in the deep – and so we should."

Italy's Admiral Cavo Dragone takes over as chair of NATO Military Committee

[NATO]

(pf) Italian Admiral Giuseppe Cavo Dragone assumed the role of chair of the NATO Military Committee on 17 January 2025, officially receiving the gavel from his predecessor, Dutch Admiral Rob Bauer, during a special session of the Military Committee in Brussels.

In his farewell address Adm Bauer, who became chair of the NATO Military Committee on 25 June 2021, talked of the importance of trust and co-operation between allies at both the political and military level, stressing that it is crucial that the committee maintains its independent role in providing unfettered advice to the political leaders of NATO countries.

In his inaugural address to the Military Committee Adm Cavo Dragone highlighted his ambition to further build co-operation, cohesion and collaboration between the NATO allies and partners, addding that, "Alone, we may go faster, but together, we can go further."

Adm Cavo Dragone's ability to foster co-operation is underscored by his years of dedicated service to the alliance through his military service in the Italian armed forces. He has previously served as commander of the Italian Joint Operations Headquarters, chief of the Italian Navy and as the Italian chief of defence. Adm Cavo Dragone has also earned a number of awards and recognitions from across the alliance, including the Knight Grand Cross and Order of Merit of the Italian Republic.

With his new role, Adm Cavo Dragone will become NATO's senior military officer: a role that covers far more than simply chairing the Military Committee. He will now serve as the alliance's primary spokesperson on all military matters and act as the principal military adviser to the NATO secretary general. Most crucially, he will be the conduit through which consensus-based advice from the chiefs of defence of all NATO countries is communicated to NATO's political decision-making bodies.

Following the session, during a special ceremony, the NATO headquarters said goodbye to Adm Bauer, who expressed why the alliance is so vital in today's global environment by stating, "We are the shield for the innocent. We are what stands between freedom and oppression."

[Leonardo]

Leonardo completes sale of UAS business line to Fincantieri

(pf) Leonardo announced on 14 January 2025 that it had completed the sale of its Underwater Armaments & Systems (UAS) business line to Fincantieri.

Under the binding agreement signed on 9 May 2024, at the time of closing Leonardo received a payment of EUR 287 million, based on the fixed enterprise value component of EUR 300 million. The variable component, up to a maximum of EUR 115 million, along with standard price adjustments, will be determined following the approval of UAS's final 2024 financial results. The total maximum enterprise value is EUR 415 million.

UAS began as Whitehead Alenia Sistemi Subacquei: a Finmeccanica company established in 1995 by the merging of the underwater activities of Whitehead, Elsag Sistemi Navali and USEA. The company specialised in the construction of submarine defence systems and in particular torpedoes, countermeasures and sonars.

In early 2016, however, the company merged into Leonardo, becoming a business line, and was renamed Underwater Armaments & Systems (UAS). The business line also includes a 50% participation in GEIE EuroTorp (established with Naval Group and Thales), which is dedicated to the design and construction of the MU90 light torpedo, and is resident at two locations in Italy: Livorno and Pozzuoli.

In 2023 the UAS line of business generated revenues of approximately EUR 160 million and an EBITDA of EUR 34 million.

ELT Group signs MoU with SAMI-AEC as part of wider Italian-Saudi industrial co-operation

(pf) Italy-headquartered defence electronics house ELT Group has signed a memorandum of understanding (MoU) with SAMI Advanced Electronics Company (SAMI-AEC): a subsidiary of Saudi Arabian Military Industries (SAMI) and a prominent player in the Saudi defence industry.

[ELT Group]

The MoU was one of 26 such agreements signed during a Saudi-Italian high-level roundtable meeting in AlUla, Saudi Arabia, on 26 January 2025 involving Italian Prime Minister Giorgia Meloni, Saudi Minister of Investment Khalid Al-Falih, CEOs, private-sector leaders and representatives from major companies of both countries.

The ELT Group/ SAMI-AEC MoU builds upon the agreement signed at the Cernobbio Forum in September 2024 between ELT Group, the Ministry of Investment of Saudi Arabia (MISA) and the Kingdom's General Authority for Military Industries (GAMI). By aligning its activities with Saudi Arabia's Vision 2030 objectives, ELT Group aims to explore collaboration opportunities in the aerospace and defence sectors, contributing to the localisation of advanced technologies.

Reducing the cost of tactical BMD

Dr Sidharth Kaushal

With adversary ballistic threat precision increasing, and the cost of ballistic missile defence rising, many assumptions within our system design requirements for ballistic missile defence need reviewing. This analytical deep dive explores how integrating sensors, adopting 'high-low' interceptor mixes, and reconsidering traditional metrics of success could reshape how we think about ballistic missile defence.

Defending forces in the field from ballistic threats is not a new challenge and has been a consideration for Western militaries since the 1980s when the USSR fielded the OTR-23 OKA SRBM. The threat posed by tactical and theatre level ballistic missiles was further underscored during the 1990s, when Iraqi Scud missiles struck US Barracks at Dharan in Saudi Arabia. However, the threat was framed primarily in terms of political risk. Since relatively limited casualties had doomed western expeditions in Lebanon and Somalia among other instances, it was presumed that even limited successes for adversary ballistic missile arsenals could pose unacceptable political risks in an age of wars of choice. Adversary arsenals were not especially large, nor especially capable (the variants of the Scud missile, for example, have a CEP of around 450 m), but they did not need to be to score a lucky hit.

In this context, achieving a defence that was as airtight as possible against a limited threat was the paramount concern. As a consequence, maximising the effectiveness of both sensors and effectors against different ballistic target types such as short-range ballistic missiles (SRBMs), medium-range ballistic missiles (MRBMs), and intermediate-range ballistic missiles (IRBMs) was the key consideration which led to the emergence of specific solutions to individual parts of the threat spectrum. Ballistic missile defence (BMD) systems, such as THAAD, which have specific utility against MRBM and IRBM targets (their IR seekers being of more limited utility at the altitudes at which many SRBMs spend most of their trajectories), were paired with shorter-range systems such as PATRIOT PAC-3 MSE built to provide functionality against SRBMs.

AUTHOR

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A Terminal High Altitude Area Defense (THAAD) interceptor launched from the Pacific Spaceport Complex Alaska in Kodiak, Alaska, during Flight Test THAAD (FTT)-18 on 11 July 2017. During the test, THAAD successfully intercepted an air-launched, IRBM-representative target. [MDA/Leah Garton]

The challenge which the BMD architectures developed over the previous several decades will face is twofold. First, ballistic threats are increasingly coming to combine both mass and precision. For example, Russian ballistic missile salvos against Ukraine have increasingly come to comprise a high-low mix, combining the Iskander-M 9M723 (an SRBM with a circular error probable (CEP) of around 10 m) with North Korean KN-25 SRBMs and Tochka-U tactical ballistic missiles (TBMs) which have considerably lower accuracy but which force the expenditure of interceptors. In the Pacific, the PLA fields a robust and growing arsenal of short-, medium- and intermediate-range ballistic missiles. Between 2015 and 2024, for example, the PLA Strategic Rocket Force produced several hundred DF-26 IRBMs. This poses a challenge to BMD architectures comprised of systems optimised against specific threat and altitude profiles which can, necessarily, only be procured in comparatively limited numbers if each layer

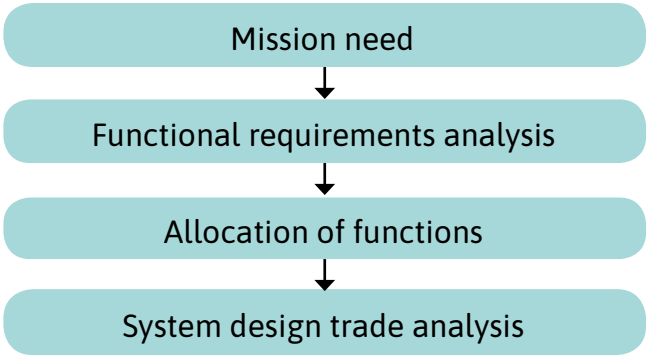
of a BMD architecture is to be separately resourced. Even so, however, one cannot ignore specific components of the threat spectrum given that many of the systems involved will be used in convergent strikes on the same targets. A recent example of this is the Russian strike on Dnipro which involved the RS-26/Oreshnik IRBM and the KH-47M2 Kinzhal (which is effectively an air-launched variant of the 9M723 SRBM). Compounding this is the fact that ballistic threats are joined by air breathing threats such as cruise missiles and UAVs. The risk is that the more layers one adds to an air defence system, the more poorly-resourced each layer becomes.

Secondly, the production of interceptors is constrained by a number of factors. Key among them is the fact that the availability of a number of long-lead items is heavily constrained. While industry stockpiling can somewhat mitigate the effects of this challenge, it is only a partial solution given the inherent inefficiencies involved in stockpiling. Moreover, many inputs such as solid fuel and the microchips involved in guidance systems are fungible and thus required by other complex weapons.

As a consequence, the question of how the costs of ballistic missile defence and in particular BMD for fielded forces at tactical and operational ranges might be reduced is a pressing one.

A different operational approach

A major consideration which shapes the conduct of BMD and integrated air and missile defence (IAMD) more broadly is the requirement for a high probability of kill (Pk), which in turn determines system design and requirements. This is, as noted, the legacy of an era in which a high level of security against a moderate-sized threat was required. To be sure, prioritisation does occur in the form of critical asset lists and defended asset lists, but once a target is prioritised, a very high Pk against an incoming target is the norm and this in turn determines the single-shot probability of kill (SSPk; the Pk of any given interceptor) and thus the design requirements of interceptors. The process by which requirements are generated involve the following steps:



▲ Graphic shows the process by which BMD and IAMD requirements are generated. Based on information from: Warren Boord and John Hoffman, Air and Missile Defence Systems Engineering (New York:Taylor and Francis, 2016). [Sidharth Kaushal]

Mission requirements are defined in terms of the physical characteristics of the threat, such as speed and altitude, which in turn define system requirements in terms of characteristics such as detection ranges and integration rates (for sensors) or kinematics (for seekers). Notably while trade-offs are discussed, this occurs later in the process after system requirements have been defined and so primarily relate to the choices to be made between, for example, seeker types (where range and resolution must be traded) rather than with respect to more fundamental questions regarding scalability and the capacity to meet a definition of sufficiency that is defined in relation to an operational requirement. Rather, expected Pks are assumed to be high.

This approach is rather problematic because when interceptor design is based on a Pk that is determined at least to some degree in isolation from the operational environment, this necessarily leads to 'gold-plating', since the determinant of success is based on engineering qualities rather than desired effects. This represents a challenge in a context where the expectation of being able to intercept every incoming target is both unrealistic and in many cases operationally unnecessary.

Instead, the required Pk might itself be understood in terms of the level of acceptable risk in a specific operational context. This in turn depends on an opponent's understanding of the criteria for inflicting crippling damage on a target site, and their capacity for salvo coordination. To use an example, Russian military theorists assume that it requires 60 cruise or ballistic missiles striking aimpoints in order to render an airbase non-functional with a high degree of confidence. The likelihood of losing even a marginal part (for example 20%) of the already large missile salvo needed to achieve this thus has ramifications for Russian planners. The reason for this is that the larger a salvo is, the more likely it is to require greater levels of planning and synchronisation, often across services, to coordinate arrival times of missiles launched from different locations. To render a tactical or operational target more difficult to attack, a defensive system need not be hermetic – instead it need only impose a requirement to launch more missiles in any salvo than an opponent can easily coordinate, and to achieve this repeatedly. Consequentially, this involves lowering SSPk and increasing scalability.

▲ 9P78-1 launcher of the Russian Iskander-M (SS-26 Stone) SRBM system, in the process of raising its two 9M723 missiles into the vertical launch position. [RecoMonkey]

Relatedly, it must be remembered that the probability of a missile striking a target is not simply determined by the likelihood of active defences prevailing. First, the missile's accuracy in CEP and warhead size are determinative. Generally speaking, the number of missiles needed to strike a target with certainty is determined by the equation:

$$SSPk = 1 - 0.5^{(\frac{rl}{cep})^2}$$

to generate salvo sizes, then b) proceeded to assess how much uncertainty factors such as a missile's own CEP, soft kill and passive defences added regarding SSPk, and then c) proceeded to the question of how high the likelihood of active defence would need to be, in order to close the delta between currently-assessed salvo size and the salvo size needed to overcome the inherent risks of both active and passive defence, would yield a considerably lower SSPk for interceptors.

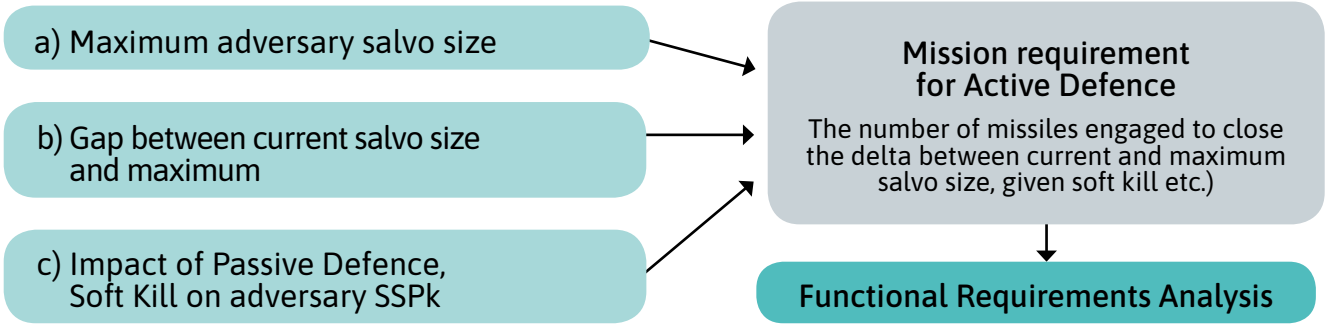


Diagram showing the key factors relevant to generating a realistic mission requirement for active defence, and consequently, required missile Pks. [Sidharth Kaushal]

Where rl is the lethal radius of the missile. So, for example, a missile with a CEP of 10 m and a warhead of 450 kg such as the 9M723 has a 50% chance of destroying a target such as a hardened air shelter. By contrast, an IRBM such as the Chinese DF-26 (with a CEP of around 150 m) has a roughly 4% chance of destroying a hardened target. It follows, then, that particularly at battlefield depths in excess of 500 km, the impact of hardening can be considerable. Even assuming more accurate missiles, palliatives such as hardening can increase the number of missiles needed per aimpoint – thereby closing the delta between real and maximally viable salvos further, and reducing the burden on missile defences.

Third, factors such as mobility, dispersion and soft kill can have a considerable impact on ballistic missile effectiveness. Take, for example, the case of the US' efforts to produce highly-accurate conventionally-armed Manoeuvrable Re-entry Vehicles (MaRVs) under the prompt global strike (PGS) programme, with tests of E2 (Enhanced Effectiveness) in 2002, and LETB (Life Extension Test Bed) modified versions of Trident missile re-entry bodies in 2002 and 2005 respectively. During tests, the loss of access to Global Positioning System (GPS) signals caused the MaRVs to land well away from their targets, though close to the locations where the navigation systems assumed the target to be. Positioning, navigation, and timing (PNT) jamming against ballistic targets is difficult given their trajectories and speed, but not impossible. The key consideration is that jamming need not be a perfect solution, merely a factor that adds to the margin of uncertainty regarding the SSPk of a single missile. The same might be said of other methods of defeat, such as the use of obscurants against missiles with optoelectronic seekers (including variants of the 9M723) and decoys.

None of this would render the ability to hard-kill missiles irrelevant. However, a mission engineering approach which began with a) an assessment of adversary capacity

For illustrative purposes, let us return to the case of the Russian criterion of 60 missiles on target to render an airbase non-functional. Assuming that the impact of the average CEP inflates this number by at least 50% (in the case of very accurate missiles like the Iskander), if measures such as hardening are taken and that other passive methods (such as the use of obscurants) impose a marginal 10% attrition, a level of attrition inflicted by active defences of around 50% would more than double the size of a required salvo and raise the required number of missiles to a number in excess of almost all of Russia's missile salvos in the Russo-Ukrainian War (and well in excess of any ballistic missile salvo).

As such a system which combined a highly-effective interceptor such as PAC-3 MSE (which reportedly has a SSPk of 0.8 in test conditions) and a much less-effective interceptor would have a cumulative Pk well in excess of the demand.

If an acceptable SSPk is defined in terms of closing the delta between real and maximum salvo sizes given other factors, this would impact several aspects of systems design. The first factor would be warhead type. Hit-to-kill interceptors geared toward the BMD role, such as PAC-3 MSE, introduce especially stringent demands in terms of missile speed and kinematics, given that the missile must make kinetic impact with its target at a very high speed to achieve target defeat. This introduces a number of design requirements, such as the use of ceramic shrouds (as on PAC-3 CRI) in lieu of more scalable Quartz Duroid shrouds (as on original PAC-3) for seekers, which are used on a number of air defence interceptors. In addition, the use of Titanium warheads rather than tungsten pellet blast fragmentation warheads imposes further costs. These costs are justifiable if one is seeking to maximise SSPk, and bespoke systems still represent an entirely valid first line of defence. However, if one is meeting a sufficiency criterion a shot doctrine for employing interceptors might well employ a 'high-low' mix which allowed the employment of bespoke

A robust lightweight for combat boots: EXTRAGUARD technology from GORE-TEX Professional Fabrics

New and innovative EXTRAGUARD upper technology is light-weight and remains lightweight – even in extremely wet conditions

Days of deployment in the rain, cold, mud and snow with hardly any time to recover: Infantry and special units brave the toughest conditions on deployment. Only the best equipment meets the requirements: EXTRAGUARD upper technology enables a completely new generation of GORE-TEX combat boots and combines the advantages of a robust, durable upper material with those of lightweight, flexible, and breathable textiles for the first time. The boots are not only permanently waterproof, breathable, and flame-retardant, but also permanently lightweight - even after a long time in wet, muddy terrain - and dry again quickly afterwards. We look forward to meeting you and sharing more information with you at our booth 7A #537 at Enforce Tac in Nuremberg, Germany, 24-26 February 2025.

EXTRAGUARD upper technology consists of three layers – a highly abrasion-resistant, easy cleaning and flame-retardant outer protective layer, a functional layer that provides mechanical protection and an innovative construction inner layer with low water absorption properties. This 3-layer upper is sealed with GORE SEAM® Tape and integrated into the shoe along with the interior waterproof and breathable GORE-TEX lining (bootie construction). The seam sealing prevents moisture from entering the shoe through the seams between the upper material and the GORE-TEX lining. The EXTRAGUARD construction absorbs practically no moisture in the outer material and the gaps from the outside even if the water-repellent treatment has worn off or the upper material is damaged.

This keeps feet dry and warm at all times in wet or cold conditions. Thanks to this unique construction, the EXTRAGUARD upper is 40% lighter than equally strong and dry leather when dry. Because it absorbs less moisture from the outside, it remains lightweight even when wet and dries significantly faster. GORE-TEX EXTRAGUARD combat boots retain their functional properties even after long-term use and constant wear in wet environments.

Comfortable fit, easy cleaning, robust protection

GORE-TEX combat boots with EXTRAGUARD upper technology are comfortable from the start, do not need to be worn in and retain their shape even after long-term use and constant wear in wet environments. Their robustness offers reliable protection against sharp objects, common chemicals, moisture and cold. Hosing with water is all that is needed for care and cleaning; specific care products are not necessary.

High performance and reduced environmental impact

EXTRAGUARD upper technology also sets new standards in terms of sustainability: according to the Higg MSI (Higg Materials Sustainability Index, higg.com), the upper is manufactured with less water, CO2 emissions, chemicals, and chrome-free. It is also produced by roll, so there is less material waste in the production of GORE-TEX EXTRAGUARD combat boots. In sum, all factors significantly minimise labour, material use, and overall environmental impact.

[W.L. Gore & Associates]

In this scale model cutaway of a PAC-3 MSE, the following components are visible: (from left to right) Lethality Enhancer (essentially a small warhead, intended for use against non-ballistic targets), the Multi-Band Radio Frequency Data link (MRFDL), Guidance Processor Unit, Inertial Measurement Unit (IMU), Attitude Control Motors, and Ka-band seeker. [Mark Cazalet]

and expensive interceptors in tandem with cheaper systems armed with high-explosive fragmentation (HE-FRAG) warheads, which can also be used in air defence intercept roles.

Integration as a force multiplier

Secondly, it should be noted that there is an inverse relationship between sensor reach and coverage on the one hand, and the cost and complexity of an interceptor on the other. For example, the shorter the homing times of an interceptor are, the more capable of high g manoeuvres it must be. Similarly, the degree to which an interceptor can receive data enabling, for example, target discrimination from other sources impacts the extent to which its own on-board seeker must be able to generate high-fidelity data (which typically requires a Ka-band seeker).

The inverse relationship between sensor range and interceptor complexity was perhaps best illustrated by the interception of an Armenian Iskander missile by Azerbaijan's Barak-8 in the 2021 Nagorno Karabakh conflict. The Barak-8, which is an air defence missile equipped with an HE-FRAG warhead, and understood to have an average speed of Mach 2, is not an ideal BMD interceptor. The intercept may have been a lucky one, but it is also potentially the case that the early detection provided by the Azeri Green Pine radar meant that the interceptor had a longer homing time and thus a more limited requirement for high-g course corrections. To be sure, this is not a substitute for dedicated hit-to-kill interceptors, but does mean that the longer one's detection range, the more effective non-dedicated interceptors will be in a BMD role – allowing for a partial erosion of the aforementioned stovepipes, particularly in tactical contexts.

The integration of sensors for air and missile defence is not necessarily new; examples include the pillar programmes of the Naval Integrated Fire Control–Counter Air (NIFC-CA) programme and the more recent cueing of a PATRIOT battery with tracks from an F-35 during US Army tests at the White Sands Missile Range. US aircraft have long been able to conduct cooperative engagements with surface launched missiles as part of NIFC-CA.

However, while the advantages of more sensor coverage and information are well understood, the relationship between sensor and effector integration is often overlooked. The more networked a surface-to-air missile (SAM) system is with sensors within the IAMD system, the less capable its own on board sensors need to be. For example, while a high-performance Ka-band seeker is needed to discriminate a warhead from decoys, such as the six 9B999 radio frequency (RF) decoys carried by the 9M723 Iskander, networking together missiles with Ka-band seekers and lower-cost missiles without them can allow the latter to draw data from the former, meaning that two missiles with costly Ka-band seekers do not need to be ripple fired for a terminal phase intercept. Instead a salvo could combine one high-perfor-

As well as PATRIOT, the SM-6 has also been demonstrated as part of NIFC-CA. Shown here is an SM-6 being launched to engage an over-the-horizon threat as part of the US Navy's first live fire demonstration to successfully test the integration of the F-35 with existing NIFC-CA architecture, at White Sands Missile Range, on 12 September 2016. [US Army/Drew Hamilton]

mance missile and one with a less-capable seeker. Similarly, the ability to cross-reference data feeds from multiple sources (such as in a multi-static radar array) can grant an air defence system both earlier detection and the elimination of false positives, in turn making it possible to lessen the demand for effector kinematics and seeker fidelity.

This does not eliminate the requirement for dedicated BMD effectors, particularly against upper-tier threats such as IRBMs. However, the point is that one consequence of a better integrated system is that the availability of information at the network level reduces the unit-level requirement to gather data, and can enable the hardware of some individual systems (such as interceptors) to be simplified.

Going long or short, and the value of offence-defence integration

One argument which has been made is that a focus on larger numbers of shorter-range interceptors which can be packed in a limited launch space (particularly at sea) might supersede the traditional approach emphasising layered defence. This has, for example, been the basis for recent US Navy tests in which PAC-3 MSE interceptors have been employed in Mk41 VLS cells. However, while there is utility to this, range remains an important means of achieving the functional equivalent of magazine depth.

If one assumes that the SSPk is roughly equivalent across the layers of a system, a multilayered system is generally more-cost effective than a single-layered system because it enables a 'shoot-look-shoot' approach. A single-layered BMD system, by contrast, must necessarily ripple fire interceptors in order to achieve a high probability of intercept against targets. This ceases to hold, however, if one of two conditions is met.

Firstly, if the cost of a long-range interceptor must exceed that of shorter-range systems by a factor of two or more, layering ceases to be useful. This is arguably not the case – interceptors such as the MBDA Aster-30 Block 1NT and the Rafael/Raytheon Stunner used with the David's Sling system even understood to cost less than PAC-3 MSE. The argument might, however, hold with respect to systems such as SM-3 in a counter-IRBM role, although there may be few alternatives to exoatmospheric intercept here. Moreover, costs for exoatmospheric intercept can be reduced considerably as illustrated by the IAI Arrow-3 which costs USD 5 million due to, among other things, its relatively simple terminal phase thrust vectoring mechanism. It would appear, then, that the logic of layering does not necessarily cease to hold.

Moreover, the ability to target launchers can significantly reduce the demand for interceptors. In many instances, the data gathered regarding a missile's boost phase infrared (IR) signature and/or trajectory can also be employed to triangulate the location of a launcher (with trajectory calculation already a feature of the AN/MPQ-65 radar of the US PATRIOT system).

Flight Test Arrow-01 demonstrated the IAI Arrow 3's ability to conduct a high-altitude hit-to-kill engagement. Interceptor tests were conducted at Pacific Spaceport Complex-Alaska (PSCA) in Kodiak, Alaska, during July 2019. [MDA]

While air-based and deep strike capabilities may be tasked with functions other than counter-launcher operations, for example suppression/destruction of enemy air defences (SEAD/DEAD), targets such as transporter erector launchers (TELs) do not require heavy payloads to destroy; loitering munitions with payloads of 40 kg (and indeed often considerably less) have been employed against these targets in several conflicts. Over short ranges where accuracy is easier to achieve, dual-use interceptors which combine offensive and defensive functions might thus prove especially useful. The employment of air defence systems in a surface-to-surface role is not new and is a feature of the SM-2, SM-6, and S-300P, among other systems. However design trade-offs have limited the use of SAM systems in this way. Arguably, the counter-battery function at tactical ranges represents the most viable offensive use of these missiles, since the major design trade-off between offensive and defensive missiles (warhead weight) matters less against TEL-type targets, against which a 150 kg warhead, such as that used on many long-range SAMs is entirely sufficient.

Conclusion: More than magazine depth

The challenge of scaling BMD solutions is a real one but the solution to it cannot be to simply make more missiles. Scaling existing capabilities is important, but it will also be important to adopt a less stovepiped approach to BMD as an enterprise, in which operational demands set requirements to a greater degree than engineering characteristics. This, coupled with efforts to use sensor integration to partially erode the silos between BMD and other parts of the air defence spectrum will be of central importance – if the defence of fielded forces against ballistic threats is not to be dependent on bespoke solutions which do not scale.

Tightening the sensor-to-shooter loop

Tim Guest

Reducing the time between detection, identification, and engagement by the appropriate weapon platform is crucial in order to maximise the chances of successful target destruction on the battlefield. This requires a near real-time sensor-to-shooter (STS) loop, enabled by the latest command and control (C2) technologies networked with effectors.

Lessons learned on the battlefields of Ukraine show that the tactics and conduct of modern warfare have changed forever, as new technologies have entered the fray and soldiers have grown proficient in understanding both how to use them and what it means to be on the wrong end of them. Loitering munitions and drones have transformed modern warfare, in large part by minimising tactical STS timeframes and maximising target neutralisation chances. They monitor the battlefield, connected through intelligent command and control (C2) systems, and then, target identified, strike with precision.

▲ **Pictured: Spike NLOS and Apache AH-64E. Platform integration with STS systems such as Fire Weaver enables automated selection of the optimum asset and effector for engaging targets locate by friendly forces. [Rafael]**

This article looks at certain tactical STS systems, relevant loitering munitions and a certain anti-armour missile development, all of which are reducing STS loops, essential to success on the future tactical battlefield.

AUTHOR

Tim Guest is a freelance journalist, UK Correspondent for ESD and a former officer in the British Forces.

Weaving magic

Before looking at specific LM programmes, a look at Israeli company Rafael Advanced Defense System's Fire Weaver STS system helps set the scene. This system can be thought of as a software layer which sits between networked sensors, C2 Systems, and effectors, and links them together; connecting and disseminating essential information to all integrated battlefield elements, in real time. Fire Weaver collects, filters, and disseminates data from multiple sources and sensors on the battlefield, using a common visual language to display that information for each individual soldier and all systems that have been integrated with Fire Weaver. It can handle large numbers of simultaneous STS transactions and provides comprehensive situational awareness (SA) of the operational area. This can include augmented reality (AR) displays in the common visual language, on all relevant optical equipment highlighting necessary battlefield information to users, for instance, friendly/hostile force locations, targets, points of interest, and others.

Fire Weaver also uses automated processes to select the optimal shooter for each target identified, in turn speeding up target engagement and decreasing the cognitive burden for commanders. The system's open architecture ensures integration is possible with various battle management systems (BMSs), radios, sensors and weapon systems, thereby supporting interoperability between joint or allied forces.

The US Army has its sights set on improving its STS capabilities and evaluated Rafael's Fire Weaver for use with battalion-sized tactical formations back in early 2021. US subsidiary, Rafael Systems Global Sustainment, demonstrated the system's ability to integrate with other tactical equipment, including disparate BMSs, and collate data from other friendly sensors to provide an overall operational picture of an area for all active units to share. This ability to integrate with other electronics was the basis for Rafael signing an MoU the same year with France's Safran, to integrate Fire Weaver with the French company's Moskito TI target locater, in advance of demonstrations for an unnamed customer.

The medium-range Moskito TI monocular target locator itself, meets NATO C4I requirements; it is designed for use by infantry and SOF, with direct view day, low-light TV, and thermal channels, as well as a laser rangefinder, capable of displaying target locations and distance measurements in seconds. Following on from the MoU in June 2022, the agreement's full sales and marketing collaboration between the two companies was officially signed, with Rafael benefitting

Fire Weaver has been integrated with Safran Vectronix's Moskito TI target locater to provide STS functionality for this target observation, range finding and geo-location device. [Safran Vectronix]

from Safran's established customer base for the widely-used target locator, including amongst several NATO nations. Indeed, it is understood that Fire Weaver integration into all Safran's target locators is ongoing, as well as, from reports, with other target locators used by allied infantry and SOF globally, including the US Army.

For its part, by 2020, Fire Weaver was already reported as having been contracted for implementation within several Israel Defense Forces (IDF) brigades, with which it was understood to have entered service, and is known under the service name 'Smart Trigger'. In early 2021, demonstrations had already taken place for the Bundeswehr, with Dutch Forces present, involving Rafael's Fire Weaver integrated with an Aeronautics Pegasus Drone, with data carried over Rafael's BNET handheld and vehicle-borne software defined radios (SDR), hosted over an exercise C2 system from Atos Information, with which Rafael had partnered to demonstrate its 3D 'transparent battlefield' concept to the Germans. Subsequent demonstrations in 2021 and 2022 took place for Dutch SOF and Marine Corps, as well as various nations in Asia.

It is worth noting that Fire Weaver has been put to effective STS use by Rafael itself, to provide a comprehensive STS dimension for its Spike NLOS (non-line-of-sight) anti-tank guided missile (ATGM). Rafael now also offers an all-in-one STS package marketed as the 'Spike NMT' (NLOS Mission Taskforce). This consists of unmanned aerial vehicle (UAV) platforms to provide information, surveillance and reconnaissance (ISR), along with a ground launch platform armed with multiple Spike NLOS missiles, with everything networked via BNET radios, and integrated with Fire Weaver.

The loitering munition: a self-contained sensor and shooter package

The latest LMs incorporate a range of sensors and guidance capabilities, as well as explosive warheads, so they can perform all-in-one location, tracking, and attack functions; unlike traditional UAVs and drones used for intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) applications, the raison-d'etre of LMs is for them to function as both sensor and shooter, able to loiter over the battlefield until performing a precision strike on their target as their final act. However, if operational conditions change, LM operators can typically abort a strike, and continue loitering until either a strike is needed or they run out of power.

One LM maker, Israeli company, UVision, has been producing LMs for many years with its Hero range of weapons increasingly widely used, including with NATO members. Hero weapon systems are designed to give front-line forces, a long-range, independent-fire capability, combined with advanced intel-gathering functions. Furthermore, all Hero systems can operate in GPS-denied environments, with the smaller models suited to forward-deployed, light tactical units and SOF. These are the Hero-30, 90 and 120, with each man-portable or suited to installation on light vehicles; they can be operational and in the air within 2-3 minutes, controlled by a single operator. The larger Hero-400EC, 900 and 1250 are for heavier land or naval vessel installation and launch.

Hero LMs are suited to both tactical and strategic short-, medium- and long-range missions, and for use by a wide range of units and forces, from standard infantry to SOF, and more. [UVision]

While Hero family LMs can be single-operator controlled using a ground station integrated with whatever launch vehicle is in play, the systems can also allow a transfer of C2 to an agile, forward-deployed team, which will then use it for its own missions. Hero munitions can connect and interoperate with other weapons and sensors, as well as established C4 systems, its advanced datalink and intelligence-gathering providing comprehensive real-time SA to users on the ground. The IDF has been a user for many years, and in September 2022, UVision partnered with Germany's Rheinmetall to produce the Hero-30 LM to meet an urgent operational requirement of the Italian SOF (unnamed at the time), for delivery in 2023. The two companies formally announced their strategic LM partnership in October 2022. The order marked the start of what Rheinmetall said at the time would be the ability to offer all Europe's armed forces a source of end-to-end LM solutions for the future.

At the end of 2022, it was also announced that Argentina was to become the first Latin American Hero user, adopting both Hero-30 and 120 weapons for evaluation by Argentine SOF, marines, airmobile and field artillery units, in line with a programme by the Argentine Armed Forces Joint Chiefs of Staff to modernise its munitions over a number of years. Not long after, in July 2023, Rheinmetall and UVision announced they had been supplying Hero LMs to Hungary under a 'three-digit million-euro' contract, with deliveries beginning 2024 and completed in 2025.

Back in the US, in early 2024, the company partnered with Science Applications International Corp (SAIC) for the US company to produce Hero-120 LMs at its South-Carolina facility, with the Hero-120 having previously been ordered in its thousands by the DOD for US Forces. This included the USMC as part of its Organic Precision Fire Mounted (OPF-M) programme. Then in June 2024, UVision announced that with its US representative, Mistral Inc., it had won a USD 73.5 million contract with the US DOD for Hero-120SF LMs to be supplied to US Special Operations Command (SOCOM), along with conversion protocols for OPF-M systems to be to converted to medium-range precision strike systems, with the contract slated for completion by 2029. Production of the LMs is taking place at UVision USA's facilities in Virginia and the new SAIC plant, while Mistral Inc. is overseeing the industrial and commercial aspects of the deal.

The US 'Replicator' initiative

It is worth mentioning the DOD's Replicator initiative. The first step, known as 'Replicator 1' was announced back in August 2023, and aims to field thousands of autonomous systems across multiple domains by late 2025. The overall goal of this initiative is for the US to be able to call upon large numbers of attritable autonomous systems to offset China's numerical superiority in conventional military capabilities.

Alongside the Altius 600M, the US armed forces have also been evaluating the larger Altius 700, shown here being launched from a UH-60 Black Hawk at Yuma Proving Ground, Arizona, on 4 March 2020. [US Army/Amy Tolson]

As part of the follow-on Replicator 1.2, the US DOD said in November 2024, that it was scaling up LM efforts by both fielding and further extended evaluation of Anduril Industries' Altius 600M LM variant of its commercial, dual-use Altius 600 platform, destined for the USMC's organic precision fires light (OPF-L) programme, to deliver a non-line-of-sight precision strike capability. The DOD said the Anduril system complements AeroVironment's Switchblade-600, which was included in the first Replicator 1 tranche.

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As well as being widely used by US Forces, AeroVironment's Switchblade LMs have been used by Ukraine against the Russian invaders, and is now in the inventories of several European NATO nations. [AeroVironment]

While much of the Replicator initiative is classified, key elements cover contracts not only for UAVs and LMs, but also for unmanned surface vehicles (USVs), and unmanned underwater vehicles (UUVs). While all NATO member countries will follow their own procurement decision processes for greater UAV and LM inventories, this US initiative will likely hold sway in terms of collective procurement opportunities as well as issues of interoperability within the Alliance. Indeed, NATO has been watching the accelerated fielding of UAV systems by the US during 2024, including over 1,000 Switchblade 600 LMs, and it seems to have had an impact.

It is worth noting first that AeroVironment won a five-year indefinite delivery, indefinite quantity contract for its LM in August 2024, from the US Army Contracting Command (ACC)-Aberdeen Proving Ground, with a potential ceiling value of USD 990 million. The Switchblades are intended to meet the US Army's directed requirement for lethal unmanned systems, with deliveries underway, having been slated to begin within months of the announcement. The contract underlines the growing importance of loitering munitions as part of the US Army's LASSO (low-altitude stalking and strike ordnance) programme, in support of infantry operations. As for NATO, the US Army's ACC signed a further contract with AeroVironment in September 2024, valued at almost USD 55 million. This was again for the supply of Switchblade, but this time for NATO members, Lithuania, Romania, and Sweden, using US Foreign Military Sales funding. Deliveries are due to be completed during 2026, and the systems supplied will incorporate modifications based on battlefield feedback from Ukraine.

However, according to reports from the Atlantic Council think tank, never one to hang around waiting for the US, the French Army already intends to achieve an inventory of some 3,000 tactical drones and loitering munitions in 2025, with an additional EUR 5 billion investment programme beyond the end of the decade for further systems and the development of a home-based French loitering-munitions industry by the end of 2030. In the short term, the French Army is also buying both the Switchblade 300 and Switchblade 600 systems from the US, as is Lithuania; both countries, along with the UK and other Allies in Europe, having been approved to do so by the US Government following the invasion of Ukraine. US approval had previously been granted for an FMS-funded contract in excess of USD 60 million, mid-2024, to go ahead for the delivery of Switchblade 300s to Taiwan.

Interest remains strong

Space precludes detailed mention of many relevant LMs, though brief mentions in closing, of recent contracts include Israel Aircraft Industries' (IAI) two early-2024 deals valued at over USD 145 million, for the delivery of long-range LMs to two unnamed customers for its Harpy NG and Harop systems. This highlights what an IAI spokesperson said at the time was the growing tactical and strategic importance of LMs on the battlefield in ensuring operational success. Elbit Systems' SkyStriker, too, is another operationally proven LM, ordered by a European customer in September 2023 valued at USD 95 million, involving delivery of several hundred units by September 2025. Finally, while the USMC's OPF-L programme has already been mentioned, final word goes to Teledyne FLIR, which signed a USD 12 million contract with the Corps in April 2024, for 127 advanced small vertical take-off and landing (VTOL) LMs, for earlier evaluation under the programme. It seems evident that interest in maintaining the tightest possible STS loops is increasing, with LMs looking to be at the forefront of such efforts with many armed forces.

Small arms sights and fire control systems developments

David Saw

The small arms sector is undergoing a significant transformation, with a growing focus on integrating advanced fire control systems (FCS). This shift is poised to reshape the future of weaponry, as users increasingly seek to enhance the effectiveness and precision of small arms systems.

The problem is that while most agree some form of optic is essential, the reality is that far too many forces still have the majority of their infantry using iron sights; this is because not enough optics have been purchased or because the new rifles that they were to be integrated with are still in the process of delivery.

For example, it is not unusual to see French troops on the anti-terrorism mission in Paris equipped with the new Heckler & Koch (HK) HK416F rifles. Although the old FAMAS rifle can still be seen, the new rifle is increasingly prevalent. While the optic selected by the French Army is the Aimpoint CompM5, it is significant that many of the rifles with units deployed in Paris still lack this optic. The first deliveries of the weapon took place in May 2017, and the number of HK416F/HK416F-C rifles will reach 94,000 by the end of 2025, with all 117,000 rifles due to be delivered by 2028. Conceivably, the lack of optics on many deployed HK416F weapons reflects the extended delivery schedule of the French rifles, although it would have been reasonable to expect rifles and optics to be deployed in parallel.

One assault rifle programme placing emphasis on rapid delivery is the British Army Alternative Individual Weapon (AIW) programme, also known as Project Hunter. An Invitation to Tender (ITT) for the procurement and support of an Armalite Rifle (AR) platform Alternative Individual Weapon (AIW) System for the Army Special Operations Brigade (ASOB) and selected Royal Marine Commando units was issued in December 2021. Total fleet requirement for the AIW will eventually be in the region of 10,000 weapons. The ITT stated that "the AIW system will be a 5.56 mm Armalite Rifle (AR) platform, optimised for use with L15A2, a 62gr 5.56 × 45 mm NATO ball round, equivalent to SS109."

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The AIW is not just a rifle acquisition; the outline technical requirement was that it must be optimised for use with a suppressor and that the system would consist of a rifle plus signature reduction system and an optic system. This is the clear trend for the future in terms of small arms programmes of this nature – an optic and/or a suppressor are no longer an add-on to be acquired after the weapon is selected, as they are included in the selection process from the start. It marks a transition from accessory to essential for these systems. Amongst the suppliers sent the AIW ITT were potential rifle suppliers, such as: Caracal, Colt Canada, Daniel Defense, HK, Knight's Armament Company (KAC), SIG Sauer and Steyr. Potential optic suppliers were Aimpoint, EOTech, Holosun, L3Harris, Leupold, Raytheon ELCAN, Steiner, Trijicon and Vortex Optics.

The British Army Special Operations Brigade (ASOB) and selected Royal Marine Commando units will receive the L403A1 Alternative Individual Weapon (AIW). This features the L900A1 Optics Suite, with Vortex Optics and Aimpoint optics. [Crown Copyright]

It is worth noting that both the British Army and Royal Marines have had extensive experience with the M16 and other AR type rifles, using them since the 1960s. Prior to the AIW selection, the main AR pattern rifle was the Colt Canada C8 carbine, which was used as the L119 A1, with Special Forces using the upgraded L119A2. The standard British rifle remains the L85, which admittedly has a less than perfect reputation, but after considerable work by HK, the current L85A3 is a more than reasonable weapon. Eventually though, the Field Army will have to select an L85 replacement, although no firm timing for this programme exists.

Winning solutions

The AIW programme came to a conclusion rapidly; as previously noted, the ITT was issued in December 2021, and by September 2023 the contract was awarded, less than two

years later. The contract was awarded by the Soldier, Training & Special Projects team of Defence Equipment & Support (DE&S) of the Ministry of Defence (MOD). An initial order was placed for 1,620 weapons with a value of GBP 15 million, with the total requirement for up to 10,000 weapons valued at GBP 90 million over the following ten years. The first AIW rifles were delivered before the end of 2023.

The prime contractor was the Edgar Brothers company, whose AIW solution was based on the Knight's Armament Company (KAC) KS-1 5.56 × 45 mm rifle, KAC also call this the SR-16 for 'Stoner Rifle'. The weapon is now designated as the L403A1 in British Service. The weapon is also fitted with a KAC MCQ-PRT suppressor, with Magpul providing PMAG magazines, the pistol grip, grip stock and other accessories. As might be expected, the rifle is equipped with ample rail systems to attach further accessories as required. Notably the new rifle, with all of its add-ons, still weighs less than the current L85A2 and L85A3 in-service rifles. The optics solution selected for the AIW is classified as the L900A1 Optics Suite. This consists of a Vortex Optics 1-10x LPVO on a Reptilla AUS mount, with an Aimpoint ACRO-2 red dot sight on a Reptilla ROF 90 mount.

All things considered, the AIW programme shows that it is possible to issue an ITT, evaluate the responses, conduct an effective test programme with the weapons submitted for trials, make a final decision and award an acquisition contract rapidly. Life could have been much simpler for DE&S and the British Army if they had just selected the standard US M4 carbine and purchased on a government-to-government basis, in parallel they could have purchased the optics suite and the various other add-ons direct. This approach was rejected, and instead the most effective rifle has been selected, along with optics and other add-ons, that best meet British requirements. With Edgar Brothers assembling the complete AIW package, with its L900A1 Optics Suite, at their Macclesfield, Cheshire facility in Northern England.

In contrast, others sometimes take a more long-term approach to the acquisition of a new rifle system and its supporting optics; this certainly seems to be the case in Germany.

Since the 1980s, when Raytheon ELCAN supplied the C79 optic for Canadian Forces C7/C8 assault rifles, the company has gone on to be a major optics player. Their Specter DR optic was selected for the Germany Army HKV Main Combat Sight programme for the System Sturmgewehr. [Raytheon ELCAN]

At the end of 2021, Raytheon ELCAN and Leonardo Germany won the German Army's HKV Main Combat Sight programme for 107,929 optics based on the Specter DR 1-4x system. This was to be integrated with the winner of the System Sturmgewehr Bundeswehr competition for a new assault rifle to replace the G36. In December 2022, it was announced by the German Ministry of Defence that the Budget Committee of the Bundestag had released funding to action the assault rifle programme. The winner of the rifle requirement had already been selected in 2021, but protests over the selection and related legal matters needed to be resolved before the programme could proceed.

At the time of the announcement it was stated that 118,718 rifles would be procured, these would be the HK416A8 which will be acquired in two variants: the G95A1 with a 16.5 inch barrel and a carbine variant, the G95KA1, with a 14 inch barrel. German Special Forces were already using the HK416A7 which is designated as the G95. The System Sturmgewehr contract was signed in January 2023, with an initial order being placed for 13,929 G95A1 and 3,104 G95KA1. In addition, 40 rifles were acquired for qualification testing, with another 350 rifles acquired for troop trials including testing in different environments, such as Yuma in the US for desert conditions and Panama for tropical conditions, with these trials commencing in January 2024. Target introduction to service of the G95A1/G95KA1 with the Bundeswehr is in 2026.

It does seem that they are taking their time in bringing the G95A1/G95KA1 into service, and nobody can doubt the need for in-depth testing, but it's not as if these weapons are that fundamentally different from the G95, which is in service with the German Special Forces. Presumably these went through an in-depth test programme before being taken into service? An interesting point is that these trials in the US apparently saw other optics used in addition to the Specter DR, supposedly to check compatibility with the G95A1/G95KA1. This does seem odd — after all, the HK416 must have been integrated with all of the major optics systems currently available over the years. Are they having second thoughts on optics or just attempting to cover all the bases in their testing programme?

American future

The British and German programmes provide two examples of how different users go about selecting a new weapon and optic; it comes down to the opinion of the new users of the rifle and optic as to which selection and acquisition approach is better. There is, of course, a different approach to all of this and that was the approach selected by the US. Selecting a new service rifle has consistently proved to be a complex prospect for the US military. The current effort started in June 2017 with the Interim Combat Service Rifle (ICSR), which was halted in November 2017; later, a new programme emerged in the form of the Next Generation Squad Automatic Rifle (NGSAR).

With NGSAR seen as a replacement for the M249 Squad Automatic Weapon (SAW), it remained a programme until October 2018, when it was replaced by the Next Generation Squad Weapons (NGSW) programme. This consisted of the Next Generation Squad Weapon-Rifle (NGSW-R) and the Next Generation Squad Weapon-Automatic Rifle (NGSW-AR), with the former set to

1st Brigade Combat Team 'Bastogne' of the 101st Airborne Division (Air Assault) conducted operational assessment of the new NGSW XM7 rifle at Fort Campbell Kentucky in October 2024. Note the XM157 FCS. [US Army]

replace the M4 carbine and the latter the M249. Both weapons would use the new SIG Sauer developed 6.8 × 51 mm Common Cartridge, also known as .277 SIG Fury in commercial applications. In 2022, SIG Sauer was selected as the winner of the NGSW competition, with the XM7 (formerly the XM5) adopted for NGSW-R and the XM250 for NGSW-AR. Both weapons will utilise the SIG Sauer SLX suppressor.

The Next Generation Squad Weapons - Fire Control (NGSW-FC) system was competed separately, with two companies selected for the final downselect in the form of L3Harris and Vortex Optics. In January 2022, it was announced that Vortex Optics had been selected for the XM157 NGSW-FC system requirement. According to the US Army: "The XM157 integrates a number of advanced technologies, including a variable magnification optic (1-8x30), backup etched reticle, laser rangefinder, ballistic calculator, atmospheric sensor suite, compass, Intra-Soldier Wireless, visible and infrared aiming lasers, and a digital display overlay." Vortex Optics could provide as many as 250,000 XM157 NGSW-FC systems through 2032, with contract value estimated at some USD 2.7 billion. The NGSW-FC will also be linked with the US Army Integrated Visual Augmentation System (IVAS).

The 6.8 × 51 mm Common Cartridge provides greatly enhanced range, accuracy and lethality than current standard 5.56 × 45 mm and 7.62 × 51 mm rounds; the NGSW-FC further enhances the accuracy and range of the XM7 and XM250. It's all very impressive and the testing programme for the new weapons started in February 2023, with both regular army and National Guard units involved. It was no secret that the US was moving forward with a new small arms programme that would inevitably involve a new round in a new calibre, so it remains interesting that both the UK and Germany have, thus far, remained wedded to the 5.56 × 45 mm NATO round.

The South Carolina National Guard was tasked with XM7 NGSW-R testing in June 2024. The attached XM157 FCS is an extremely sophisticated piece of equipment, but will others be prepared to make major FCS investments for a rifle? [US ANG]

If the US does purchase 250,000 NGSW systems, that will certainly provide economy of scale in terms of pricing, but a new weapon, a sophisticated FCS and a new calibre round all add up to a major investment. While allied nations will obviously be interested in NGSW, it will probably require that the US military commits to substantial numbers of these weapons, before other users take the plunge.

Different thoughts

It might seem heretical to suggest this, but do you really need an expensive and highly sophisticated FCS for an assault rifle or squad automatic weapon? Nobody could argue with providing an FCS for a weapon such as the Browning M2HB 12.7 × 99 mm Heavy Machine Gun (HMG), bearing in mind its operational range. Similar logic could apply to Medium Machine Gun (MMG)/General Purpose Machine Gun (GPMG) systems in 7.62 × 51 mm, especially since such weapons can be used in an indirect fire role to supplement or as an alternative to mortars.

That being said, FCS developments for small arms continue; for example, Elbit has the Assault Rifle Combat Application System (ARCS), while Raytheon ELCAN have developed their own FCS solution. In the near-term though, it does seem debatable how much an FCS will add to an assault rifle versus how much it will cost. The Australian Army adopted the Specter DR 1-4x system as its optic for the 5.56 × 45 mm EF88 assault rifle. How much difference did the optic make? Marksmanship standards had to be increased out to accommodate engagements at 600 m. Accurate engagements at 600 m with a 5.56 × 45 mm weapon demonstrate serious capability. One might argue why an FCS is needed if one can already achieve accurate engagements with a weapon of this calibre at such ranges?

Ultimately, it comes down to the ranges at which you expect to fight, and some of the threats one might be fighting. A red dot sight can cover close-in engagements, while a proper optic can cover everything else in the context of assault rifle battle ranges. For many, an advanced FCS would be an aspirational capability to add to small arms; for others, being able to provide modern optics for their assault rifles would provide more than enough capability for effective infantry combat. Having said that, one more compelling argument for small arms FCS adoption may perhaps be found with the rise of small drones and loitering munitions, which are numerous, cheap, and difficult to shoot down with traditional marksmanship. As these threats proliferate and become increasingly common, interest in solutions capable of being incorporated at the lowest level is only likely to increase. While FCSs may perhaps not represent a panacea to the small drone threat, they may nonetheless represent a more attractive prospect than reliance on traditional optics or iron sights.

Vehicle turrets: A market overview

Alexey Tarasov

The market for armoured fighting vehicles' (AFVs) is growing, and the vehicle turret market is following suit.

The armoured fighting vehicle and vehicle turret markets are closely linked, both influenced by shared dynamics and various factors—political, technological, and tactical. Some of these factors were present during the past decade, while a number of new factors have emerged only since 2022. This unique combination has shaped the market and created favourable conditions for growth and development in the short term.

▲ TsNII Burevestnik's Kinzhal unmanned turret showcased at the Armiya-2022 exhibition. This turret was integrated with the BMP-3 IFV and T-15 HIFV platforms, but its development status remains unclear. [Alexey Tarasov]

According to a forecast by Research and Markets, the AFV market is expected to reach USD 36.65 billion by 2030, while the turret systems market is projected to grow to USD 2.7 billion by the same year. The overall AFV market is expected to grow at a compound annual growth rate (CAGR) of 3.43% from 2024 to 2030, while the turret systems market is anticipated to grow at a CAGR of 4.0% during the same period.

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Key drivers

One of the most significant factors influencing arms markets is the growth in military spending over the last decade. According to the Stockholm International Peace Research Institute (SIPRI), global military expenditure experienced a slight decline from USD 1.94 trillion to USD 1.88 trillion between 2010 and 2014. However, starting in 2015, global military spending has experienced steady yearly growth, reaching nearly USD 2.4 trillion in 2023. With strategic uncertainty and growing international tensions as key drivers fuelling the need to bolster military capabilities, this trend is likely to continue beyond 2025.

The AFV and vehicle turret markets have generally followed global trends over this period, with some notable milestones. Prior to 2015, low-intensity conflicts with sub-peer adversaries were considered the dominant form of warfare for the next decade. Accordingly, the demand for heavy armoured vehicles or advanced turret systems was relatively low, with the main efforts focused on lightly armoured and mine-resistant ambush protected (MRAP) type vehicles, as well as remotely controlled weapon systems, such as Kongsberg's remote weapon station (RWS) family.

The ensuing years were marked by rising geopolitical instability, which led to increased military spending and a general understanding that a large-scale conventional conflict was once again possible. This factor has led to multi-year army modernisation programmes in many countries, which included investments in new armoured platforms and turret systems.

▼ Remdizel's K-4386 (ZASN-D) multipurpose armoured vehicle is armed with a 30 mm autocannon and coaxial 7.62 mm machine gun in a 32V01 unmanned turret. [Alexey Tarasov]

Modular 'Military Off The Shelf' solutions for ring mounts and turrets

With the experience of delivering 1,500 ring mounts and turrets to armies, border and national guards, Special Operations Forces, and Special Police, SIMA Innovation's 'Better Protected' concept draws upon nearly 20 years of expertise in designing, adapting, and delivering their solutions.

The core vision behind the primarily motorised ring mounts and turrets is to create solutions that, through modularity, provide end-users with a range of interoperable products featuring a high degree of interchangeable parts within each ring mount series. These ring mounts incorporate user feedback, which SIMA Innovation describes as "innovated for soldiers, by soldiers."

The basic building block is the platform-agnostic motorised ring mount, suitable for platforms such as 4×4s, APCs, or logistics trucks. Additionally, a range of specialised soft mounts optimised for each weapon type serves as a stable effect delivery platform for the operator. On this foundation, various accessories can be added: From ammunition box shelves, spare barrel mounts, gunner protection kit, sun covers, and smoke launchers; to tailor the 'Military Off The Shelf' product line to end-user needs.

With modularity in mind, the fully-fitted turret can be adapted to changing operational environments and tasks by changing soft mounts, removing or adding gunner protection kits, or similar modifications. The ring mount can serve as a ring mount/soft mount-only solution one day, and as a complete turret with full protection the next. Adaptation to changing tasks can be done away from workshops with simple means.

▲ Patria 6×6 APC fitted with motorised RM-750 ring mount, equipped with a 12.7 mm (.50 cal.) Heavy Machine Gun and 76 mm Wegmann Protection System. [SIMA Innovation]

▲ Defenture Mammoth 4×4 multirole combat platform fitted with motorised RM-750 ring mount carrying the KNDS France P20 pintle-mounted 20 M 621 20 mm automatic cannon. [SIMA Innovation]

The compatibility with modern vehicle platforms and harsh, complex combat environments is highlighted by the fact that the motorised turret is easy and intuitive to use, even in stressful situations. The operation of the ring mount or turret is controlled by a stepless 'thumb joystick', allowing the operator to focus on protecting the vehicle and fellow soldiers in the area, even on 30° slopes. A full 360° rotation is completed in 8 seconds, whether it is a bare ring mount or a fully-protected turret.

SIMA Innovation's products are combat-proven and modular Military Off The Shelf solutions that enhance the capability of a wide variety of vehicles to defend themselves and soldiers around them. The solutions can be integrated onto both legacy and new platforms. This means that the same solutions can be fitted to multiple fleets of vehicles, providing the possibility of integrating the same types of ring mount solutions across various platforms.

▶ Sisu GTT All-Terrain Vehicle fitted with motorised RM-750 ring mount, equipped with a 12.7 mm (.50 cal.) Heavy Machine Gun and 76 mm Wegmann Protection System. [SIMA Innovation]

An example of such an advancement is the Stryker Infantry Carrier Vehicle – Dragoon (ICV-D), which was fitted with a Kongsberg MCT-30 turret armed with a Mk44 Bushmaster II 30 mm cannon, with the first prototype delivered in January 2017. The decision to enhance the lethality of the Stryker was made following a US Army Urgent Operational Needs statement in March 2015, which identified a number of capability gaps across the US forces stationed in the European theatre compared to Russian Ground Forces.

The most recent of the primary drivers was the onset of the Russo–Ukrainian War and a series of conflicts in the Middle East between 2022 and 2023. The combat experience gained from these conflicts highlights several key insights.

Armoured vehicles continue to play a vital role on the battlefield, and a modern conventional conflict will likely require large numbers of AFVs. While procuring new platforms is preferable, modernising legacy platforms will also be necessary. The number of active AFVs is expected to increase through 2030 and beyond. In order to operate and survive on the modern battlefield, both new and legacy platforms will require upgrades to enhance their survivability, lethality, situational awareness, and other characteristics. In many cases, these upgrades involve new turrets or systems and subsystems fitted to turrets.

C-UAV and VSHORAD

The proliferation of small drones and loitering munitions has been evident since the early 2010s. By 2014–2016, UAVs built from commercial components had proliferated in the Middle East, being used by various factions. Small UAVs were employed in reconnaissance roles, as bombers, as well as improvised loitering munitions and long-range strike assets during the conflicts in Syria and Iraq. By 2020, this threat had been recognised at the highest level in many countries, including the US, and had led to R&D and procurement programmes aimed at countering it.

Another driver is the need to bolster very short-range air defence (VSHORAD) capability at the tactical level. After the end of the Cold War, this capability was largely lost due to budgetary constraints and the prevailing understanding of the nature of warfare at the time; this led to many systems being retired or mothballed upon reaching the end of their life cycles. By the mid-2010s, VSHORAD was identified as a critical capability gap, and today it arguably remains one of the most pressing challenges for Western militaries.

The modern battlefield is saturated with various classes of drones and aerial targets, which continue to evolve, while major NATO adversaries, such as Russia and China, have retained a VSHORAD capability with their ground forces. These factors continue to fuel developments in the field of C-UAV and tactical air-defence capabilities integrated into many vehicle turret designs. The designs offered today largely fall into two general directions.

First, there are vehicle turrets designed for C-UAV or VSHORAD roles, with notable examples being Rheinmetall's Oerlikon Skyranger family, and the reconfigurable integrated-weapons platform (RIwP) by Moog.

Rheinmetall's Skyranger 35 turret on a Leopard 2 MBT hull showcased at Eurosatory 2024 event. [RecoMonkey]

The Skyranger system is based on a modular design and can be configured with various sensor packages and weapons, including a 35 mm x 228 KDG revolver cannon in the Skyranger 35 turret or a combination of a 30 mm x 173 KCE revolver cannon with a coaxial 7.62 mm machine gun and man-portable air defence (MANPADS) class missiles as an option in the Skyranger 30 turret. According to the manufacturer, both autocannons can engage a wide array of aerial targets, including UAVs, missiles, artillery, and mortar rounds, using AHEAD airburst munitions. Integrations of other capabilities, including high-energy laser systems and vertically launched counter rocket, artillery and mortar (C-RAM) missiles, are under development.

The Skyranger system has been integrated with various platforms, including the Boxer, KF-41 Lynx, Mowag Piranha V 8×8, Indonesian Pindad Badak 6×6, as well as 6×6 and 8×8 RMMV trucks. At the AUSA 2023 exhibition, Rheinmetall showcased a Skyranger 30 turret on a Textron Systems Ripsaw M5 unmanned ground vehicle (UGV), while a concept featuring the Skyranger 35 turret on a Leopard 2 MBT hull was unveiled during the Eurosatory 2024 exhibition.

Moog's RIwP is built around the same modular principles. It is both payload and platform agnostic, able to accommodate various payloads and can be integrated into a wide array of manned and unmanned platforms (platform agnostic). In 2023, for instance, General Dynamics Land Systems (GDLS) showcased a TRX tracked robotic platform fitted with Moog's RIwP turret in C-UAS configuration. Other integrations include BAE's Armoured Multi-Purpose Vehicle (AMPV), Boxer 8×8, JLTV 4×4, to name a few, with the latest integrations of RIwP in the VSHORAD configuration displayed at the IAV 2025 exhibition on both the Supacat 6×6 Armoured Closed Cab High Mobility Transporter (HMT) and the KNDS Dingo 3 4×4. Notably, RIwP has also been integrated onto the M113. While considered a legacy platform, it remains in service in many countries, and with the installation of a new turret, it could become a valuable asset capable of performing various combat roles.

The second major direction involves existing turreted solutions equipped with C-UAV capabilities through software and hardware upgrades. One notable example here is Kongsberg's Protector RWS family. On 4 December 2019, the company announced a contract with Germany's Federal Office of Bundeswehr Equipment, Information Technology, and In-Service Support (BAAINBw) to deliver a C-UAV system based on the Protector RWS. According to the official statement, the system would include Hensoldt's Spexer 2000 3D MKIII radar for UAV detection, a 40 mm grenade

A DINGO 3 protected vehicle fitted with Moog's RIwP turret in VSHORAD configuration [KNDS Deutschland]

launcher with airburst munitions, MANPADS missiles, and any of the weapons used with the Protector RWS, including up to a 30 mm autocannon. On 14 August 2023, Kongsberg released another statement regarding the delivery of multiple C-UAV solutions to Ukraine. This solution involves software and hardware developed by Teledyne FLIR, Kongsberg's Protector RWS and the CORTEX Integrated Combat Solution (ICS). The system has been integrated with the DINGO 2 4×4 platform.

Medium-calibre turrets

The demand for medium-calibre turrets is another growing segment driven by several key factors. The evolution of warfare and the threat landscape have led to substantial changes in the combat roles of medium platforms, including IFVs, reconnaissance vehicles, and fire support vehicles. Medium-class AFVs now require enhanced protection, improved situational awareness, and the capability to operate in complex environments such as urban areas, often separated from heavy armour. Additionally, the range of threats that they must detect, avoid, or neutralise has expanded significantly. Addressing these threats requires enhancements in firepower, which have prompted many militaries to initiate modernisation programmes, aimed at the procurement of new-generation medium-class platforms or upgrades for legacy platforms.

Notably, integration of medium-calibre turrets equipped with modern optics, fire control systems (FCS) and armaments is often considered a labour and cost-effective way of improving combat capabilities of legacy AFVs. Examples of such capability enhancements through upgrades include Russia's BMP-1AM Basurmanin, the BRM-1K reconnaissance vehicle, BMP-2M with the B05Ya01 Berezhok turret, Finnish BMP-2MD, and a capability enhancement and life-extension programme currently offered by FNSS Defence for ACV-15 IFVs. The disadvantage of this approach, however, is that upgrades typically focus on 'what is possible', constrained by design and budgetary limitations, rather than on 'what is needed' from a military perspective.

A BRM-1K at the Army-2021 event. The vehicle is equipped with an unmanned turret featuring a 2A72 30 mm autocannon and PKTM 7.62 mm machine gun. [Alexey Tarasov]

In turn, the integration of medium-calibre turrets with modern and future platforms allows for a greater variety of options. This is made possible by the modularity of both the turrets and armoured vehicles, as well as the improved power generation, increased internal space, and other design-related advancements of modern platforms.

Currently, the demand for medium-calibre turrets for medium-tracked and wheeled platforms is driven by large-scale programmes aimed at replacing ageing medium AFVs with next-generation platforms. Such programmes include the XM30 Mechanized Infantry Combat Vehicle in the US, the Futuristic Infantry Combat Vehicle (Tracked) in India, the Kurganets-25 and Bumerang programmes in Russia, the Borsuk in Poland, and Australia's LAND 400 Phase 3, among others.

Finally, technical and tactical factors are prompting changes and expanding the market of medium-calibre turrets. One such factor is the requirement for lethality enhancements for medium platforms. Over the last few decades, most designs have evolved from the typical 20-25 mm autocannons of the Cold War era to more capable medium-calibre weapons ranging from 30-40 mm, to 50–57 mm. The latter category includes experimental systems such as the XM913 50 mm automatic cannon (chambered in 50 × 228 mm 'Supershot'), Russia's AU-220M turret featuring the 2A91 57 mm cannon (chambered in 57 × 347 mm SR), and Epokha turret featuring the 2A94 57 mm cannon (chambered in 57 × 93 mm RB). While none has yet entered service, the XM913 Bushmaster

Chain Gun has been selected as the primary weapon for the US Army's Next Generation Combat Vehicle programme.

Another area for growth is the need to increase survivability for medium platforms, which can be achieved through enhancements in passive protection, as well as the implementation of active and passive protection systems in turret designs. While earlier IFV and APC protection relied primarily on passive armour, the latest variants typically feature both hard-kill and soft-kill active protection systems and advanced sensor packages. Examples include the US Army's Bradley M2A4E1 IFV, the CV90 MkIV, the AS21 Redback, the ASCOD platform and the KF41 Lynx.

▲ **A B19 IFV fitted with the Epokha unmanned turret at the Army-2022 exhibition. While this turret has seen limited production, its current status remains unclear. [Alexey Tarasov]**

It is important to highlight that over the next decade, many countries will focus their efforts in two directions simultaneously — the procurement of new platforms and the modernisation of ageing medium and light platforms, both for their own armed forces and for overseas customers. This factor could potentially further expand the medium-calibre turret segment over the short term.

Large-calibre turrets

The demand for large-calibre turrets is driven by the need for lighter, more cost-effective armoured vehicles capable of delivering firepower, without the high operational costs of main battle tanks (MBTs), as well as the specific conditions of certain theatres of operations and the requirements for the rapid deployment of combat vehicles. These factors have sparked interest in fire support vehicles based on medium-tracked and wheeled platforms, equipped with large-calibre turrets, and have also revived interest in fire support vehicles (FSVs), sometimes colloquially referred to as 'light tanks'.

Over the last decade, FSVs have proliferated and entered service in many countries, including Indonesia (Kaplan MT/Harimau), the Philippines (Sabrah), and the US (M10 Booker), among others. In a similar vein, China has introduced the ZTQ-15, but this is far closer to a 'true' light tank than the aforementioned vehicles. More countries are likely to either open R&D programmes or express interest in procuring this class armoured vehicles. The latest is Slovakia, which is considering the procurement of CV90120 FSV as an alternative to the Leopard 2A8, as reported by local media citing the country's Deputy Prime Minister and Defence Minister, Robert Kaliňák, on 9 January 2025.

Modern medium-weight platforms are based on the principles of modularity, allowing them to be equipped with various turret solutions available on the market, whether medium or large-calibre, and configured according to the specific needs and requirements of the army. For instance, Otokar's Tulpar multipurpose platform has been showcased in multiple variants, including the IFV fitted with a medium-calibre turret, while the

▲ **A combat vehicle marketed as Lynx 120 mm medium battle tank unveiled at Eurosatory 2024. A HITFACT MkII turret fitted on a KF41 medium-tracked platform. [RecoMonkey]**

FSV variant was displayed with Leonardo's HITFACT II turret, featuring a 120 mm smoothbore gun. An earlier variant featured a Cockerill 3105 turret with a 105 mm high-pressure gun.

Another notable example is the Sabrah FSV, currently in service with the Philippine Armed Forces in two platform types – wheeled and tracked. Both are modifications to existing platforms offered by Elbit Systems and are armed with the same turret system, featuring a 105 mm gun, optoelectronic sights, as well as fire control and battle management systems. The tracked variant is based with the ASCOD 2 platform, the wheeled variant is built around the Pandur II 8×8 platform.

Finally, large-calibre indirect fire solutions appear to be emerging as a distinct segment of the vehicle turret market. A notable example is the RCH 155 artillery system by KNDS; this automated artillery module, featuring a 155 mm L52 gun and an autoloader, was initially developed for the Boxer 8×8 platform but, by 2025, was integrated with several other platforms, including the Boxer tracked, Piranha IV Heavy Mission Carrier (HMC) 10×10, a modified ASCOD 2 platform (Donar), and an Iveco Trakker 8×8 truck (AGM Iveco).

A similar example is the artillery module co-developed by Rheinmetall and Elbit Systems, simply referred to as the 'Artillery Turret' by Rheinmetall, armed with a 155 mm L52 gun. This has so far been shown integrated with Rheinmetall's

HX3 truck, and an Oshkosh truck, known as the 'Sigma' in the latter iteration.

While the large-calibre turret segment is arguably the most complex in terms of production and engineering, the growing interest in automated and modular artillery systems may drive the emergence of new products and integrations.

Looking ahead

The ongoing complex geopolitical situation is likely to remain a key market driver, fuelling the growth of military spending worldwide.

The AFV turret market will need to adapt to changes in tactics and ground warfare, necessitating further improvements in AFV turret designs. The need for enhanced firepower, survivability, and adaptability will prompt the integration of cutting-edge systems, such as new optics/sighting systems, the integration of reconnaissance UAVs (both tethered and untethered), next-generation ATGMs, and advanced situational awareness systems, among others.

It is possible that, in the future, the vast majority of combat vehicles will receive C-UAV capabilities in some form — such as fire control system (FCS) upgrades, air-bursting munitions, software updates, or the implementation of electronic warfare or other soft-kill countermeasures, as well as hard-kill effectors. All of this will require further developments in the vehicle turret segment.

Pictured: The Boxer-based RCH 155 self-propelled howitzer (SPH). The artillery turret segment is relatively new, but shows significant promise. The RCH 155 was delivered to its first customer Ukraine in January 2025, and either on order, or planned to be ordered soon by several others including Germany, Qatar, Switzerland (on the Piranha IV HMC), and the UK. [KNDS]

While several turrets have been tested with UGVs, this class of vehicle has not yet been widely adopted due to various factors. However, with ongoing developments in unmanned technology, the demand for UGVs, and consequently unmanned turrets, is likely to increase.

Most AFV fleets will feature a combination of modern and legacy designs, but overall, the number of AFVs in service will likely increase, further driving the demand for modern turrets. Ultimately, the overall increase in AFV numbers will ensure that the market for turrets remains strong in the coming years.

Marketing Report: EVPÚ Defence

ARGUS:
New Laser Threat Detector

On the modern battlefield, soldiers can be exposed to laser irradiation in various situations. They may face threats from laser designators, illuminators, drones equipped with laser systems, or other devices whose laser irradiation can cause glare and disorientation. Additionally, laser targeting and tracking systems can detect soldiers, monitor their movements, and reveal their position, putting them at risk of targeted attacks.

EVPÚ Defence has introduced a new solution—the ARGUS laser detection system, which can be mounted on helmets or other tactical gear. The ARGUS system, inspired by Greek mythology where it symbolizes tireless vigilance and watchfulness, detects and warns against targeting and tracking by various laser means. By providing real-time alerts, ARGUS gives soldiers valuable time to respond and adapt to the situation.

Upon detecting exposure to laser irradiation, ARGUS warns the soldier through vibrations and/or sound, enabling swift decisions such as seeking cover or changing position. Its directional alert capability helps soldiers locate the source of the threat, a critical feature for situational awareness during targeted attacks or the defense of strategic positions.

[EVPÚ Defence]

ARGUS protects against a broad spectrum of laser threats while minimizing false alarms, ensuring that soldiers are alerted only to real dangers. This reliability helps maintain focus and prevents unnecessary distractions.

The device's lightweight and compact design is ideal for long missions, where minimizing the load is crucial. ARGUS integrates seamlessly with various military gear without compromising mobility or comfort. Furthermore, its compatibility with standard ballistic helmets simplifies deployment and preparation. Powered by replaceable rechargeable batteries, ARGUS ensures long operational life and straightforward maintenance. Soldiers can easily replace or recharge the batteries during operations, reducing the risk of downtime at critical moments.

ARGUS will be showcased at IDEX in Abu Dhabi, held from February 17–21, 2025, Hall 8, Booth A10.

Wheeled SPA platforms: A wheely good or wheely bad idea?

Shaun Connors & Pat Kennelly

Recent years have seen wheeled self-propelled artillery platforms proliferate, outpacing procurement of their tracked counterparts. Yet what challenges do designers of these platforms face, and do the claimed advantages of wheeled platforms outweigh their potential disadvantages? Yes and no.

Wheeled self-propelled artillery (SPA) is by no means a new concept, with the first examples of the type appearing while the military horse was still a common sight within all but frontlines. With regard to those early designs, it is most definitely true to say that Messrs. Heath & Robinson would have been proud of most of them, these literally being no more than assorted towed or even naval guns 'bolted' to the rear of a standard truck; and often not even an all-wheel drive truck, these in their infancy at that time. Basic trailing arms or stabilisers of sorts were employed for some of the bigger guns, but essentially that was it in terms of modifications.

Despite WWII, development in the SPA area remained surprisingly slow and unimaginative for decades, but by the time the world was firmly in the grip of the Cold War things had shown some progression. By this time SPA generally meant a fully armoured, turreted and tracked platform to the majority of higher-tier armed forces. Towed artillery of course remained very relevant, however, for anything other than the towed role 'wheels' were for the most part limited to roadwheels within caterpillar tracks.

By the early 2000s, the fall of the Berlin Wall, the first Gulf War and numerous other smaller global events had combined to shift the focus of top tier military strategists from a peer-on-peer slogging match in central Europe to the very real threat of numerous simultaneous more asymmetric global scenarios. Deployability and strategic mobility quickly became the new buzzwords of these military strategists.

The first examples of wheeled SPA appeared while the military horse was still a common sight within all but frontlines. [CIO]

20 years later and a second World War, but the concept had evolved little. [Frank Hurley]

The wheel emerges

The key to achieving 'buzzword compliance' for SPA is argued by some to be the adoption of a platform based or derived from a wheeled truck design, as opposed to the tracked steel box norm of the Cold War era. Adding weight to this theory, some of the simpler wheeled offerings, such as the original

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CAESAR 6×6 from Nexter (now KNDS France) even managed to be air-transportable in a C-130 Hercules, a feat way beyond anything comparable that is armoured, turreted and tracked. Wheeled detractors of course raise the all-important issue of tactical mobility, arguing this usurps both deployability and strategic mobility, and that a tracked solution will always have superior all-terrain mobility to any size/weight comparable wheeled peer.

However, the 'would strategic or tactical mobility win out' debates is one of those for which there appears to be no winner in sight. What is not debatable though is that those wheeled platforms, even the most sophisticated examples, will be cheaper to procure. Estimates of course vary, but these average out at around a 30-40% cost saving for wheels compared to tracks, and through-life costs will also favour the wheeled option. The tracked steel box option will however have the potential for a longer service life, even if that includes a mid-life refresh and/or upgrade of some form.

However, before any of the aforementioned points can become a real issue, the actual gun has to selected and mounted to a platform; and by the early 2000s the tube artillery landscape had seen considerable evolution. Naval guns were no longer a realistic option, having neither the calibre nor desired range, with their land equivalents (be that towed or self-propelled) having grown to a standard calibre (NATO) of 155 mm, and weights (towed) of anything up to 10 tonnes; and that is 10 tonnes without any enclosure for the gun, ammunition or protection for the vehicle and gun crew. A gun crew was still required at this time as full automation was essentially still an emerging technology for artillery applications.

For completeness, calibres below the NATO standard 155 mm should of course be given a notional mention here. These do account for a small percentage of recent and current generation designs and proposals, and while for some applications these smaller calibres will continue to be adequate, for the majority of the world's top-tier armed forces bigger is definitely better. Bigger delivers the required mix of explosive payload, plus the ever-important increased range.

One of the first designs to emerge from the post-Cold War upsurge in wheeled SPA interest was KNDS France's CAESAR. [US Army/Sgt Teddy Wade]

With bigger being most definitely being better, it probably goes without saying that the days of essentially bolting a gun to the body and/or chassis of a truck and 'getting on with it' are long gone. The technical issues in adapting even the heaviest of truck chassis to mount and handle the weights and recoil forces of a modern artillery piece without damage are no longer insignificant. However, before we look in more detail at the design challenges involved here with regard to usability, longevity and mobility, a quick look at the current and near-term SPA market will potentially explain the plethora of such designs that have emerged in the last two decades.

Projections

The statement that in terms of believability and overall accuracy, statistics rate below 'lies and damned lies' springs to mind when looking at the SPA market. With the usual suspects (China, North Korea, Russia etc.) excluded for the standard viable data availability reasons, a cursory projection for the tube artillery market over the next ten years suggests a potential value of EUR 50+ billion. However, in excess of 50% of that is attributable to just three countries – Poland, South Korea and the United States – and established/ordered tracked platform expenditure.

Drill further down though and over that same 10 year period, even the more conservative of estimates suggest that for to-be-placed new-build orders the wheeled market value will likely be double that of the tracked market value. With wheeled platforms cheaper than tracked platforms, this suggests that close to 75% of anticipated new-build orders could be for wheeled platforms. These new-build orders are expected to be placed for one or more of a variety of reasons that include delivering a new capability, supplementing or replacing a tracked capability, or supplementing or replacing a towed artillery capability.

As with all such projections, caution should be applied here, with many variables and caveats to be considered. In this particular instance the world's largest defence market, the US, provides two of those. Firstly, after announcing the cancellation of the M109-based (tracked) Extended Range Cannon Artillery (ERCA) in early 2024, in its continued and urgent search for a longer ranged tube artillery solution the US Army stated following an August 2024 released solicitation that to meet this requirement both wheeled and tracked solutions will be considered. This was followed in January 2025 by an announcement that the search would commence with a Phase 1 request for proposals to be launched mid-February, with contracts to be issued around a July-September 2025 timeframe. The current suggested timeline for this effort sees initial fielding around 2030, and potentially of more than one solution. Also during 2024, US Army Futures Command head Gen. James Rainey said: "I personally believe that we have witnessed the end of the effectiveness of towed artillery: The future is not bright for towed artillery." The US Army's current inventory for these two types, both of which use 155 mm L39 guns, totals over 1000 pieces, 671 of those tracked (400 M109A6; 271 M109A7), with a further 850 M109A6s reported to be in storage. Ahead of the

aforementioned January 2025 competition announcement, these figures will likely be bolstered by the acquisition of 689 additional M109A7s announced in early February 2025.

Additionally, it should be noted that the current spike in artillery interest has been fuelled in no small part by the war in Ukraine. In what is an artillery-heavy conflict, Ukrainian military commanders estimated that by late 2024 around 80% of casualties on both sides had been caused by artillery.

Agreement

Industry, it appears, would broadly concur with the facts, figures and projections provided in this feature, as in the last 20 or so years somewhere in the region of 30 truck-based SPA platforms have been shown by manufacturers in one form or another. That figure grows closer to 50 if China and Russia were to be included.

Pictured: Russia's 2S35-1 Koalitsiya-SV-KSh. Even with China and Russia excluded from figures, in the last 20 or so years roughly 30 truck-based SPA platforms have been shown by various manufacturers. [TV Zvezda]

Designs promoted vary in complexity and sophistication, with some lower-tier armed forces still attempting the simpler retro approach of mounting little more than a towed artillery piece, minus wheels, to a truck flatbed. At the opposite end of the scale we have far more sophisticated purpose-designed solutions such as BAE Systems' Archer, KNDS' latest CAESAR Mk2, or the Oshkosh-based Elbit Systems Roem/Sigma.

While some have, it is fair to say the majority of those 30 or so designs have not and/or will not make it into mass production, but even so, comparing those numbers to a figure of less than five new tracked systems appearing over that same time period and it becomes crystal clear the direction that industry believes the market is heading. If any more kudos to the wheeled argument is required, even Hanwha, the manufacturer of the market dominating K9 Thunder 155 mm tracked SPA is actively developed a wheeled K9 derivative.

However, as previously noted, to successfully design and produce a wheeled self-propelled artillery piece that capitalises on the types' benefits whilst minimising any impact from limitations is nowhere near as simple as it once used to be.

Technical challenges

The key factors that underpin SPA performance include structural integrity and mobility, and what is interesting from a technical perspective is that these requirements often compete with one another. An early task then for any integrator or OEM has to be to determine where compromises are best made to get an appropriate level of performance.
When looking at any base chassis, alongside simple packaging and integration, the key element is structural integrity. While modern weapons have sophisticated control systems to manage recoil and movement, it is fair to say that base gun performance will be improved by having the stiffest possible platform mount. This is where things first start to get interesting.

There are limited exceptions (RMMV's HX range being one), but the vast majority of 'military trucks' are based around a commercial chassis, albeit a heavier-duty 'construction grade' one. These with very limited exception are fitted with traditional beam-type (solid) axles, rather than independent suspension. Beam-type axles, while proven and cost-effective, offer limited wheel travel. In many cases to achieve the necessary wheel travel for reasonable levels of off-road mobility, it will be necessary to allow a degree of flex in the chassis. This flex can be in the region of up to 400 mm diagonally from corner to corner. Such flex is completely incompatible with the need to have a stiff mounting platform for the weapon and significant modifications and/or strengthening will likely be required to introduce a degree of torsional stiffness.

On a slightly more subtle note, the issue of dealing with recoil is something that will be discussed below, but in the context of the interface with the chassis, it does present a challenge. Actual recoil forces vary significantly from weapon to weapon, but at the top end, consider forces in the order of 35 tonnes, and applied in a fraction of a second. Recoil management is a key part of the weapon design, but regardless, the interface and the chassis itself need to be stiff enough to support the weapon. At the same time though, some method to provide controlled compliance will result in a much longer life. As an example, it is not uncommon to see mounts employing stacks of Belleville washers to provide a controlled stress gradient across the interface, balancing platform performance against fatigue life and durability.

In addition to structural integrity, weight distribution is also an important factor, with the bulk of the weight often con-

Elbit's SIGMA/Roem is based on a military specific Oshkosh chassis and believed to have independent suspension, CTIS and 16.00 R 20 tyres. [Elbit Systems]

centrated at the rear, where the weapon is mounted. If not tackled correctly, this can lead to overload on some axles and inevitably premature failure. Overload can be offset to some extent by clever placement of the auxiliary support systems and ammunition storage, but variations in weight distribution when laden versus unladen still need to be managed. With some of the 6×6 platforms on the market, it can be readily seen that the rear two axles are quite a long way aft. This location will provide more direct support for the weapon and will help with weight distribution, but the longer wheelbase it generates can have other negative implications such as ramp breakover angle issues and a larger turning circle.

As we move down into driveline and suspension, stability and mobility become critical factors. Off-road (tactical) mobility of a wheeled platform will never be as high as that of a tracked platform, but the argument is this is generally offset by much better on-road (operational) mobility, and often easier air-transportability making for better long-distance (strategic) mobility. However, some level of off-road mobility will still be required.

Beam axle solutions, while robust and reliable, are again not your best friend here. Apart from the wheel travel limitations mentioned previously, the roll stiffness of a truck with independent suspension could be four times higher than an equivalent size vehicle with beam axles (spring spacing squared on beam axle, versus track width squared on independent suspension). This has significant implications for stability, particularly with the high centre of gravity that comes from mounting a heavy weapon high up, and operating it on uneven terrain. The addition of anti-roll (sway) bars may help control body roll, but at the expense of a further reduction in off-road mobility. While not confirmed by Oshkosh for competitive concerns, the military-specific Oshkosh platform used for Elbit's Sigma/Roem appears to be one of very few truck-based SPA solutions to have an independent suspension set-up; the only other known independent suspension solution is offered by TATRA.

The suspension of all but the heaviest of truck chassis will likely need upgrading to manage both the increased weight and the loads from operation, but it is from the suspension onwards that the impact of recoil is most felt. For the suspension units themselves (springs/dampers/hydro-pneumatic struts) performance can certainly be improved by having some form of lock-out on the system during firing. However, the ground-platform interface, the tyres, are also a major factor. Most wheeled solutions will employ some form of outrigger to mitigate load and recoil forces. This can be either some type of spade (usually rear-mounted) that digs in to transmit recoil forces directly to the ground, or side-mounted outriggers similar to those commonly seen on mobile cranes.

In addition to reducing mechanical stress on the chassis and downwards through the suspension from recoil, the use of outriggers in particular enables firing in otherwise difficult scenarios (90° traverse, limited elevation, full charge), and they will also assist in keeping the barrel 'fixed' for sequential firing. The structural forces involved can make these quite substantial pieces of kit, and a further design problem for engineers is getting and spade or outrigger assembly to deploy easily and be recovered quickly, critical for survivability and the ability to conduct 'shoot and scoot' operations.

Clearly visible, the four substantial outriggers fitted to Serbia's NORA-B52. [Serbian MoD]

Tyres should also not be overlooked. Many of the larger pieces of wheeled SPA are fitted with 16.00 R 20 tyres, not their lower profile counterparts, which for legislative compliance reasons are in many cases fitted to comparably-sized chassis when used for day-to-day military applications. These 'full size' tyres are not only capable of carrying heavier loads than their lower-profile counterparts, but they also contribute significantly to improved off-road mobility. Additionally, and for genuine off-road mobility, the ability to adjust tyre pressure on the move is vital. A central tyre inflation system (CTIS) and associated run-flat inserts are common on wheeled tactical vehicles, but they are a lot less common on commercial vehicles, and CTIS in particular is not easily incorporated into designs that (primarily for cost reasons) retain their standard commercial drive axles. While, as previously stated, wheels will never match tracks off-road, with thoughtful design there is no reason why the mobility capabilities of wheeled artillery should not exceed those of comparable size towed artillery.

RMMV's SPA offering, known officially as the WASD (Wheeled Artillery System Demonstrator) is shown here with the 'Artillery Turret Interface (ATI)' outrigger stabilisers engineered by Supashock of Australia. The latest WASD prototype, scheduled to commence live fire testing shortly, will have an ATI developed by Elbit Systems, similar to that fitted to the Oshkosh-based Elbit SIGMA/Roem. [RMMV]

So far, we have concentrated on safety, performance and service life implications for the platform, but equally, there are a selection of other tasks required to achieve a good solution. These can include power supply (electrical, hydraulic, pneumatic), auxiliary systems, control systems and weapons integration. Most of these challenges are self-explanatory and readily understood. Other less obvious areas include crew protection.

Given the battlefield role of SPA, it is likely that a level of ballistic protection (in addition to basic muzzle blast protection) will be required for the crew, this leading to the need for an armoured cab. Most of the challenges associated with the mounting of the weapon (additional weight, interface to the chassis, higher centre of gravity) will also apply to the installation of this cab. The cost and complexity of testing and certifying a protected structure such as a cab are not insignificant.

Wheeled alternatives

While a ladder- or truck-type chassis is readily-available for SPA applications and has clearly been the go-to solution for many designs, other options with wheels do exist for designers. BAE Systems' Archer was originally offered on a modified Volvo frame-steer dump truck chassis, and while such a platform sits at the very top end of wheeled vehicle all-terrain mobility, for current Archer contracts BAE Systems has swapped to a RMMV HX truck chassis.

Elsewhere, South Africa opted to design a platform from the wheels up for its 155 mm SPA, the G6 Rhino. It should be noted however that South Africa was well ahead of the wheeled curve with the G6, design work starting in the late 1970s. Ultimately the G6 would be exported in small numbers

Pictured: Type 19 155 mm SPH of the Japanese Ground Self-Defense Force. Most but not all wheeled SPA being adopted by top-tier armed forces feature enclosed and automated ordnance and a ballistically-protected cab for the crew. [JGSDF]

Some of the simpler SPA systems require manual loading by a gun crew that are exposed to the elements, incoming fire and similar, but the majority of higher-tier armed forces are now adopting automated systems. In this configuration having a cab and any required gun crew separate from the ordnance/turret also has the significant advantage of separating all personnel from the ammunition.

Through all of this, the basic controls for development of a modern solution in the defence space still apply. Regardless of the process chosen, or how it is described, fundamental development systems engineering is required. Even if mounted on a commercially-sourced truck chassis, this is still a formidable and complex piece of kit. From the stakeholder needs and system requirements at the front end, through to test, validation, verification and certification at the back end, each step is an important piece of the journey to a safe and reliable solution.

to Oman and the UAE, both countries where the prevalent terrain types reduces the importance of the wheels vs tracks mobility argument. As an aside, it is worth noting that Iraq was quite taken with the G6 concept and from 1988 the design of two comparable platforms began, though these never came to fruition.

A further wheeled option for any SPA is that of an armoured personnel carrier (APC). Such options are relatively 'late to the party' and while a small number of design proposals have been muted, as of early 2025 only KNDS' Artillery Gun Module has made it to production orders, this on ARTEC's Boxer 8×8, along with an order on GDELS Piranha IV Heavy Mission Carrier (HMC) 10×10 platform likely to be ratified later in 2025. China's NORINCO entered the fray in late 2024 with the SH16A, reportedly based on an VN23 8×8 base; however, there are currently no known orders for the SH16A.

KNDS' Boxer-based solution is the only APC-based SPA known to be in current production. [KNDS]

Compared to a truck/chassis-based solution, a key advantage of these APC-based designs is that both the Boxer and Piranha options are reportedly capable of firing on the move. While this capability can do nothing for accuracy, it is still something no truck-based solution is capable of. No stabilisers or earth spade are fitted, recoil forces being mitigated by the combination of weapon design, a monocoque structure, and suspension. Of note for comparison, NORINCO's SH16A is equipped with two stabilisers on each side, these centre- and rear-mounted.

Also potentially a key advantage of basing SPA on an APC platform is that with little exception these vehicles are fitted with independent suspension, have a driveline designed for 60% slopes, are not fitted with mobility-limiting lower-profile tyres, and have a central tyre inflation system (CTIS). These are all features that theoretically give a significant improvement in off-road mobility when compared to a baseline truck-type chassis. However, as always, the devil is in the detail.

For larger APCs, the most common tyre size fitted is the 16.00 R 20, which is readily available in the field. The maximum practical weight limit for reasonable soft ground off-road performance is 9 tonnes per axle, even with CTIS. Once above that weight, you also have the challenge of how to package an adequate brake unit inside a 51 cm (20 inch) rim. For tactical vehicles with hydraulic brakes, most will already have two calipers on at least the first couple of axles, but air brake units are physically bigger, so packaging two on an axle is not feasible.

This suggests 36 tonnes as being a practical limit for a four-axle platform, but looking at some options currently being offered it appears that platform weights are likely to reach or exceed 40 tonnes. Of note, NORINCO quote just 32 tonnes for the SH16A, which suggests a lower level of protection when compared to contemporary Western designs.

For a platform like Boxer, the weight issue is tackled by using tyres wider than 16.00 R 20. That is fine if you are operating your SPA alongside a comparable fleet, but if your primary fleet runs 16.00 R 20, this introduces an additional logistic burden for spare parts and maintenance, particularly in theatre.

On the driveline side, a step up from a nominal 36 to 40 tonnes obviously impacts peak torque and duty cycles, potentially requiring an upgrade, redesign, or a shorter life. It may only represent an 11% increase in tractive effort requirements, but the 60% grade climb is often a limiting factor in platform performance and the base vehicle may not have enough margin to accommodate the upgrade. A 'simple' modification might be to change the low ratio in a two-speed transfer case, but that assumes the housing can accommodate the different gear sizes, and you still run the risk of overloading differentials, shafts and hubs.

Pictured: Piranha IV HMC 10×10 with KNDS' AGM module. Compared to their tracked counterparts, wheeled SPA will be lighter, but they will also be narrower and taller. [GDELS]

An alternative approach is to add an additional axle, moving from a nominal 8×8 configuration to 10×10. This is what GDELS have done with their Piranha IV HMC 10×10 base for KNDS' AGM. This approach can preserve axle loadings, but may impact other areas, such as turning circles, requiring all wheel, or multi axle steering. With contra-steer on its two rearmost axles, GDELS' 10×10 Piranha has a turning radius of <18 m, which is 3 m more than Boxer's 15 m with skid steering. All the preceding challenges can be overcome, but each one adds complexity, risk, and of course cost to any project. From a design perspective, the configuration of the base vehicle also has implications for the options available and the design work necessary to accommodate the change. Some 8×8's have a protected hull structure mounted to a chassis or sub-frame that houses the driveline. This is the most flexible solution, allowing a custom structure to be designed, still providing protection for the crew and potentially a lower mounting point for the gun, to reduce overall height and centre of gravity. Boxer's exchangeable mission module concept is the current 'gold standard' of this flexible approach.

The majority of platforms have a monocoque hull (without a sub-frame or chassis), this making the design of a new hull more complex, as much of the initial design integration for the driveline will need to be revisited and possibly re-designed. This has implications not just for performance and mobility, but may require additional durability testing to prove the package. Overall though, the result when using a wheeled APC-type platform is almost certain to be a solution that is narrower than any tracked equivalent (roughly 3 m versus 4.3 m), but more importantly significantly taller (roughly 3.6 m vs 2.75 m), with the associated mobility impact on centre of gravity and lateral stability.

A wheeled APC-based platform on average weighs around 20% less than a comparable tracked solution, and while benefits of this not previously covered include transport and battlefield recovery, the simpler overall box-style of most tracked platforms will, for a broadly comparable overall internal volume, offer up the ability to carry as much as 60% more ammunition.

A note on hybrid designs

Finally, this feature would not be complete without a cursory look at the unique Czech DANA and its derivatives. The DANA (Dělo Automobilní Nabíjené Automaticky; ENG: self-propelled gun loaded automatically) was designed in what is now Slovakia, and entered service in what was then Czechoslovakia in 1981. A 'hybrid' design, the DANA is based on a TATRA truck chassis, which is based around a torsionally-stiff backbone-type tube with swinging half-axle suspension, and suspension being fully independent on later models. Despite the chassis and suspension arrangement, the DANA also has three hydraulic stabilisers to mitigate recoil forces. The DANA has an armoured

The Czech DANA: arguably the odd one out? [Polish MoD]

cab, and the engine compartment is located at the rear. The separate centre-mounted turret is armed with a 152 mm gun and features an early-generation automatic loading system. With the Czech Republic and Slovakia's accession to NATO the DANA evolved to become Zuzana with a NATO-standard 155 mm gun, with the latest evolution of the concept (which is still TATRA-based) marketed as DITA.

Dawn of the drone wars

Doug Richardson

Small, adaptable, and increasingly autonomous, unmanned systems are increasingly reshaping the battlefield and changing how military operations are conducted, with numerous countries and non-state armed groups demonstrating their potential in conflict zones.

During his long career as a member of Hamas, and as its leader in Gaza since February 2017, Yahya Sinwar probably accepted a growing risk that this could end with his death in combat with the Israel Defence Forces (IDF). That risk became reality on 16 October 2024 when an Israeli drone observed him entering a building in the southern Gazan city of Rafah.

Seemingly already injured in a firefight, he was then located within the building by what may have been the same drone. Small enough to be able to fly into the building via a window, it hovered in the room, then moved forward into the next room, where Sinwar could be seen seated in a chair, from which he threw a stick at the drone. Initial reports suggested that he was subsequently killed by gunfire from an IDF tank, but a later autopsy showed that he had been fatally injured by a bullet wound to the head.

In many ways it is surprising how much things have changed in such a short time. When the US began using uncrewed aerial vehicles (UAVs) for reconnaissance purposes during the 1960s, these were relatively large, and flew at medium altitudes. This trend remained relatively steady for many decades, but recent conflicts have seen of small drones become near-ubiquitous, with an exponential increase in usage over the last three years. These are often adapted versions of the commercially-available drones flown by enthusiasts, with many being rotary-winged, and able to move or hover as required. Press reports from Gaza have described the near-constant buzzing sound created by Israeli drones; a sound so common that among Gazans it has now made its way into slang as 'Zanana'.

OWA drones and decoys

Israel remains fairly tight-lipped regarding its tactical drone capabilities, but drone operations by both sides in the current conflict between Russia and Ukraine give significant insight into this rapidly-evolving technology. Following the start of its full-scale invasion of Ukraine in February 2022, Russia began importing Shahed one-way attack (OWA) drones from Iran, and later launched a programme to manufacture these in Russia as 'Geran' drones. The intensity of Russian drone attacks against Ukraine increased sharply during 2024. This may have been facilitated by a major expansion of a drone factory in the Alabuga Special Economic Zone, in Russia's southern Tatarstan region. The facility is thought to be manufacturing Iranian-designed attack and surveillance drones. Russia's Geran-2 version of the Iranian-developed Shahed-136 is probably the main product at the Alabuga plant.

The Izdeliye-52 variant (pictured) of Zala's Lancet family was designed to conduct strike missions at ranges of more than 30 km. [Zala]

One of Russia's most notable precision-attack loitering munitions is the Zala Lancet family. These comprise a cruciform-winged design powered by a tandem-mounted piston engine. The Izdeliye-52 model has a maximum range of more than 30 km, and carries a 3 kg warhead, while the larger Izdeliye-51 model has a maximum range of over 50 km and carries a 5 kg warhead. Terminal guidance for both is by means of a nose-mounted optoelectronic seeker. By early 2024 Lancet family munitions were credited with having been used in more than 1,000 strike missions against targets that included surface-to-air (SAM) and radar systems, towed and self-propelled artillery, parked aircraft, naval vessels, tanks, and vehicles.

Ukraine has been more forthcoming than Russia at releasing information regarding its drone operations. Its Aerorozvidka military organisation has created the R18 octocopter, with eight rotor blades, a flight time of 40 minutes, a thermal imager, and a carrying capacity of five kg. This allows it to carry loads such as three RKG-1600 bombs. Created by adapting

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Soviet-era anti-tank hand grenades, these bombs weigh around 1 kg. A further example is the hexacopter Vampire developed by the Ukrainian company Skyfall. Fitted with a thermal camera for nighttime operations, it can carry up to 15 kg of munitions, and can be used to target AFVs, ammunition depots, and a wide range of defensive structures.

In 2023 Ukraine started to make extensive use of what are termed 'first-person view' (FPV) drones. These transmit video imagery that operator can view using goggles similar in function to virtual-reality headsets. Small and relatively inexpensive, these were adapted for military use by attaching explosive payloads such as anti-tank grenades and rocket-propelled grenade (RPG) warheads. This improvised armament was often fixed in place with crude methods such as plastic cable ties, and often used fairly primitive fuzing, but the result was a weapon that was cheap enough to be regarded as 'one-shot' and worked by crashing into its target. At first, the drones that Ukraine was using over the battlefield could obtain imagery only by day, but by the end of 2023 drones fitted with thermal cameras were allowing night-time attacks to take place.

Ukraine has also explored alternatives to kamikaze-style attacks by arming some FPV drones with reuseable weapons such as shotguns or grenade launchers. The autumn of 2024 showed video evidence of what may be another reusable payload, with the release of video showing a drone flying along a Russian trench line and releasing a continuous stream of incendiary material purported to be thermite powder.

For Ukraine, long-range OWA drones are its only method of attacking targets deep in Russia. For example, on 10 November 2024, Russia claimed that it had successfully engaged 84 Ukrainian drones, some of which had been approaching Moscow. What Ukraine claimed was the largest-scale attack against military targets deep inside Russia was conducted on the night of 13/14 January 2025. Targets were reported to have been between 200 km and 1,100 km distant, and included sites in the Bryansk, Saratov, and Tula oblasts, as well as in the Republic of Tatarstan. On 20 January, Ukraine claimed to have attacked military facilities in Kazan, including the SP Gorbunov Kazan Aviation Plant, which produces Tu-22M3 and Tu-160 strategic bombers. An attack against a bomber base at Olenya in Murmansk reported in July 2024 would have involved a flight of around 1,700 km, close to the 1,800 km maximum drone range claimed by Ukrainian Deputy Prime Minister Mykhailo Fedorov in a December 2024 interview. Production of these long-range drones has been increased on a large scale, he stated, and the plan for 2025 is to manufacture up to 30,000 units.

▲ **The Ukrainian police described this downed OWA drone as a Shahed, but the Cyrillic markings suggest that it is probably a Russian Geran-1 derivative of the original Iranian Shahed-131. [Ukrainian Police]**

Drones can sometimes be used in conjunction with cruise missiles in order to help saturate the enemy's defences. A good example of this tactic came in late 2024, when Russia conducted major attacks against the Ukrainian energy infrastructure. A total of 200 missiles and drones were used on 28 November, followed by 93 missiles (a mix of ballistic weapons and cruise missiles) and almost 200 drones on 13 December.

A December 2024 report by the Washington-based Institute for Science and International Security noted the Russian use of two types of decoy drone during missile and drone strikes on Ukraine. It identified two types – the Gerbera and the Parodiya – both of which were intended to mimic threats such as the Geran-2. The report noted "Both of these drones can be mass produced quickly and are built from simple materials like plywood, foam, and a few electronics".

Such simple construction makes these much less expensive than the threat systems that they are emulating. As a result, they can be launched in large numbers at the same time as missiles and OWA drones. Since Ukrainian air defenders have no way of distinguishing between threats and decoys, they are forced to engage both, expending large quantities of anti-aircraft missiles and ammunition, and thus reducing their available stockpiles. Initially, these Russian decoys were unarmed, but were soon reported to be carrying an explosive payload and being directed towards ground targets that do not warrant the use of a full-sized OWA drone.

One potential method of countering drone attacks is to use a 'friendly' drone to attack the intruder. This concept has been adopted by both Ukraine and Russia. In 2024 Ukraine launched a competitive evaluation of interceptor drones, and by the end of the year had fielded a system that has since been credited with around 20 interceptions. Shotgun-armed Ukrainian drones have been used against ground targets including individual infantrymen, but have also taken part in air-to-air engagements against Russian drones.

Sea and land drones

Attacks by Ukraine against Russian warships have been successfully mounted by means of uncrewed surface vessels (USVs), but Russia responded by using fixed-wing aircraft and helicopters to engage these attackers.

Russia's response triggered a counter-tactic, with Ukraine arming its Magura V5 USVs with a 'Sea Dragon' system that mounted two R-73 (AA-11 Archer) infrared homing (IRH) air-to-air missiles (repurposed as SAMs) on fixed launchers. On

A Russian helicopter pursues a Ukrainian naval drone that seems to have expended one of the R-73 missiles that form part of the USV's Sea Dragon anti-aircraft system. [Russian MoD]

one occasion the Russians were able to engage and destroy a missile-armed Magura V5 USV which had apparently launched one of its two R-73 rounds, but on 31 December 2024, the Ukrainian Ministry of Defence released video imagery of what it claimed was a successful engagement of a Russian Mi-8 helicopter by an R-73 missile launched from a Magura V5 USV. A second helicopter was reportedly damaged and had to return to its airfield.

One method of increasing the range of FPV drones is to air launch them from a location close to where they are needed. In September 2024 the Telegram messaging service displayed a Russian video sequence that showed two operators releasing a drone from a helicopter flying in an over-water location. One man was shown launching the drone from the door of the helicopter, while another wearing what looks to be an FPV headset seemed to be operating a control unit.

As this Ukrainian Ratel-3 unmanned ground vehicle demonstrates, off-the-shelf ordnance can be mounted in an improvised manner. [Brave1]

The representative of a Ukrainian brigade operating in what was described as "the Kharkiv direction" reported on 20 December 2024 that on an unspecified earlier date Ukrainian forces had conducted their first ground attack made exclusively using robotic systems instead of infantry. Carried out near Lyptsi (north of Kharkiv City), the attack had involved "dozens of UGVs equipped with machine guns", and purportedly successfully destroyed a number of Russian positions. Other UGVs had been used to lay and clear mines in unspecified locations in the area, the spokesman stated.

At least five types of UGV are known to have been developed under Ukraine's Brave1 programme:

- Ratel-S is a small wheeled vehicle able to carry a payload of anti-tank mines or other explosives weighing up to 35 kg. Its operating time is 40-120 minutes (depending on speed).
- IronClad uses a hybrid power plant able to produce off-road speeds of up to 15 km/h for up to 13 hours. It carries a Shablya M2 turret, equipped with day and thermal cameras, and is provided with a level of ballistic protection to resist enemy small-arms fire. The turret can be armed with a 7.62 mm or 12.7 mm machine gun. While the vehicle is reported to have a range of 130 km, the command link has a range of only 5 km, or 10 km if a repeater is available; or just 1 km if the fibre-optic cable option is used.
- Described as a "reconnaissance and strike ground robotic complex", the D-21–11 combines a D-21 logistical ground robotic chassis with the D-11 – a stationary ground combat module that allows an operator to aim and fire its weaponry against enemy personnel, light armoured vehicles, and helicopters flying at low altitude.
- Volya-E is a radio-controlled tracked vehicle developed for logistic tasks such as the delivery of cargo and provisions. Initially fielded to carry up to 150 kg, it was soon being tested with 300 kg payloads.
- FoxTac was developed to evacuate wounded soldiers from the battlefield, and take them to a front-line location where they can be transferred to a medical evacuation vehicle.

The growing role of fibre-optics

Both sides in the Ukrainian conflict have made large-scale use of jamming in order the disrupt drone operations by the enemy. Operations with drones that relied on RF links are still possible, despite the growing level of jamming, but this technique is slowly becoming unviable. One 2024 estimate claimed that up to 75% drone sorties by both combatants were being affected. Fibre-optic links proved a workable solution to the jamming problem. For example, the widely-used quadcopter drones could be fitted with a belly-mounted spooling mechanism able to disperse an optical fibre which allowed higher-bitrate data exchange, worked even at very low altitudes, and was immune to jamming.

In early 2024, the Russians were documented as having started to use drones controlled by optical fibre. Later in the year, commentators noted that these were limited in range by the length of the fibre, and noted that the fibre system posed a weight penalty, and could face problems due to the

trailing fibre becoming caught on obstacles. The need to avoid terrain features that could snag or break the fibre is a significant factor that may reduce the range of a fibre-optic guided drone.

A Russian drone fitted with a fibre-optic communication link sent back this pre-impact image of a Ukrainian AFV. The bandwidth of the link is greater than that available from radio-based links, so provides a clearer image that is possible with the older technology. [Russian Armed Forces]

A noteworthy and relatively new Russian model of drone with fibre-optic datalink is the 'Prince Vandal Novogorodsky' (KVN). While the use of optical fibre restricted the operational range of the drone, it provided higher-quality imagery to its operator than had been typical when RF links were being used. Russian forces were increasingly using drones that used fibre-optic communications links, a representative of one Ukrainian brigade reported on 8 January 2025, but claimed that these drones were slower and less-manoeuvrable, so were more vulnerable to small-arms fire. The Ukrainian General Staff reported in December 2024 that Ukrainian officials had completed tests of a drone linked to its control location by a fibre-optic cable.

Swarms and AI

During operations in Gaza in mid-May 2021, the Israel Defense Forces (IDF) were reported to have begun using a swarm of small drones to locate, identify and attack Hamas militants. A networked entity that incorporates artificial intelligence, these swarms were understood to require only a single human operator to direct them towards targets, and be able to keep operating even if many of its individual members were jammed or shot down.

One factor that may encourage the deployment of swarms is the trend towards smaller UAVs. This raises the inevitable question of just how small future drones might be. Originally developed by the Norwegian company Prox Dynamics AS, the Teledyne FLIR Black Hornet Nano is only 168 mm long and weighs less than 33 g, but can transmit live video or stills back to its operator from its low-light day and thermal cameras. In 2017, Israeli Minister-without-Portfolio Ayoub Kara claimed that some future drones might be as small as flies, and could become operational within three years, but to date no hardware of this size has been publicly announced.

Many current types of precision-guided weapon offer a 'man-in-the loop' capability that allows the operator to observe seeker imagery during the final stages of weapon flight in order to ensure that a valid target is being attacked, or to break off the engagement if this proves necessary, either because the target is not valid, or in order to prevent civilian casualties. However, the technology needed to create a fully-autonomous weapon able to identify and attack a pre-defined class of target already exists. The robotic killer drone able to identify and attack a pre-defined class to target is no longer a future development, but may already have been used operationally.

Ukraine's Saker Scout has already been given a degree of autonomous target-recognition capability. [Saker]

When first deployed in 2023, the Ukraine's Saker Scout quadcopter drone was used for reconnaissance. It was reported to be able to autonomously recognise Russian military vehicles, then transit their coordinates to a ground station. UN allegations that drones conducted autonomous attacks in Libya during 2020 remain unproven, but news reports published the spring of 2024 claimed that Ukraine's Saker Scout was able to carry out autonomous strikes on Russian forces without a human operator. According to the Saker company, its drones were able to recognise 64 different types of target, including tanks, armoured personnel carriers and other hardware. As a result, they could operate in areas where Russian jamming had blocked normal communication between drones and their controllers. If GPS is being jammed, the drone could navigate by recognising known terrain features.

Autonomous target-recognition may not come with a high price tag. In November 2024 the UK newspaper The Daily Telegraph demonstrated how a commercial off-the-shelf drone could be given fully-autonomous homing capability. Luis Wenus, described by the newspaper as "a young Norwegian tech entrepreneur who is concerned about the use of drones as weapons" modified an inexpensive commercial drone into a potential assassination device in just a few hours. The journalists uploaded a facial image of one of their number into the modified drone, which was then released into a rented conference room being used for the demonstration. During its subsequent autonomous flight, the drone was able to manoeuvre around room features such as pillars and chairs, and check the facial features of anyone it could see before recognising and flying into its pre-programmed victim.

Drone 'motherships'

Another emerging technique is to use a UAV to launch smaller UAVs. This allows the latter to be used in locations beyond their normal operating range. Several notable developments have happened in this sphere within the last few years:

- In early January 2025 Ukraine claimed to have used USVs to launch drone attacks against Russian targets on the coast of the Black Sea, and released imagery showing an attack mounted against a Pantsir-S short-range air defence (SHORAD) system.
- In September 2024, Russia revealed the Burya-20, an aircraft-style drone able to fly more than 60 km from its ground control station, release a number of FPV attack drones, then act as a communications relay station for these.

A still from a video showing the Dovbush T10 in flight, with FPV drones under the wings. Note that here the drone munition is used as an adaptor between FVP and mothership weapon pylon, with the drone mounted upside down. [Serhii_Flash Telegram Channel]

- In 2022 Ukraine had begun to field the Dovbush T10 reconnaissance drone, but it has now adapted this as a drone mothership. In this role the T10 can carry up to six FPV drones, then act as a communications relay once these have been released.
- In 2021 the Chinese company Zhongtian Feilong conducted a test flight of a drone able to carry and release multiple smaller drones that could form a swarm. It released a video showing a 'mothership' releasing nine smaller drones. According to the company, the location, speed, and direction of each release could be configured to allow the mini-drones to form a swarm. A team lead by Professor Shi Zhiwei of the Nanjing University of Aeronautics and Astronautics is reported to have taken the air-launched concept a stage further by developing a drone that can separate mid-flight into two, three, or even six smaller drones, each able to perform specific roles.

A look to the future

Ukraine became the first country to establish a dedicated military force to operate uncrewed systems. The Unmanned Systems Forces (USF) was created in June 2024 operate unmanned military robots on land, sea, and air.

Speaking at the Royal United Services Institute (RUSI) in London on 10 December 2024, Deputy US Secretary of Defense Kathleen H. Hicks said "Every war offers a window into how future wars will be waged. Unquestionably, Russia's war against Ukraine has much to tell us. . . we're seeing novel applications of both old and new technologies, some of which will be significant factors in how wars of the future will likely be fought."

Like the first use of Mark I tanks at the Battle of the Somme in September 1918, the Ukraine's pioneering use of an all-robotic attack force late in 2024 had little effect on the overall position of the front line. However, just as the tanks used on the Somme gave a first glimpse of the role that tanks would play in future battles, perhaps current operations by Ukraine and Russia will mark the beginning of an era in which drone wars will be fought over and on future battlefields. Yet one thing seems certain – just as the tank spurred the development and deployment of anti-tank guns and other anti-armour weapons, the drones of today are already providing impetus for the development of a new generation of anti-drone defences.

Non-state actors embrace drones in the Middle East and Africa

Sam Cranny-Evans

While the Middle East and Africa are no strangers to the use of drones in warfare, increasingly, many of the technological developments, trends, and tactics in unmanned vehicle employment observed in Ukraine appear to be proliferating.

It was around December 2023 when the first evidence began to appear on social media – a grainy video feed with two propellers just visible at either edge of the screen, with various warnings flashing in white between them. Only this time, the drones providing this video were flying over wide green fields with banks of orange soil and hunting down cars in impoverished towns. First-person view drones (FPV) had made their way to Syria. With the help of Russian advisors, the Syrian regime was striking at opposition forces and their civilian supporters using the same types of small drones that had been prominent in Ukraine for over a year. To some, this might herald the beginning of drone warfare in the Middle East, but the region is no stranger to munitions commercial drones.

The use of drones in the Middle East and Africa by non-state actors has grown rapidly since 2011, both in terms of the number of players and the types of drones used. The trend may have started with Libyan rebels in 2011, in a story that has likely been repeated in various forms a thousand times since. A Canadian veteran travelled to Libya from Malta on a tuna boat with a drone from Aeryon Labs stowed in his luggage. Hundreds of emails coordinating donations from eight countries had paid for the drone from the Canadian company, which was used by the Libyan Transitional National Council to conduct reconnaissance on its march from Misrata to Tripoli. At USD 120,000, that drone may have been relatively expensive compared to the ones that would be used in its wake. For instance, the Islamic State of Iraq and Syria (ISIS) had used commercially-available drones since 2013, leading to a well-established infrastructure for procuring and employing them by the time of the battle of Mosul in 2016. Its preferred drone was reportedly the DJI Phantom, which could be bought on Amazon for around USD 650 in 2013.

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Over the last few years, the proliferation of drones in combat roles, particularly small drones such as the Mavic Pro quadcopter pictured, has accelerated, notably in the Middle East and Africa. Additionally, attacks involving drones have increased in technical and tactical sophistication. [USMC/Cpl Shellie Hall]

ISIS used drones extensively in the battle for Mosul, flying over 300 missions, leading General Raymond Thomas, Head of the US Special Operations Command at the time, to state that ISIS enjoyed tactical superiority in the air over Mosul. At one point in 2016, ISIS deployed over 70 drones in a 24 hour period in Mosul, many of them armed, which almost brought the Iraqi offensive to retake the city to a halt. Maj Gen Roger Noble of the Australian Army was the deputy commanding general of the Combined Joint Forces Land Component Command – Operation Inherent Resolve during 2016; he recounted one company-level attack conducted by ISIS that involved armoured vehicle-borne improvised explosive devices (VBIEDs), indirect fire from mortars, bridging equipment, infantry, as well as drones for reconnaissance and command and control, indicating the level of complexity that non-state actors have used drones for.

Then, in January 2018, a wave of drones built from plywood and plastic bags began to emerge in Syria, shortly before a large attack on Russia's Khmeimim airbase, which the Russians claim to have foiled.

This image shows some of the drones that were captured after the 2018 attack on Khmeimim airbase in Syria. Several others of a similar design were documented in the area leading up to the attack, indicating that the users had ambitions for wider use. [Russian MoD]

In July 2021, Iran used a drone to strike the MT *Mercer Street*, a commercial tanker as it travelled through the Gulf of Oman on a journey between Tanzania and the UAE. The strike hit the pilot house killing two crew. The drone used was likely a predecessor of the Shahed family, which has since been sold en masse to Russia for its war against Ukraine, employing a delta-wing design and large explosive payload. The guidance methodology used for the strike is unclear. It seems probable that the drone was remotely controlled onto the target, which was travelling at around 27 km/h (15 kt) shortly before it was hit. The *Mercer Street* strike marked the early phases of what would become a coordinated campaign against shipping in the Middle East, including missiles, aerial- and sea drones that contributed to the sinking of the MV *Tutor* in 2024. The *Tutor* was attacked by an uncrewed surface vessel (USV) carrying a large quantity of explosives and two mannequins, which convinced the ship's crew that they were being approached by a crewed fishing vessel.

The drones used in these attacks varied in quality and capability, but their use over a decade of warfare indicates that they are here to stay. And now, sub-peer actors throughout the Middle East and Africa have access to them, adding to their ability to fight and counter the traditionally superior firepower of state forces.

Syria

FPV drones were first used in Syria in December 2023, or at least that's when the first public evidence that they were being used by Assad's forces became available. By the time their use had made it into major news outlets in February 2024, they had already been used in 13 attacks, often against individuals, civilians and agricultural areas, according to Munir Mustafa, deputy director of the civil emergency group, the White Helmets. The FPVs were manufactured in a lab south of Hama with guidance from Russian and Iranian instructors, as reported to *Al Jazeera* by Abu Amin who monitors the Syrian and Russian military. At first, it seemed that Assad's Syrian Arab Army (SAA) were the primary users, but by the end of December 2024, they were also being used by the Syrian Defence Forces (SDF), backed by the US, and the Syrian National Army (SNA), backed by Türkiye. Most notably, perhaps, the Ukrainians also supplied 150 FPV drones and 20 instructors or operators, to Hayat Tahrir al-Sham (HTS) that were used in its offensive that was ultimately successful in deposing Assad's regime.

A fighter from the SDF's Martyr Haroun Unit's reconnaissance detachment targets artillery and vehicles used by the Syrian National Army in southeastern Manbij using an FPV, December 2024. [SDF Press Centre]

From available video footage, the FPV drone used in Syria – regardless of the operating faction – are closely based on the systems built for use in Ukraine. They are typically designed to carry a large payload such as a PG-7VT tandem high-explosive anti-tank (HEAT) warhead, low resolution camera, and just enough battery power to get the drone to its target. The lack of landing gear means that the drone must be perched on a surface before launching. Quadcopter configurations are typical and control is shown to be through FPV goggles. If the FPV drone is fitted with a PG-7VT warhead weighing around 3.3 kg, penetration of up to 500 mm of rolled homogeneous armour equivalent (RHAe) is possible, with behind-armour effects. Such a setup is also a relatively effective munition for use against personnel in structures and trenches, according to one manufacturer.

The tactics and results of FPV drone use are not surprising. There are already videos showing the drones being used against the vulnerable rear turret armour on a T-55. A T-55 turret is made of cast steel with thicknesses between 48 mm and 200 mm; approaching it from the rear with a PG-7 type warhead ensures a very high chance of penetration and behind-armour effects, assuming that the fuzing method used in the FPV drone design works successfully. In other examples, the SDF claims to have conducted a number of strikes against Syrian National Army armoured vehicles, including what appears to be a Cobra II 4×4 armoured vehicle fitted with the Aselsan SERHAT II mortar detection radar. In others, the FPVs are flown into buildings after a reconnaissance drone observes person-

nel entering the facility. Many SDF videos show the operator emerging from a camouflaged and concrete-reinforced bunker to conduct the mission before returning to cover.

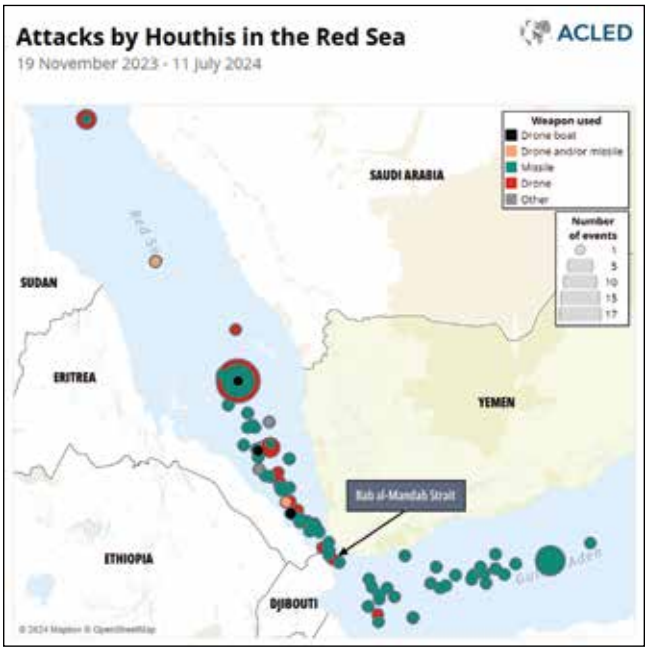
For the SDF and HTS, it seems as though FPV drones provided them with a vital form of precision targeting to counter the traditional firepower of their adversaries, or at least exploited the apparent inability of the Russian and Syrian air forces to interdict HTS's movements. This has allowed them to pick apart armoured forces of the regime and Turkish-backed groups, which would otherwise pose a real challenge to light infantry forces. FPV drones can also be used against defensive positions to quickly facilitate advances. With the Syrian regime forces defeated and much of the country's aircraft destroyed on the ground by Israel, it is likely that FPVs will be the only form of precision strike available to HTS's forces as they work to consolidate their control over the fractured country.

Ansar Allah

Ansar Allah (also commonly referred to as the Houthis) have arguably achieved the greatest success of any non-state actor through using drones, albeit as part of a wider and much more capable arsenal of weapons including anti-ship ballistic missiles. The Houthis differ from other groups covered here in that their drones tend to be used as long-range strike systems rather than tactical assets. Arguably, the uncrewed surface drones used against shipping in the Red Sea are a tactical system, but they are still employed over long distances, making the Houthi inventory more akin to an arsenal of missiles than drones.

This is partly a result of the nature of the wars that the Houthis are fighting; for example, they have tactical drones such as the Rujum, a hexacopter system that can carry 10 kg of payload up to 10 km. Similar drones were introduced in 2021, leading to a spike in drone attacks, according to ACLED. The Houthis often combined the commercial, multi-use drones with their one-way attack drones, especially in the failed attempt to capture Marib city in 2021. The Rujum has featured in over 25% of Houthi multi-use drone attacks, but the non-state actor favourites, the DJI Mavic and Matrice have also been used.

In 2017, the Al-Madinah, a Saudi Navy frigate was reportedly struck by three USVs carrying explosives as it patrolled the Red Sea, leading to the deaths of two crew and injuring three others. At the time, Vice Admiral Kevin Donegan, commander of the US Fifth Fleet and head of US Naval Forces Central Command ominously remarked that he was concerned this new Houthi technology would extend into commercial interdiction and create huge challenges for shipping in the Red Sea and Bab-el-Mandeb straits. Their use of sea drones has expanded significantly, with 25 attempted attacks between July and August 2024, four of them successfully hitting their targets. The Houthi surface drones are believed to be the product of Iranian kits used to convert fishing vessels or fast boats into uncrewed systems carrying an explosive payload weighing up to 500 kg. ACLED data indicates that surface drones are mainly used in the southern Red Sea, which is likely driven by the reduced distances and port infrastructure there.



This map from ACLED shows the distribution of Houthi strikes by weapon type in the Red Sea, Gulf of Aden and Bab-el-Mandeb straits. It indicates that drones are only seen as suitable weapons against targets close to the coast of Yemen. [ACLED]

A sign on display Joint Base Anacostia-Boling in Washington, D.C. 24 January 2018, provides details about the 'Shark-33' unmanned surface vessel (USV) packed with explosives. [US DoD/E. J. Hersom]

In the long-range sphere, the Houthis have had the greatest success, including applying strategic effects leading the Saudis and the UAE to seek a compromise and ceasefire in 2022. This has involved the use of Qasef one-way attack drones and Samad long-range drones for reconnaissance and strikes against critical national infrastructure. The Houthis often combine drones and missiles in a single coordinated strike when they are focused on strategic effect; the 2019 strikes on the Aramco processing facilities which led to a huge but temporary loss of oil output is one such example.

However, they have employed similar tactics in support of ground offensives, against commercial shipping in the Red Sea, and against Israel with varying degrees of success. The one-way attack drones and long-range reconnaissance systems are only really effective when combined with missiles, however. They force interceptions upon a defender at a disproportionate cost. An SM-2 missile launched by a US Arleigh Burke guided missile destroyer, for example, costs around USD 2 million, whereas the drones they are used to intercept might cost between approximately USD 50,000 and USD 200,000.

The finite magazine depth of those ships also means that they can quickly be forced back to a friendly base to reload, further exacerbating the costs imposed on a defender. When combined with missiles, drones increase the risk to a defender by complicating the air defence picture; if successful in making it to a target, they can cause significant damage.

Boko Haram/ISWAP

Boko Haram and the Islamic State's West Africa Province (ISWAP) operate in the northeastern regions of Nigeria, as well as in Chad, Niger, Cameroon and Mali, and have been known to employ drones in attacks on security forces in the region. The South African Institute for Security Studies (ISS) reports that messaging platforms associated with al-Qaeda and the Islamic State are used to share knowledge on the use of drones with partner organisations in Africa. It is also likely that the groups are using their own connections to source and buy the drones that they have used. One ISWAP attack in late December 2024 appeared to employ a DJI Mavic type drone; an 82 mm mortar round was also shown alongside the drone. It is worth noting that an 82 mm mortar bomb weighs around 3.1 kg, which is well in excess of the maximum take-off weight of a DJI Mavic, so it is not clear whether or not the bomb was actually deployed by the drone. The group may have used drones since 2022 for reconnaissance and mortar fire correction, with the adaptation of drones to carry munitions being a natural evolution from that point.

The Mavic is a popular choice for drone operations and is seen more often than the more bulky DJI Phantoms. The Mavic (depending on variant) can fly for up to 43 minutes and transmit 1080p/60 fps HD video footage at ranges up to 15 km, with a maximum flight range of 28 km. Put simply, this means that the video relayed by the drone would be sharp and detailed. The Mavic can also fly at altitudes of 6,000 m, at which height the whine of its four motors would be barely audible. Like many drones operating in this space, it includes automated flight controls that reduce the training burden on the operator and interchangeable batteries, which is another key area for the use of drones in combat. They may be used to fly almost continuous missions, providing no time for recharging batteries. So, swappable battery packs allow operators to keep drones in the air for multiple successive missions. The drone weighs around 900 g, and payload release kits are commercially available for Mavics and other drones, with some users indicating that they can carry their payloads corresponding to their own weight. This payload limitation is what drives the use of the VOG-17/VOG-30 families of 30 mm grenades as drone-dropped munitions. These munitions are designed to be fired from the AGS-17 automatic grenade launcher, and are relatively light, with a VOG-17 weighing around 350 g, which provides enough payload headroom to add an improvised stabilising fin at the rear of the munition.

Boko Haram reportedly attacked a Nigerian Army base in Wajiroko in the Damboa Local Government Area on 24 December using drones. The attack combined indirect fire from mortars with small arms fire. Four drones were deployed, armed with home-made grenades, according to one local news outlet, and may have been a different type to the Mavics used by ISWAP. They caused casualties amongst the Nigerian troops at the base but the attack did not achieve much else of note. The group has previously used commercial drones for reconnaissance and surveillance, but this strike may represent its first steps towards armed drone strikes. It is worth balancing the use of drones by these non-state actors with Nigeria's own procurements; the country appears to have ordered 43 Bayraktar TB2s in December 2024 which would be a very significant order if confirmed. It also operates the Wing Loong II from China. These types of unmanned combat aerial vehicle (UCAV) operate at significant altitudes, making it difficult for forces such as Boko

It is important to balance discussion of non-state actor drone capabilities with awareness of the survival pressures placed upon them. Many have little ability to counter the strikes from larger UCAVs like the Bayraktar TB2 or MQ-9. [Baykar Technologies]

Haram to counter them. While this is not the case for others like the Houthis, it does give Nigeria a degree of tactical aerial dominance.

Mali

In Mali, there is some evidence of Tuareg rebels employing small drones in strikes against the Malian armed forces (FAMa) and Wagner positions in October 2024. Ukraine's military intelligence appeared to claim some credit for teaching the rebels to operate the drones, especially in the wake of the July attack on a Wagner column that left 84 Wagner and Malian soldiers dead. However, this was later walked back by the country's foreign ministry after Mali and Niger severed diplomatic ties with Kyiv, citing its decision to arm rebels and terrorists as the reason. The truth of the matter is unclear, however Ukraine is understood to have also coordinated drone attacks on Wagner-backed forces in Sudan, according to a September 2023 CNN report. So, it is reasonable to presume that Ukraine may have provided some support to the Tuareg rebels, but its importance should not be overstated.

This image is a still taken from a video released by Tuareg rebels which claimed to show an October 2024 drone strike with two munitions against a Malian base in Goudan, Timbuktu. [Tuareg Rebels]

The tactics themselves are familiar from drone operations around the world. The Tuareg videos show a quadcopter type drone hovering over a military base with the tail of an underslung munition occasionally swinging into view. The movement of personnel below the drone indicates that they are unaware of its presence, which means the munitions are quite effective once dropped. From two available videos, it seems that at least two munitions were deployed in each engagement, both fitted with fins at the rear of the body to stabilise the round as it falls. They are likely to be 30 mm grenades, as are commonly deployed from small drones. The technology used is fairly typical of non-state actors seeking to embrace drones, and may have been employed to help coordinate other attacks against Malian forces using vehicles and conventional weapons. However, as is the case for Boko Haram, there is little evidence to suggest that drones are fundamentally changing the way that the Tuareg fight. This may be because the group lacks access to more advanced or useful designs like the FPV drone, or because it cannot scale its use of drones to really impact the FAMa and Wagner forces.

Moreover, the Tuareg drones are somewhat outgunned by Mali's own Bayraktar TB2s, as is also the case for Boko Haram against Nigeria. Mali's TB2s have been used in frequent strikes against the Tuareg and other groups in the country. Mali is thought to deploy at least 17 TB2s, based on the tail numbers that have been seen in FAMa press releases, however the UCAVs are often delivered in batches of six, which may mean that the true number is 18. The TB2 is obviously a completely different type of strike system to the small hobby drones used by the Tuareg rebels, but Mali's use of the type and extensive reliance upon them shows how unmanned aerial vehicles (UAVs) in general are spreading and proving their utility, especially in airspace where the threat from ground-based air defence and air-to-air engagements is limited.

Looking ahead

The Middle Eastern and African groups covered here are relatively advanced in their adoption of drones for tactical purposes. The scale of FPV drone use in Syria appears significant from the available evidence on social media, and the tactics and technology used are also similar to that being deployed in Ukraine. They offer a meaningful and available route to cause attrition on armoured forces that are often stationary or exposed by a lack of air cover and electronic warfare (EW). The Houthis have proven themselves to be the most successful in the use of long-range drones for strikes against critical in-

This image shows the Jet FPV drone designed and manufactured in Ukraine, fitted with a forward-firing explosively-formed penetrator (EFP) warhead. This modification should enable to drone to engage targets at distances approximately up to 50 m, and so potentially bypassing some forms of anti-drone protection such as many hard-kill active protection systems (APSs). It is likely that FPV drones used by non-state actors will improve in quality and resilience over the coming years, increasing the threat posed to conventional forces. [Sam Cranny-Evans]

frastructure and other targets, but this mostly relies upon their ability to combine different weapon types into a single strike and do so at some scale. The capacity to replicate this across other groups is limited and reliant upon assistance.

Militant groups in Africa are arguably at the start of their drone development programmes. They likely need time to establish supply chains and networks for the delivery of a greater number of drones, which is where this type of weapon really begins to add to a non-state actor's capabilities. ISIS was able to jeopardise SAA supply routes and logistics bases for example, with regular drone orbits and strikes at a peak rate of 16 strikes per day using two to three drones simultaneously. Alongside coordinating attacks on the ground and conducting reconnaissance, this may be one of the most effective uses of drones for non-state actors in Africa, especially those fighting over large areas, since the armed forces they face may be operating at great distances from their main bases and supply depots. At the tactical level, perhaps, it is the FPV drone that will become the most useful for its ability to precisely strike moving targets, but the likelihood is that a mix of drones will remain in use and be expanded to perform new roles over the coming decades.

Regardless of location, counter-drone capabilities will continue to grow in importance for armed forces over the next decade. The response must be layered in many ways; the typical air defence paradigm holds that weapons should be matched to targets and layered according to range. So, ballistic missiles will be targeted by one interceptor and cruise missiles another, with some short-range defences providing a very last line of defence. For drones, however, EW may be one of the most suitable options for its ability to provide wide area coverage – assuming that friendly forces don't need those frequencies. Yet it is not a robust solution, as regular updates to software in Ukraine have ensured that both sides are able to keep their drones flying and adapt to changes in EW. At the same time, fibre-optic drones that are immune to jamming are beginning to proliferate, and it can be assumed that this technology will spread to other theatres. This means that soft-kill solutions have to be layered with kinetic solutions able to reliably shoot drones down, as well as reverse targeting of the drone operators, and a last line of defence for soldiers on the ground, such as a shotgun with special ammunition designed to defeat FPV drones.

In many ways, this describes a typical approach to air defence with layers and redundancy, and effects matched to threats. However, the drone defence network would, in many cases, have to sit alongside and within the conventional air defence network since so few of its systems are relevant to conventional air threats. This requires specialisation, both in terms of skills and equipment. ISIS, Ansar Allah, and Hamas have all shown what can be achieved with drones against a well-armed conventional force. They have disrupted attacking forces, destroyed defences, and led complex attacks with them. Even factoring in the cost asymmetries of dealing with small drones, the price of not adopting a comprehensive layered approach will arguably be far higher than adopting it.

The Counter-UAV fight

Paul 'Foo' Kennard

As cheap drones transform modern warfare, counter-drone technologies are experiencing a massive surge in interest. This piece explores how the latest developments in C-UAV systems aim to restore the balance against the drone threat.

Revolutions in Military Affairs (RMAs) don't come along very often. In the last century, the machine gun, tank, aeroplane, submarine and nuclear weapons all fundamentally changed the paradigm of warfare. From laying waste to mass infantry attacks, usurping the horse on the battlefield, finding and striking enemies from the sky or beneath the sea, or threatening the very existence of our species, these RMAs forced militaries to re-evaluate the very core of their Strategic Doctrine, and to rapidly adapt to the new Operational and Tactical realities presented to them.

A USAF 163rd Reconnaissance Wing MQ-1 Predator shown during post flight inspection at dusk, from Southern California Logistics Airport, on 7 January 2012. Despite their effectiveness, large UAVs such as this did not ultimately shape the battlefield to the extent their smaller and cheaper counterparts would. [USAF/Master Sgt Stanley Thompson]

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In the last quarter of the 20th Century, the potential for Unmanned Air Vehicles (UAVs) to become a RMA seemed remote. They were certainly proving effective in the Intelligence, Surveillance and Reconnaissance (ISR) role – where the long endurance and unblinking sensor eye of the MQ-1 Predator and similar platforms created an unheard of level of scrutiny and coverage over important areas. Where once the recce 'take' would have been delayed by minutes or even hours as images and wet film were collected and processed, now the 'ISR gap' was measured in seconds. Yet Predator et al did not provide a true RMA.

Their sensors depended on good weather between the ground and the altitude of their orbits. They were also slow to get to their operating locations, were more susceptible to strong winds and icing than most manned aircraft, and, when all said and done, as Remotely Piloted Aircraft (RPA) rather than truly autonomous platforms, they required just as much, if not more, manpower and training budget than a conventional manned Recce Squadron.

Finally, they were vulnerable. In the face of a determined enemy with a credible Air Defence network, including radar guided Surface-to-Air Missiles (SAMs), medium-calibre radar-laid gun systems and manned interceptors, UAV survival was limited.

Going small

While arguably not a true RMA yet, the potential for UAVs to become a genuine RMA has emerged more recently, and at the opposite end of the cost and complexity scale to RPA. 'Hobby' UAV, or 'drones', had become something of a staple birthday or Holiday gift. They were cheap, easy to fly with minimal or no training, and they used simple technology found in most mobile phones for stability, control and navigation. They were also being mass produced, especially in China by DJI, who it is estimated have built some 90% of the world's small 'drones'. Militaries initially dismissed the concept that such 'toys' could have any meaningful battlefield effect. After all, they were small, cheap, built en masse by companies outside the traditional Military Industrial Complex and often used by children – quite the opposite of the 'reassuringly expensive' weapon and recce systems offered by established 'primes' after protracted development and engineering lifecycles. Not for the first time, the military was wrong. Very wrong.

The first indications that 'hobby drones' could be an issue were sporadic weaponisation as assassination weapons in South America, the Middle East, and Africa. The hybrid war in Ukraine was also witnessing the imaginative use of smaller drones for ISR, especially artillery spotting. The Orlan-10 became a harbinger of doom in the Donbas; Ukrainian troops fighting pro-Russian separatists in border areas were painfully aware that an Orlan-10 loitering above their position made an artillery or rocket strike by Russian forces a distinct possibility.

Russia's Orlan-10 UAV proved effective when coupled with artillery, as part of what Russia refers to as a 'reconnaissance-strike complex'. More importantly, it marked a key step in the trend of UAVs becoming smaller and cheaper. [RecoMonkey]

However, what really grabbed attention was the closure of London's Gatwick airport after reports of drone incursions over the airfield and runway in December 2018. No aircraft arrived or departed for nearly 30 hours. Over 1000 flights were cancelled, tens of thousands of passengers had their Christmas holiday plans ruined, and both the airlines and Gatwick incurred large financial losses. Worse, to this day, nobody has been successfully prosecuted for the incident, and there remains some degree of scepticism over the reliability of the drone reports. Gatwick proved a pivotal point in the story of Counter-UAV (C-UAV).

Other international airports were horrified by the ease with which Gatwick had been paralysed. It highlighted the vulnerability of Critical National Infrastructure (CNI) to drones. Whilst closing Gatwick only proved costly in financial terms, what impact could the more nefarious use of drones have on power stations, government facilities, prisons and military establishments? What if a drone operator targeted an airliner taking off or landing?

Unsurprisingly, several companies rushed to fill this newly identified capability 'gap'. Within weeks, C-UAV systems were very publicly deployed to Gatwick and Heathrow airports in the UK. How effective these systems were, or indeed are, remains open to speculation – but the intent was clear: 'Don't bother trying, you won't succeed – worse, we'll find you and prosecute you'. While probably enough of an incentive to deter low-level interference, this was unlikely to prevent a more motivated actor from attempting to disrupt or even attack operations.

While Gatwick spurred the rapid deployment of 'First Generation' C-UAV systems, the true acceleration has come since the start of Russia's 24 February 2022 full-scale invasion of Ukraine. Both sides have made extensive use of small and cheap drones as intelligence, surveillance, and reconnaissance (ISR), target acquisition and even direct

attack platforms. Newsfeeds and social media accounts have become congested with videos of drones finding opposition units and watching dispassionately as artillery and rocket fire pours down upon them, conducting correction of fire and instant battle damage assessment (BDA). As the war continued, there was a sharp increase in first person view (FPV) drones being used to attack vehicles, artillery and troops in the open.

What really has Western militaries worried is that these drones don't require sophisticated electronics, so can largely bypass sanctions, are cheap and can be produced, deployed and used at a large scale far in excess of more complex and expensive traditional loitering and guided munitions.

Detecting & tracking the threat

Walk the floors of any major Defence exhibition since 2022 and you'll see ample evidence of the seriousness with which the C-UAV fight is being taken. From man portable tech to sophisticated vehicle mounted systems, C-UAV systems are now proliferating almost as quickly as the drones themselves. However, how do they work, how effective are they, and what is the current direction of travel in technology terms?

Many common types of drones are controlled by a Ground Control Station (such as the one pictured), via an RF link. This link can be detected by direction-finders, and jammed. [US Army/Daniel Amburg]

Key to C-UAV is the Detect, Track, Identify and Engage (DTI&E) cycle. It's logical to examine the requirements and evolving technology at each stage. Fundamental to any C-UAV system is the ability to detect the presence of an unexpected UAV in your area. This is actually harder than it seems. 'Gen1' C-UAV systems could often rely upon the drone and operator itself. Many civil optimised drones were controlled from a Ground Control Station (GCS). The GCS connects to the drone via a radio frequency (RF) command link – and this link can be detected by passive devices such as direction-finders. The RF link can also be used to derive a backward bearing to the GCS location – potentially enabling the operator to be found and appropriate action taken. Understandably, those seeking to operate without detection will not use a GCS (launching the drone on a pre-planned mission) or if they do, design it to use an 'out of band' frequency that is not as actively monitored or uses relatively low power settings.

If the drone will not 'comply' with civil norms, then detection can be achieved by other means, both passive and active. Passive detection can be the deployment of optoelectronic day or infrared (IR) cameras, or the use of acoustic sensors. All have limitations due to the difficulty in detecting a small UAV at a tactically useful range. At night, a day camera will be largely useless unless the UAV is silhouetted against afterglow or starlight, while IR cameras can be expensive. Acoustic sensing only gives a fleeting warning – normally that a UAV has passed by – which is often too late for any action to be taken.

Radar is the obvious 'active' detection capability, but also tend to be expensive. Many of the 'Gen 1' C-UAV systems used radars repurposed from other areas in a vendor's product portfolio – such as personnel and vehicle detectors. The issue with repurposing a radar is that while, technically, a UAV is within detection parameters, by adjusting settings to detect a UAV it often opens up significant false alarm potential (such as birds), as many UAVs are small and relatively slow-moving targets. Additionally, lighting up a traditional Fire Control Radar (FCR) is often akin to a standing invitation for an Anti-Radiation Missile (ARM) to come calling. However, newer C-UAV systems have changed the approach to radar detection. Electronically scanned (E-Scan) radars have lower power outputs and operate in frequencies well away from the 'SEAD Window'. They also use electronic beamforming to focus energy and reduce side-lobes to make detection more difficult. E-Scan C-UAV radars can also look for different parts of the 'target', such as the micro-doppler return off a UAV's rotor blades. Such radars are also small,

As the threat of small drones has proliferated, so have radar designs capable of reliably detecting this class of threat, such as the Weibel XENTA series X-band AESA radar pictured. [Weibel]

lightweight, mechanically simple and therefore often much cheaper to buy and maintain than a traditional system – making them ideal for the C-UAV role on a modestly-sized vehicle or ship mount.

This trend towards E-Scan radars helps enormously with the 'track' and 'identify' phases of the fight. Holding a track using an optoelectronic camera can be difficult if the target is small and fleeting in nature – as most UAVs are. Factors such as background, obstructions, relative contrast and weather conditions can all hamper the ability of any optical system to track a UAV. IR cameras can help, but they are significantly more complex and expensive, as well as having their own set of limitations such as thermal cross-over and atmospheric attenuation. Radar provides a much tighter target lock - allowing the UAV's flight path to be determined, potentially helping with an assessment of Point of Origin (PoO) and intended target. The key discriminator with radar is the ability to determine range. The range, bearing and azimuth data that a radar produces is essential for most effectors to be deployed.

It's easy to overlook 'identify' as not being as important as 'detect' or 'track'. However, a Positive ID (PID) on the UAV can be a critical piece of information. Initially, it's essential to know if the UAV is friendly or hostile. Unlike manned aircraft and larger UAVs, small tactical UAVs rarely carry Identification Friend-or-Foe (IFF) or Combat ID (CID) due to weight and cost issues, nor are they included in the Air Tasking Order (ATO). Furthermore, the vast majority of their users are utterly ignorant of the ATO and associated Air Control Measures (ACMs). If small UAV cannot network to the Common Operating Picture (COP) for CID, then the onus will fall on the C-UAV operator to hold 'weapons tight' (only engaging targets confirmed as hostile) if a friendly UAV is detected and tracked. This significantly increases the risks of fratricidal 'blue-on-blue' incidents.

Identification is also important to understand the type of the UAV and, by extension, the nature of the threat it poses. A radar can be used to cue the optronics for a closer look, or even make an ID based upon micro-doppler blade returns. An Orlan-10 style drone, for example, can be easily associated with ISR and TA and therefore might pose a grievous threat to friendly forces. A small quadcopter carrying a package might be a weapon or cargo. Such nuance can be important; the C-UAV operator may not wish to give away the location of an effector needlessly. In a civil setting, the 'identify' function could help with an estimation of how long the drone is likely to remain 'on station' and, crucially, using a reference library, understand if it has been modified in any way. The nature of the response, and any effector applied, relies upon timely and accurate threat estimation such that if an electronic or kinetic effect is required, the chain of command can be informed and a decision made before the UAV reaches its target. What that effect should or could be is the final part of the cycle.

Neutralising the threat

Once the threat is detected and tracked, and identified, the C-UAV operator's attention moves to neutralisation. '1st gen' C-UAV systems, could often exploit the UAV's reliance on a command link with the GCS. The link is usually unencrypted and of modest power, so can be easily jammed. Breaking the link to the GCS normally results in the drone applying a 'lost link logic' routine, which, usually mandates that the drone holds its last position (using GPS if available) for a set amount of time to see if the link is re-established, then either:
a) Attempt to return to launch site; OR
b) land at current position and power down.

A US Army paratrooper assigned to the 173rd Airborne Brigade uses a Dronebuster 3B at Exercise Shield 23, in Pula, Croatia, on 20 April 2023. Jammers of this type work by overwhelming the receivers on the UAV with a stronger spurious signal on the same frequencies as their RF command link. This in turn triggers the drone's pre-programmed 'lost link' routines, such as returning to its launch site, or landing at its current position. [US Army/Sgt Mariah Y. Gonzalez]

Likewise, global navigation satellite system (GNSS) signals can be denied in the area the UAV is operating in. GNSS jammers have become a staple on the modern battlefield, helping to reduce the accuracy of GNSS-enabled weapons such as JDAM. If GNSS navigation and command link are both denied, a simple UAV will typically try to hold its position but will inevitably drift as it loses its 3D navigation plot and wind changes in strength and direction.

However, exploiting the RF command link and jamming it and/or GNSS is problematic. There are legal restrictions in many countries about employing any form of RF jamming – let alone in the vicinity of airports. Additionally, most civil-sourced drones operate in the 2.4-5 GHz frequency range. If those numbers sound familiar, they should do – they are the most common WiFi frequencies as laid down by IEEE 802.11. Jamming a drone could cause significant disruption to other vital communications, and interfering with GNSS could put aircraft and other systems at risk – especially in bad weather.

However, on a battlefield such niceties can be ignored. Several Pro-Kremlin bloggers have noted that swathes of territory are being denied to Russian drone operators by Ukrainian jamming of navigation, telemetry/video and GNSS services – rendering some tactical drones unflyable. However, not all UAV rely upon RF command links or GNSS. As seen over

2024, drones with un-jammable fibre optic command links are becoming increasingly common in Ukraine, particularly in Russian service. Aside from this, advances in automation and artificial intelligence (AI) have made it possible to employ drones capable of identifying and engaging targets without input from a human operator.

When jamming isn't an option, the alternative is to kinetically defeat the UAV. The industry seems to be, thankfully, past the point now of thinking a soldier with a gun can reliably down a drone. Recent footage of Ukrainian drones flying slowly along predictable flight paths, in daylight, targeting Russian ships in harbour in Crimea, has a soundtrack alive with the crackle of ineffective gunfire. Unless a weapon is optically, radar or laser laid, the chances of a telling hit on a UAV is slight. The solution lays in a combination of 3D tracking, weapon stabilisation, highly accurate pointing and proximity-fuzed ammunition of a large enough calibre to create a 'kill zone' commensurate with the accuracy of the gun system at the required range.

Realistically this means 20 mm or bigger, and the 30mm M230LF Bushmaster is rapidly becoming the West's 'C-UAV cannon of choice'. As used in the AH-64, the M230LF can exploit different ammunition subtypes, including the bespoke XM1211 C-UAV High Explosive Proximity (HEP) round. The USMC's MADIS system exploits a Kongsberg RS6 remote weapon station (RWS) to carry the XM914 (a variant in the M230 cannon family) and sensors on the JLTV 4×4 platform. The EOS Slinger RWS also mounts the M230LF, with an Echodyne EchoGuard active electronically scanned array (AESA) radar, optoelectronic sighting system with day and thermal channels, a laser rangefinder for pointing accuracy, and a wind sensor, all of which maximise the chances of a 'first shot, first kill' capability. Such accuracy reduces the chances of detection, conserves ammunition and minimises friendly or non-combatant damage or injury.

The growing area in effector technology, however, is using directed energy weapons (DEWs). DEWs can generally be divided into two primary classes: High-power microwave (HPM) systems, which aim to damage or disrupt a UAV's sensitive electronic subcomponents including as engines or guidance systems; and high-energy laser (HEL) weapons, which aim to cause direct thermal and kinetic damage to the body of the UAV itself.

US company Epirus' Leonidas, and the UK's Radio Frequency Directed Energy Weapon (RFDEW) being developed under Project Ealing, are examples of leading HPM system projects. Capable of delivering a train of high-energy electromagnetic pulses (EMP), such systems can target individual UAVs or swarms. The electromagnetic effect they deliver can cause damage or disruption to electronic components, such as power, flight control and communications systems – either rendering the drone inert while in flight, or severely compromising its mission effectiveness. While manufacturers may choose to 'harden' their drones against EMP, to do so dramatically increases weight, size and cost while reducing payload. As well as the added bonus of being effective against swarms, HPM systems are very cheap per shot when compared to cannon ammunition, let alone missiles, and the depth of 'magazine' is theoretically only limited by the amount of electrical power available – making them persistent effectors, albeit ones that will inevitably be targeted.

HELs represent a more direct approach to the UAV problem. The battlefield use of lasers is nothing new; laser rangefinders and laser target designators have been part of the order of battle for several decades. Alongside these, laser dazzlers lasers have also appeared – though subject to misgivings over their ethical legality. HELs on the other hand are designed to physically damage or destroy their target. In the UK, much publicity has surrounded the 50 kW class Dragon-

▲ The Northrop Grumman XM914 30 mm cannon has been used to arm the JLTV-based MADIS C-UAV/VSHORAD vehicle, shown here in the Mk2 configuration at Marine Corps Base Hawaii, on 14 January 2025. [USMC/Cpl Eric Huynh]

The UK's RFDEW is an HPM system being developed by under Project Ealing, by Team Hersa, comprising prime contractor Thales UK and sub-contractors QinetiQ, Teledyne e2v and Horiba Mirais. On 23 December 2024, the UK MoD announced that RFDEW had been successfully tested for the first time, and was capable of defeating drones at a range of 1 km. [Crown Copyright 2024]

Fire HEL, which underwent its first test firings against small aerial targets in January 2024. Small enough to be fitted to ships and vehicles, the system opens the door to the 'sniping' threats at range, with low cost per shot, high cycle rates and a (theoretically) deep magazine. Israel's Rafael is showcasing its Lite Beam 10 kW class HEL on vehicles as small as a JLTV, and the US company Blue Halo is making progress with its JLTV-mounted LOCUST system as part of the USMC MADIS DEW capability upgrade pathway, initially supplementing the Bushmaster cannon but, in time, potentially replacing it.

Compared to conventional kinetic solutions such as cannons and missiles, HPMs and HELs have the advantage of minimising the risk of collateral damage to friendlies and non-combatants. There's no 'frag envelope' to consider, and no worries over missed shots carrying on 'downrange'. Provided sensible rules of engagement (RoE) are in effect, and the location of non-hardened critical systems logged, HPMs and HELs can be used with relative tactical freedom – even in urban areas, where their output power can be moderated for non-destructive effects if required, such as dazzling in the case of HELs.

In sum, the C-UAV 'fight' is characterised by detect, track, identify and effect phases. While some 'Gen 1' systems are still out there, and may still prove capable against simple threat UAVs, their role now is mainly as a deterrence against protestors and activists. On the battlefield, where UAVs don't play by the rules, the C-UAV world has needed to up its game. The expanding use of E-Scan radars, highly accurate mounts/sighting systems, dedicated ammunition and a surge in HPM and HEL systems is ensuring that the balance is moving toward being restored. After all, every measure invites an opposing countermeasure.

Modern ATGM capabilities

Alexey Tarasov

The demand for anti-tank guided missiles is expected to grow in the near future, with a clear need for new capabilities.

Since their introduction in the 1950s and 1960s, anti-tank guided missiles (ATGMs) have evolved from purely anti-tank assets into versatile weapons capable of engaging a wide range of targets, including armoured fighting vehicles, low-and-slow aircraft, and fortifications. Today, ATGMs are in service in numerous countries worldwide, with newer generations of these systems continuously being developed and produced.

▲ Front view of MBDA's Akeron MP ATGM, showing the dual-band (Day TV and IIR) seeker. At Bourges, on 26 January 2017. [MBDA/Laurent Guichardon]

It is important to highlight that earlier expectations, which proposed that various types of drones would replace or assume the functions of ATGMs on the battlefield, appear to have been exaggerated. The experiences of ongoing conflicts in Ukraine and across the Middle East show that these types of weapons successfully coexist and complement each other, despite their somewhat overlapping capabilities.

Looking forward, the global market for man-portable anti-armour weapons is expected to grow by 2.98% to 5% between 2025 and 2031, according to market analyses. The analysis by IMARC Group sets the lowest expected figure, predicting that the global ATGM market could reach USD 4.3 billion by 2033, with a compound annual growth rate (CAGR) of 2.98% from 2025 to 2033. In turn, a Research and Markets report published in January 2025 expects the ATGM market to reach USD 9.6 billion by 2030, with a CAGR of 5.0% between 2023 to 2030. Other analytical companies generally follow these expectations, forecasting growth figures between 3.35% (Market Research Future) and 4.1% (Coherent Market Insights).

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Existing capabilities

The systems currently in service in various countries around the world vary widely in age and generation. While some countries still use first-generation systems, such as the Soviet-era 9M14 Malyutka or its modernised derivatives, others have already adopted so-called fifth-generation systems, such as MBDA's Akeron MP and Rafael's Spike LR2 and Spike NLOS. However, the backbone of ATGM weaponry in most countries consists of man-portable and vehicle-mounted systems from the second and third generations.

Generational distinctions are not always cut-and-dry, with plenty of room for debate. Capabilities can differ greatly across systems of the same generation, or earlier and later versions of missiles within the same family. For example, the Russian Kornet ATGM is considered by some as a third-generation system, despite featuring a semi-automatic command to line-of-sight (SACLOS) guidance system more typical of second-generation ATGMs. On the other hand, the Kornet family's 9M133M-2 missile has range of 8 km, and a powerful tandem-HEAT warhead capable of defeating over 1,300 mm of rolled homogenous armour equivalent (RHAe). Added to this, the launch station is provided with a thermal sight to facilitate targeting at night. Such characteristics and performance are more commonly associated with third-generation systems.

▲ Two missiles from the Kornet family on display at EDEX-2021. The 9M133FM-3 (left) is provided with HE-FRAG warhead and proximity fuze, for engaging low-and-slow aircraft, while the 9M133M-2 (right) is fitted with a tandem-HEAT warhead for engaging tanks. [Alexey Tarasov]

Examples of second-generation systems include the 9K115 Metis, 9K111 Fagot, 9K111-1 Konkurs, 9K133 Kornet family, the Skif (Stugna-P) family, the BGM-71 TOW family, the MILAN family, among others. Despite some of these systems being introduced in the 1970s and 1980s, they remain in service and have been continuously upgraded to prolong their service life and improve combat capabilities. One of the latest instances of such

an improvement is Russia's 9K111-1M Konkurs-M system, which received remote control capability, as reported by Kalashnikov Concern on 27 December 2024. According to the manufacturer, the remote control system was developed based on the combat experience of using ATGMs in Ukraine (notably, remote control functionality has long been a feature on the Ukrainian Stugna-P ATGM). This feature is intended to increase the survivability of both the system and its crew, and a single remote control system enables an ATGM operator to remotely control three Konkurs-M launchers sequentially during daylight hours.

It is worth noting that second-generation ATGMs were primarily introduced and mass-produced during the Cold War. Today, these systems remain the most numerous (with tens of thousands in surplus) and are cost-effective to produce, while still possessing sufficient combat effectiveness.

By comparison, third-generation ATGMs include a number of advanced capabilities that, on the one hand, improve their combat performance, but on the other, increase complexity, as well as maintenance and production costs. Representatives of this generation include systems such as the FGM-148 Javelin, AT-1K Raybolt, Hongjian-12 (HJ-12), and others. Most third-generation medium-range systems are capable of attacking targets within a range of a few hundred metres to over 5 km.

Systems classed as third-generation typically entered service between 1990 and 2010. These tended to share several common features, such as a lock on before launch (LOBL), as well as allowing the operator to select between direct and lofted (top-attack) trajectories. These missiles would also typically be equipped with an imaging infrared (IIR) seeker for guidance.

LOBL, also commonly referred to as 'fire-and-forget' mode, is arguably the most important development introduced in third-generation systems. Compared to first-generation manual command to line of sight (MCLOS) or second-generation SACLOS systems, where the operator needs to keep the sight on target until impact, ATGMs featuring LOBL allow the crew to rapidly change their position after launch, increasing the survivability and tactical flexibility of ATGM crews on the battlefield. However, similar levels of crew safety from return fire can be achieved on second-generation systems using remote controlled SACLOS firing posts.

The final distinctive feature of third-generation ATGMs is top-attack capability. Originating as a solution to counter advancements in the protection of main battle tanks (MBTs) in the late 1980s and 1990s, it has proliferated over the decades and become a standard element in third-generation and newer ATGMs. Top-attack capability allows a missile to target the weaker roof armour of a heavily armoured target such as a tank, thereby bypassing the majority of its passive protection.

It is important to highlight that, while some third-generation ATGMs have been deployed in combat and used against armoured vehicles, these instances typically involved technologically inferior adversaries in low-inten-

▲ 9P163-3 Kornet-EM vehicle, shown with Kornet quad-launchers deployed. This version displayed at the Armiya-2024 exhibition is based on the Remdizel K-53949 Taifun-K 4×4 platform. [Alexey Tarasov]

sity conflicts. The ongoing Russo-Ukrainian conflict has therefore become the first armed conflict where third-generation ATGMs (such as FGM-148 Javelin) were deployed *en masse* against a peer (or peer-plus) adversary. While the top-attack and fire-and-forget capabilities were seen as important, it is difficult to evaluate their overall performance against Russian armoured vehicles, as well as their overall impact on the war.

Notably, some classifications define fourth-generation systems as similar to third-generation ones, with the main distinction being the datalink between the launch unit and operator, allowing the operator to change the missile's flight parameters or switch targets mid-flight, or abort the mission if necessary.

▲ A POS-145 light anti-tank weapon featuring fire-and-forget capability. Currently in development, showcased by Yugoimport at EDEX-2021 [Alexey Tarasov]

TABLE 1

Key characteristics of select third-generation ATGMs

System	Country of origin	Maximum range	Top-attack capability	Firing modes
FGM-148 Javelin	USA	2.5 km (Baseline CLU); 4 km (Lightweight CLU); 4.75 km (Vehicle mounted)	Yes	LOBL
Type 01 LMAT	Japan	4 km	Yes	LOBL
AT-1K Raybolt	South Korea	2.5-3 km	Yes	LOBL
HJ-12 Hongjian-12	China	4 km (daytime); 2 km (night)	Yes	LOBL

Meanwhile, some countries have already developed and adopted fourth- and fifth-generation ATGMs—depending on the classification used—such as MBDA's Akeron MP and Rafael's Spike LR/LR2, Spike ER/ER2, and Spike NLOS systems. These ATGMs broadly began entering service after 2010, and tended to feature more advanced modes, such as lock-on after launch (LOAL) capability, also referred to as 'fire-and-update' mode. LOAL mode allows the operator to observe the battlefield in real-time through the projectile's IIR and/or day seeker and update the target or missile flight parameters during the flight, if needed. This mode allows non-line-of-sight (NLOS) engagements to take place.

An illustrative example of such a system is Turkish company Roketsan's OMTAS, which includes both LOBL and LOAL modes. The OMTAS launcher and missile are connected through an RF datalink, allowing the operator to lock on to a target once the missile is in-flight, as well as switch targets during flight.

The most advanced ATGMs to date belong to the fifth generation. These systems feature sophisticated capabilities, such as third-party cueing, enabling their deployment in modern network-centric warfare. They are also typically very versatile, offering multi-platform integration and multipurpose tandem-HEAT warheads with fragmentation sleeves, capable of defeating explosive reactive armour (ERA) and defeating armour in excess of 1,000 mm of RHAe.

The fifth-generation ATGMs typically feature an extended range of operational (firing) modes, including LOBL, LOAL, and fire-to-coordinates modes. The fire-to-coordinates mode enables firing at pre-designated coordinates in NLOS scenarios. While the latter mode does not require the operator to track a target and enhances survivability and concealment, it is best suited for stationary targets. Some systems, such as MBDA's Akeron MP and Spike NLOS, allow for third-party target designation. This capability means that targeting

data can be received from manned or unmanned aerial or ground-based intelligence, surveillance, and reconnaissance (ISR) assets.

According to manufacturers, many fifth-generation systems are resistant to jamming, whether using fibre-optic datalinks which have no way to be jammed, or encrypted radio frequency (RF) datalinks, which are quite difficult to jam. Additionally, ATGMs of this generation can be equipped with sophisticated seekers that feature both colour television (TV) and uncooled IIR channels, sometimes along with other sensors.

As a sign of the direction things are headed, the most recent iteration of Rafael's Spike NLOS has added several additional noteworthy capabilities. The first is a salvo firing mode, in which up to four missiles can be simultaneously launched and controlled while in the air by a single launcher. The second is a guidance handover capability, in which control over a missile can be transferred from one platform to another. The tactical possibility this opens is for the original launch platform to quickly relocate or hide after firing, while a second platform takes over guidance to ensure the target is successfully engaged. A third capability is that of uploading aerial imagery of the target to the launch platform and then matching these images to the video feed from the missile seeker. This can assist a fire team with quickly distinguishing and identifying the correct target.

Future systems

Several trends in the future development of ATGMs can be identified. Firstly, ATGMs are moving towards greater range capability, not least to maintain relevance relative to loitering munitions. While the majority of systems currently in service have a maximum range of up to 5 km, the requirements for future systems point to an increase in standoff distance.

▲ Rafael's Spike family of ATGMs showcased at DSEI 2017. [RecoMonkey]

For example, the requirements for the Close Combat Missile System – Heavy (CCMS-H), a potential successor to the BGM-71 TOW family, include a maximum range of 4.5 km for direct engagement and a cooperative engagement range of

TABLE 2

Key characteristics of select fourth/fifth-generation ATGMs

System	Country of origin	Maximum range	Top-attack capability	Firing modes	Datalink
OMTAS	Türkiye	4 km (ground launch)	Yes	• LOBL • LOBL	RF datalink
Spike LR2	Israel	5.5 km (ground launch); 10 km (air launch)	Yes	• LOBL • LOBL • Fire-to-coordinates	Fibre-optic datalink
Spike ER2	Israel	10 km (ground launch); 16 km (air launch)	Yes	• LOBL • LOBL • Fire-to-coordinates	RF datalink
Spike NLOS	Israel	32 km (ground launch); 50 km (air launch)	Yes	• LOBL • LOAL • Third party target designation • Guidance handover	RF datalink
Akeron MP	France	4 km (ground launch)	Yes	• LOBL • LOAL man-in-the-loop for non-line-of-sight (NLOS) scenarios • Third-party target designation	Fibre-optic datalink

equal to or exceeding 8 km. Earlier, Mark Andrews, Director of the Combat Capabilities Branch at the Maneuver Requirements Division, stated that the US Army wants the CCMS-H to retain many of the TOW's advantages but have the capability to defeat the most advanced enemy tanks out to 10,000 m. A similar trend can be seen in the growing number of long-range Spike ER2 and Spike NLOS systems procured or on order around the globe in recent years.

As became obvious from the conflict in Ukraine, systems—both man-portable and vehicle-mounted—with a maximum range of 4-5 km, operating close to enemy lines, are likely to be spotted by one ISR assets—such as reconnaissance drones—and targeted by artillery, loitering munitions, or other available fire assets long before they are in a position to engage the enemy. The standoff distance of up to 5 km, combined with the fire-and-forget mode, once understood as sufficient measures to avoid detection and enemy fire, now seems inadequate.

The second trend is driven by recent developments in armoured fighting vehicle (AFV) protection. In response to the proliferation of anti-tank assets, including advanced missiles and loitering munitions, militaries across the globe have accelerated the pace of implementing advanced protective solutions for both armoured and soft-skin vehicles. Therefore, the capability to defeat armoured vehicles equipped with advanced multilayered protection suites, incorporating both soft-kill and hard-kill active protection systems (APS), is now becoming mandatory.

Another trend is the growing versatility of ATGMs. While during the Cold War this class of armaments was seen as the primary weapon for defeating enemy armour, today the spectrum of combat missions performed by ATGMs is significantly wider. The variety of combat scenarios and operational environments in which ATGMs are employed has also increased.

▲ A THeMIS UGV fitted with remote weapon station (RWS) with FGM-148 Javelin. [RecoMonkey]

The need to adapt ATGMs for diverse combat scenarios has resulted in continuous improvement and the implementation of new functions that have increased their flexibility. An illustrative example is the introduction of the so-called 'soft-launch' feature, which allows ATGMs to be used in confined spaces during urban warfare, as well as the use of smokeless propellants, contributing to better concealment. Another direction is the development of multipurpose missiles (with selectable or modular configurations) or munitions offered with with thermobaric or high-explosive fragmentation (HE-FRAG), or tandem-HEAT multipurpose (HEAT-MP) warheads, allowing for employment against a wide range of targets. Alongside this is the addition of more fuzing options. A good recent example can be found in the Spike LR2, which features operator-controlled fuzing, allowing for air-burst, impact-delayed (for defeating bunkers or fortified structures), and impact fuzing modes.

Finally, there are ongoing developments in capabilities that are likely to be introduced in the next generation of ATGMs or through upgrades to existing systems. For example, MBDA unveiled the Ground Warden AI at the Eurosatory 2024 event—an artificial intelligence (AI)-powered system designed to enhance target acquisition and the decision-making process for the Akeron MP family of weapons. Other manufacturers, including Rafael Advanced Defense Systems, Lockheed Martin, and others, are also working on developing and implementing AI and machine learning technologies into missiles, including ATGMs.

Further ATGM enhancements may include swarming capability, data sharing between multiple missiles in a network, new propulsion systems, autonomous guidance and targeting, and integration with both manned and unmanned platforms. While some of these capabilities have already reached the prototyping and testing phases, the timeline for adoption and deployment remains unclear.

Conclusions

Today, ATGMs remain an essential precision-guided weapon at the tactical level, employed against diverse targets such as armoured and soft-skin vehicles, watercraft, aircraft, field fortifications, buildings, and infantry – whether concealed or in the open – among others. Thanks to inexpensive technology and vast Cold War-era surpluses, second-generation ATGMs will likely remain in service and production in some countries, complementing more advanced ATGMs and loitering munitions. These older systems are expected to receive upgrades and capability enhancements, allowing them to perform with acceptable efficiency at least until the mid-2030s.

As a result, many countries' ATGM arsenals will consist of a combination of simpler and cheaper ATGMs, loitering munitions, and advanced ATGMs with enhanced capabilities. While not ideal, this configuration offers several advantages. For instance, second-generation ATGMs are more affordable and ready for large-scale production, while military personnel, including reserves, can arguably be trained to use them more easily.

An FGM-148 Javelin ATGM captured during the Battle of Mariupol in 2022 at the exhibition in Patriot Park, 2024. [Alexey Tarasov]

The latest-generation ATGMs will continue to evolve, although they will be produced and procured in limited numbers. Probably the most significant factors contributing to this limitation are their complex designs, higher production costs, and longer production cycles. For example, in their January 2023 report 'Rebuilding U.S. Inventories: Six Critical Systems', the Center for Strategic and International Studies (CSIS) estimated that it would take 12.5 years to replenish the 8,500 FGM-148 Javelin systems supplied to Ukraine if the pace of production remains as it has been in recent years, and 6.5 years if the production rate increases.

While the technological advantages of newer generations of ATGMs are indisputable, they raise concerns from a military perspective. The increasing complexity of these systems, coupled with often higher personnel training requirements, risks transforming a basic tactical weapon – originally designed to be common, affordable, and expendable – into an expensive, scarce, and difficult-to-replenish asset, potentially challenging to employ during a large-scale conflict.

Finally, it is important to note that a certain number of guided (FGM-148 Javelin, BGM-71 TOW family) and unguided (NLAW, Panzerfaust-3, RGW 90) anti-tank weapons were captured by Russian forces during the conflict in Ukraine. While many of these weapons do not belong to the latest generation of anti-tank systems, they remain in service in many countries worldwide. It is possible that some of these systems might be reverse-engineered by Russian defence companies or, more importantly, handed over to Russian allied countries such as China, Iran, and North Korea. Access to these systems could incentivise domestic development of anti-tank guided missiles and various countermeasures, both passive and active, in these nations. While the impact of the latter would likely be minimal in the immediate term, nonetheless over the longer term it could potentially influence ATGM and countermeasure development in some countries and even alter the market landscape.

Defending the skies – US style

Doug Richardson

As aerial threats continue to evolve, air defence likewise evolves to keep pace. This article explores how changing battlefield dynamics have driven the US military to continuously reimagine its air defence systems, from legacy systems to the latest programmes aimed at defending the skies of tomorrow.

The US Army has rarely fought under unfriendly skies, and has nearly always been able to rely on US air superiority. Given this background, it is perhaps not unsurprising that for many decades tactical surface-to-air (SAM) systems able to protect front-line forces were never given a high priority. But by the late 1950s, the US Department of Defence (DoD) saw the need for short-range SAM systems mounted on vehicles, able to redeploy quickly in order to defend mobile assets.

In 1960, development began on the General Dynamics MIM-46 Mauler, a system that would mount search and target illumination radars, plus a launcher armed with nine launch containers mounted onto a turret fitted on an M113 armoured vehicle. The project was unsuccessful, so a lower-technology solution was fielded by the US in the form of the Ford Aerospace MIM-72 Chaparral. This mounted a four-round launcher for adapted AIM-9 Sidewinder missiles onto a tracked chassis. Chaparral remained in US service until the 1990s, and is still operational with Egypt, Morocco, Taiwan and Tunisia. Egyptian systems are reported to have been upgraded under a programme launched in 2000. Chile, Ecuador, Israel, and Portugal also procured Chaparral, but have now retired the system.

A late-1970s plan to create a US-built version of the Euromissile Roland mobile SAM system did not proceed smoothly, and only 27 fire units and 600 missiles were built, and briefly served with the US Army National Guard.

Stinger: The lightweight SAM

More recent US vehicle-mounted systems have all been based on the Raytheon FIM-92 Stinger family of missiles. Originally developed as a shoulder-launched man-portable air defence system (MANPADS) able to replace the earlier General Dynamics FIM-43 Redeye, Stinger is perhaps unique in terms of US missile designations in that it tends to be referred by series name rather than by its traditional number/letter designations.

Stinger Basic (FIM-92A) entered production in 1978. Stinger POST (FIM-92B) introduced a new seeker, and was manufactured from 1983 until 1987, when production of the -92A and -92B variants ended, giving way to the Stinger-RMP (FIM-92C). This featured a new reprogrammable microprocessor allowing missiles to be upgraded in the future by uploading new firmware. An improved RMP variant was designated FIM-92D.

▲ **FIM-92 Stinger being operated by a member of Ukraine's 30th Brigade. [Ukraine MoD]**

The designation Stinger-RMP Block I has been applied to several versions. An upgraded sensor and the software intended to improving the missile's performance against low-signature targets resulted in the FIM-92E delivered from 1995 onwards, while a further software upgrade introduced in 2001 created the FIM-92F. A service life extension is expected to keep the Block I in service until 2030.

Stinger-RMP Block II (FIM-92I) entered development in 1996 with the goal of using a new focal- plane-array sensor to improve the missile's effectiveness in high clutter environments, and giving increased target-detection distance. It should have entered production in 2004 but fell victim to budget cuts.

Stinger models -92A to -92I were fitted with a contact fuze which responds to a direct impact with the target. While this was an effective solution for larger threats such as aircraft and cruise missiles, it was less suitable for smaller and more elusive targets such as smaller drones. Tests of rounds fitted with proximity fuzes, known as Stinger PROX, were completed in the summer of 2017, and included firings against an

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MQM-170C Outlaw and an unidentified smaller target. Stinger PROX exists in two variants. FIM-92J is an upgrade of the Block I missile which replaces ageing components in order to extend the missile's service life a further 10 years. It adds a proximity fuze intended to improve lethality against UAVs, and replaces ageing subsystems such as the flight motor and gas generator. FIM-92K is similar, but reported to also include a datalink for vehicle-mounted targeting applications.

The Stinger production line closed in December 2020, but in 2022 the US Government signed a USD 687 million contract for 1,468 Stinger rounds intended to replenish US stocks following the supply of missiles to Ukraine. It was understood that these are being delivered through refurbishment of older missiles rather than new-build production. However, since some of the components needed are no longer commercially available, the electronics in the seeker head will have to be redesigned once current component stocks are exhausted.

In 2021, Raytheon successfully demonstrated that a Stinger missile could be fired from a Javelin Lightweight Command Launch Unit (LWCLU); the missile engaged a UAV. If adopted for operational use, this capability would allow personnel to engage air and ground targets while carrying only a single type of launch system. In July 2024, the NATO Support and Procurement Agency (NSPA) signed a multi-year contract worth USD 780 million for the procurement of 940 FIM-92K Stinger Block I to be delivered to Germany, Italy, and The Netherlands.

Alongside its infantry-portable variant, Stinger has been fielded on self-propelled anti-aircraft vehicles. For several decades, this role was in US service was filled by the Boeing AN/TWQ-1 Avenger. This vehicle consists AM General 4×4 high-mobility multipurpose wheeled vehicle (HMMWV), with a gyro-stabilised one-person turret on the rear, armed with two pods of four ready-to-launch Stinger missiles. Developed in the early 1980s, it was selected by the US Army in 1987 after a competitive evaluation of rival designs, and ordered into production. Deliveries started in 1988 with Taiwan placing an order for 74 fire units – delivered in 1999. Known export users of the Avenger are: Bahrain, Chile, Egypt, the Kurdistan region, Iraq, Lithuania, Taiwan, and Ukraine. At least 20 Avenger systems are known to have been supplied to Ukraine since 2022. More recently, Stinger has also served as the effector of choice for the newer Maneuver-Short Range Air Defense (M-SHORAD) Increment 1 system.

The US Army ups its VSHORAD game

With much of its recent combat experience having been in the Middle East, the US Army had neglected its very short-range air defence (VSHORAD) capabilities. Realising this capability gap, and the future threat posed by UAVs, it launched the M-SHORAD programme to develop and field a Stinger-armed version of the Stryker eight-wheeled armoured fighting vehicle.

While Stinger has enjoyed a long service history spanning over four decades, it is due to start being replaced relatively soon. [USMC/Lance Cpl Colton Brownlee]

While Stinger's time is coming to an end, a replacement is on the horizon. A request for information for a next-generation MANPADS was issued by the US Army in 2020, with the associated programme of record known as Next-Generation Short-Range Interceptor (NGSRI). Boeing, Lockheed Martin, and Raytheon Technologies submitted proposals, but in March 2023 the Army selected Lockheed Martin and Raytheon Technologies to develop competing prototypes. A technology demonstration of NGSRI is expected in FY2024, leading to an operational demonstration in FY2026, and a planned production decision by FY2027 for a total of 10,000 missiles.

In 2018, Leonardo DRS was selected to supply the mission equipment package and to work with Moog to integrate the reconfigurable integrated-weapons platform (RIwP) onto the vehicle. The reconfigurable turret is armed with an M230LF 30 mm chain gun, coaxial M240 7.62 mm machine gun, a pod of four Stinger missiles, and two launch rails for AGM-114L Longbow Hellfire missiles. For target detection, it is equipped with four fixed-face DRS RADA RPS-42 multi-mission hemispheric radar (MHR) antennas. By late 2022, the 5th Battalion, 4th Air Defense Artillery Regiment had become the first fully-equipped unit to operate what has become known

as M-SHORAD Increment 1, which has now been allocated the name 'Sgt Stout'. US Army representatives previously confirmed to ESD that there are plans to fit a second pod of Stinger missiles in place the of the Hellfire launcher, so that each vehicle will have eight ready-to-fire Stinger rounds. These efforts appear to have started in 2024.

The US Army displayed the two-Stinger pod configuration of 'Sgt Stout' during the 249th Army Birthday Festival at the National Museum of the US Army, Fort Belvoir, Virginia, on 15 June 2024. [US Army/Bernardo Fuller]

In place of missile, the follow-on M-SHORAD Increment 2 Multi Mission High Energy Laser (MMHEL) Guardian is due to feature a 50 kW class laser from Raytheon and Kord Technologies. The M-SHORAD Increment 3 can be thought of as an upgrade of Increment 1; it is intended to use the NGSRI in place of Stinger, and its 30 mm cannon will be given the XM1223 multi-mode proximity airburst (MMPA) munition, which is intended for use against air and ground targets.

On 8 May 2024, the Army issued a request for information (RFI) for a planned M-SHORAD Increment 4. The proposed system is to be capable of integration onto ground platforms such as the Joint Light Tactical Vehicle (JLTV) and/or a robotic vehicle, and the intention is to make the system transportable on a C-130 aircraft, air-droppable, and suitable for delivery as a sling load. The Army envisages a series of solutions that would meet near-term (FY2027 to FY2028), mid-term (FY2030 to FY2032), and long-term (beyond FY2035) requirements.

To meet its own air-defence needs, the US Marine Corps plans to arm its Low Altitude Air Defense Battalions with the Marine Air Defense Integrated System (MADIS). The system uses two JLTVs, one armed with turret-mounted Stinger missiles, while the other has a 360° surveillance radar and a command and control suite. Both vehicles have a direct-fire weapon on a remote weapons station, an optoelectronic infrared sight, and an electronic warfare system. In December 2023, a low-rate initial production model successfully engaged several drone targets during live-fire testing at the Yuma Proving Ground in Arizona. Some were engaged by Stinger missiles, others by 30 mm cannon fire. The USMC's 3rd Littoral Anti-Air Battalion was scheduled to be the first unit to receive the MADIS.

Plugging the C-RAM gap

Intended to protect high-value military sites against enemy cruise missile, UAVs, rocket, artillery, and mortar (RANI) attacks, the US Army's indirect fire protection capability (IFPC) system is expected to consist of a launcher and interceptors able to bridge the gap between existing VSHORAD systems and PATRIOT.

The initial solution adopted by the US Army had been Rafael's Iron Dome, but its service with the Army was to prove short-lived. On 12 October 2023, less than a week after the Hamas attack against Israeli communities living close to Gaza, and the start of a major rocket bombardment of Israel by Hamas, Washington allowed US-owned Tamir missiles that were still in Israel to be transferred to Israeli ownership for potential use by the country's Iron Dome batteries. A week later it announced that the hardware of both of the US batteries would be returned to Israel.

When Iron Dome proved unsatisfactory, the Army launched the IFPC Increment 2 programme, and in September 2021 awarded a three-year prototype Other Transaction Authority Agreement (OTA) to Dynetics (a subsidiary of Leidos) for the development and delivery of 16 launcher prototypes, 60 interceptors, and associated all-up-round magazines.

A CG render of the 'Enduring Shield' launcher being developed under IFPC Increment 2. [Dynetics]

First deliveries needed to support testing were expected to begin in the fourth quarter of FY2022, and the first combat-capable battery was due to be available to the Army in the fourth quarter of FY2023. This timescale was expected to lead to a Milestone C Decision to transition to procurement in the second quarter of FY2024, allowing the first IFPC Increment 2 battalion to be fielded by FY2026. The system developed by Dynetics has been dubbed 'Enduring Shield', uses an open architecture that would allow it to handle different missile types, including the AIM-9X Sidewinder and the AGM-114L Longbow variant of Hellfire. When the Army selected the Dynetics launcher, it expected to receive the first example in September 2022, but this date proved impossible to meet, and the first launchers were not delivered until December 2023.

A June 2024 report by the US Congressional Research Service (CRS) cited one unidentified official as saying: "It is now

clearer that the service needs a second interceptor that is more capable against lower flying, supersonic cruise missiles." The National Advanced Surface to Air Missile System (NASAMS) had been mentioned as a potential candidate, but the US Army is reported to want a missile that would offer a capability similar to that of the AIM- 120D, while being small enough to allow 18 rounds to be carried in the IFPC Increment 2 launcher. Development of such a missile would probably take the rest of the current decade, with low-rate initial production starting sometime after 2030, the CRS predicts.

The US Marine Corps (USMC) on the other hand had a more positive experience with Iron Dome, and adopted some of its components while also seeking to make the overall system more mobile. The resulting medium-range intercept capability (MRIC) can be thought of as a towed variant of Iron Dome with mostly US components. MRIC integrates several existing systems: the AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR); the Skyhunter (the US domestic variant of the Tamir) missile and the Common Aviation Command and Control System (CAC2S) as the command post. Early live-fire tests conducted by personnel from the equipment manufacturers and from the programme office have gone well, and will lead to the training of a USMC air-defence battalion. Following a reportedly successful quick reaction assessment (QRA) in late 2024, the system is expected to move into production in 2025.

SAMs able to provide top cover

From 1958 onwards, the Western Electric (later Douglas) MIM-14 Nike Hercules was widely deployed by the US and its allies. Known export users were Belgium, Denmark, West Germany, Greece, Italy, Japan, The Netherlands, Norway, South Korea, Taiwan, and Türkiye.

In 1983, the US began to field the Raytheon PATRIOT as a Nike-Hercules replacement, but other NATO nations kept the older system operational until the late 1980s. Known export customers for PATRIOT are Bahrain, Germany, Greece, Israel, Japan, Kuwait, The Netherlands, Poland, Qatar, Romania, Saudi Arabia, Spain, Sweden, Switzerland, South Korea, Taiwan, Ukraine, and the United Arab Emirates.

A PAC-3 MSE missile in the process of being launched, during an interception test at the White Sands Missile Range, on 29 November 2012. [US Army/John Hamilton]

Israel seems to have been the first user to retire the system. By early 2024, that country was reported to have begun phasing out some PATRIOT batteries, and all were expected to be withdrawn from service by mid-2024. Israel will now rely on its Iron Dome and David's Sling systems, which were designed specifically to counter rockets and missiles, which are in practice the prime threats the country faces.

Ukraine is reported to have been supplied with seven PATRIOT batteries. The US and Germany have each donated three batteries, while Romania donated one battery. Germany has also provided an additional four launchers, while a further five launchers were supplied by The Netherlands. Inevitably, Ukrainian PATRIOT batteries have been high-priority targets for Russia, which has released video sequences which show what are described as successful strikes against deployed PATRIOT systems, and of hardware being moved by road. On several occasions, deployed systems were attacked with Iskander tactical ballistic missiles equipped with a submunition payload. In January 2025, Ukrainian steel producer Metinvest announced that it had developed an appliqué armour scheme for the PATRIOT Engagement Control Station, and had already completed the first installation on an operational vehicle. Intended to protect the operators and electronic systems from what the company described as "debris damage", the upgrade used almost 200 individual steel plates up to 8 mm thick, and adds around 2.6 tonnes of weight.

The original AN/MPQ-53 radar of the PATRIOT system used a passively-scanned phased array antenna, but in 2014 Raytheon demonstrated an active electronically-scanned (AESA) antenna based on Gallium nitride (GaN) technology, which would become known as the Lower Tier Air and Missile Defense Sensor (LTAMDS). This demonstrated roughly twice the range, an increase in azimuth coverage, and improved reliability. While the main GaN-based AESA array is oriented toward the primary threat, two new rear panel arrays, each about quarter the size of the main array, serve to provide all-round coverage, a first for PATRIOT.

The company identified a number of design changes for PATRIOT that would allow the system to work with LTAMDS, and following a contract award in 2019, it built six LTAMDS radars. To accelerate the programme, all six were rotated through simultaneous integration and testing at company and US government sites. During contractor verification tests, the complexity of the simulated threats was increased incrementally. In a trial conducted in November 2023 at the White Sands Missile Range, New Mexico, a PATRIOT PAC-3 system integrated with the LTAMDS radar engaged an air-breathing target. In March 2024, military leaders from seven countries were at White Sands to witness the latest in a series of successful live-fire events involving the LTAMDS radar, which acquired and tracked a cruise missile surrogate flying at high altitude, high speed and at a long range in a potential operational environment. Milestone C, the transition from development to production, is expected in the second quarter of 2025.

A view of the LTAMDS (pronounced: L-TAMS) radar, which increases detection range substantially over the legacy PATRIOT radars. [PEO Missiles & Space/Darrell Ames]

In 2023, the Polish Minister of Defence approved a Letter of Acceptance with the US Army for a scheme to enhance its existing PATRIOT systems with 12 LTAMDS radars. The resulting low-rate initial production batch of radars is due to be completed by November 2028.

The existing PATRIOT Engagement Control Station is to be replaced by the Northrop Grumman Integrated Air and Missile Defense [IAMD] Battle Command System (IBCS). This is based on a plug-and-fight network that will allow any radar or other form of defensive sensor feed its data to any available weapon — a capability often described as 'any sensor, any shooter'. Development began in 2004, but initial operational test and evaluation (IOT&E) was not completed until 18 years later, leading to full-rate production being approved in 2023.

In order to deal with emerging air and missile threats, including targets flying at hypersonic speed, the US Army had planned to develop a Lower-Tier Future Interceptor (LTFI) that could eventually replace PATRIOT. However, the likely cost of this proposed missile doomed the programme, and its cancellation was announced in October 2024. The Army now plans to develop an upgraded version of the current production PAC-3 Missile Segment Enhanced (MSE) interceptor.

Standard becomes the USN solution

The US Navy (USN) has memories of surface ships having to defend themselves (sometimes unsuccessfully) against air attack. It is perhaps not unsurprising that naval SAM systems have always enjoyed a high priority.

By the early 1970s, the USN was conducting regular combat operations in waters close to the coast of North Vietnam, and realised that its ships needed a point-defence system able to counter the threat posed by Russian-supplied P-15 Termit (SSN-2 'Styx') anti-ship missiles. By the summer of 1972, it had deployed a naval version of Chaparral aboard its *Gearing* (FRAM-1) class destroyers.

These Sea Chaparral systems had only a brief service life, and were removed in the following year. However, in 1974 the system was adopted by Taiwan. The last ships still fitted with the system are Taiwan's Kang Ding (Lafayette class) frigates, with Sea Chaparral being replaced by the indigenously-developed Hai Chen II missile system.

The current short-range SAM system used by the USN is the Raytheon RIM-116 SeaRAM. This consists of a 21-cell missile launcher linked to other onboard defences such as the radar and optoelectronic system of the Phalanx CIWS Mk-15 Block 1B. The original Block 0 configuration used a passive radio frequency (RF) subsystem for midcourse guidance, then transitioned to infrared passive homing for the terminal phase of flight. Block 1A missiles can fly an autonomous IR-all-the-way attack, so are effective against threats that do not rely on onboard radar seekers. The Block 2 missile has a larger rocket motor, an improved control section fitted with four canard control fins rather than the two used by earlier variants, and an evolved RF receiver. Current export users are Egypt, Germany, Greece, Japan, Mexico, Qatar, Saudi Arabia, South Korea, Türkiye, and the UAE.

The only variant of the original Standard 1 missile is the RIM-66E (SM-1MR Block VI). While no longer in service with the USN, the RIM-66E remains in service with other export users. The RIM-66C/D Standard MR (SM-2MR Block I) was developed in the 1970s as part of the Aegis combat system and New Threat Upgrade (NTU) programme. It uses a combination of inertial and command mid-course guidance, so requires target illumination by shipboard radars for a few seconds in the final stage of flight. This greatly increases the number of targets that can be engaged in quick succession.

The SM-2 has demonstrated its reliability in more than 2,700 successful live firings. Production had ended in 2013, but in June 2017, Raytheon announced it was restarting the SM-2

While engaged in torpedo evasion manoeuvres, the guided-missile destroyer USS *Curtis Wilbur* launches a Standard Missile-2. [US Navy/MC 2nd Class Matthew R. White]

production line to meet orders placed by Australia, Japan, The Netherlands and South Korea. The first launch of the new-production batch was conducted at the White Sands Missile Range (WSMR) in New Mexico, on 10 February 2020. Later that year, the Royal Australian Navy's first ***Hobart*** class air warfare destroyer (AWD) used an SM-2 missile to successfully engage a target drone. Successful integration of the SM-2 Block IIIA missile and Mk 41 vertical launcher system (VLS) on the Royal Danish Navy's ***Iver Huitfeldt*** class frigate ***Niels Juel*** was demonstrated by a firing conducted on Norway's Andoya test range off Norway on 2 May 2022.

On 19 October 2023, three land-attack cruise missiles and eight UAVs launched from Houthi-controlled territory in Yemen were successfully intercepted by SM-2 missiles fired from the ***Arleigh Burke*** class destroyer USS ***Carney***. The ship was not under threat, but missiles and UAVs had been flying north towards Israel. Further missile and UAV attacks by Houthi forces were engaged by USN warships between October 2023 and January 2024. Most of these engagements were conducted using SM-2 missiles, whose unit procurement cost was much higher than that of the targets being shot down. During a 'blue-on-blue' incident in the Red Sea area in February 2024, the German Sachsen class frigate Hessen launched two SM-2 missiles at a US MQ-9 Reaper drone, although both SM-2s were reported to have crashed into the sea due to an unspecified technical problem.

On 22 December 2024, the USN ***Ticonderoga*** class guided-missile cruiser USS ***Gettysburg***, which was engaged in USN operations in the Arabian Gulf, launched a missile against an F/A-18F Super Hornet of Strike Fighter Squadron 11 (VFA-11) from the aircraft carrier USS ***Harry S. Truman***. This resulted in destruction of the aircraft, whose crew survived the incident. The results of the formal inquiry into the incident had not been published by the time this issue of our journal closed for press, but according to a posting on 25 December on X (formerly Twitter) that claimed to be by the pilot of the downed aircraft, the crew had seen the incoming missile, and decided to eject when they realised their aircraft was the target. A second missile launched by the USS ***Gettysburg*** was reported to have targeted a second F/A-18F, but the latter aircraft successfully conducted evasive manoeuvres.

The longer-range RIM-156A Standard SM-2ER Block IV incorporates a Mk 72 booster, but is able to be installed in the Mark 41 vertical launching system. The RIM-174 Standard extended range active missile (ERAM) – also known as Standard Missile 6 (SM-6) – was designed for extended-range anti-air warfare (ER-AAW) purposes. It is not intended to replace the SM-2 series, but to act as a longer-range adjunct. Able to engage fixed and rotary-wing aircraft, anti-ship cruise missiles, and UAVs, the RIM-174 can also conduct terminal defence interceptions of ballistic missiles. It combines the airframe of the earlier SM-2ER Block IV (RIM-156A) missile with the active radar seeker of the AIM-120C AMRAAM. The latter feature improves performance against highly agile targets, and allows the missile to engage targets beyond the effective range of the launching vessels' target illumination radars. The RIM-174 achieved initial operating capability in November 2013.

The Arleigh Burke class guided missile destroyer USS *John Paul Jones* (DDG-53) launches a RIM-174 (SM-6) missile. [US Navy]

In April 2024, Raytheon was awarded a USD 344 million contract for the development of two new versions of the Standard Missile. The resulting SM-2 Block IIICU and SM-6 Block IU will use the same newly designed guidance section, target detection device, independent flight termination system and electronics unit, so the company plans to manufacture both missiles on a common production line. In addition to the US, other first users of the updated missiles will be Australia, Canada, Japan, and South Korea.

During exercise Valiant Shield 24 in July 2024, Raytheon demonstrated a simulated complex engagement that used track data from Army LTAMDS simulators and its Integrated Air and Missile Defense Battle Command System (IBCS) to link with the Navy's SM-6 engagement control software.

While the range of targets engageable by the SM-6 includes ballistic missiles, some of the threats currently faced by US warships are of modest performance, so hardly constitute viable targets for the Standard Missile. Once again, Stinger has proved a potential solution. Since 1984, Stinger has been used for point defence by many USN warships, particularly those operating in Middle Eastern waters. The engineers who developed the Stinger in the early 1970s could have had no idea of the flexibility and future roles of the weapon they were creating.

Studies proceed in earnest to develop a next-generation NATO rotorcraft

Peter Felstead

In July 2024 the NATO Support and Procurement Agency issued study contracts ultimately intended to kickstart the development of a next-generation medium, multi-role rotorcraft capability for the alliance: an ambitious project that could see a preferred solution selected by the end of 2027.

The Next-Generation Rotorcraft Capability (NGRC) effort is a NATO Support and Procurement Agency (NSPA)-led High Visibility Project in which the participating nations – Canada, France, Germany, Greece, Italy, the Netherlands and the United Kingdom – are combining their efforts to work on the design, development and delivery of a future medium, multi-role rotorcraft capability.

The multinational NGRC initiative was initially launched by France, Germany, Greece, Italy and the UK though a letter of intent signed in November 2020. In June 2022, when those nations launched the concept stage of the project through the signature of a memorandum of understanding (MoU), the Netherlands joined as the sixth nation participating in the NGRC effort, while Canada subsequently joined in March 2024. The United States and Spain are currently acting as observers on the NGRC effort.

In July 2024 the NATO Support and Procurement Agency (NSPA) awarded contracts to Airbus, Leonardo, and Lockheed Martin's Sikorsky business for a 13-month study into the future concepts for the NGRC, also known as Concept Study Five. The three companies' responses to this – which could theoretically each comprise up to two concepts – are to be delivered in October 2025, enabling the NSPA to prepare a subsequent report to the participating nations.

After October 2025, the participating nations will then identify their preferred solutions from those concepts presented before then writing the requirements for the NGRC programme in earnest. Meanwhile, the NSPA has been working on two additional studies that are meant to inform what the NGRC solution's powerplant and open-system architecture (OSA) might look like, with Lockheed Martin contracted for the OSA study.

Speaking to Defence iQ ahead of the company's February 2025 International Military Helicopter conference, Cyril Heckel, programme manager for the NGRC concept stage at the NSPA, said, "We plan to identify, potentially, an NGRC preferred solution by the end of 2027, and we have also in mind for nations that, ideally, we would like to have the first asset delivered by 2038." Heckel additionally noted that the NSPA is targeting a unit fly-away cost for the NGRC solution of EUR 35 million, with affordability being a key aspect of NGRC considerations.

Heckel told *ESD* on 30 January 2025 that, with the programme currently at the concept stage, "we don't have yet requirements but only attributes or high-level expectations. We explore what could be possible concepts. To explore these options, the nations and NSPA defined a concept of operations (CONOPS) containing 11 missions."

An NH90 in French Navy service. The NH90 programme stands as currently the largest military helicopter project in Europe, but issues with the programme have led more than one user to withdraw the type from service. The NH90 is one of the helicopter types the NGRC effort is looking to replace. [NH Industries]

AUTHOR

Peter Felstead a UK-based journalist who joined ESD as News Editor in February 2023. Before pursuing a freelance career and joining ESD, Peter had worked for Janes for almost 33 years, editing titles such as Janes Defence Weekly and Janes Intelligence Review.

These missions Heckel listed as: air assault, transport, attack, personnel recovery, special forces aviation, maritime/littoral strike, anti-submarine warfare (ASW), anti-surface vessel warfare, helicopter delivery service, self-deployment and humanitarian assistance. "Through Concept Study Five we ask our contractors to present possible NGRC concepts and how they fit against our list of attributes and the CONOPS," Heckel added.

NGRC attributes

A NATO factsheet on NGRC describes the rationale for the effort as follows: "A significant amount of the medium multi-role [helicopter] assets currently in service [with] Allies will reach the end of their life cycle in the 2035-40 period and beyond, with the subsequent need for replacements. These existing inventories are all based on designs dating back to the previous century. The aim of the NGRC initiative is to respond to this upcoming requirement, in a timely and cost-effective manner, while concurrently leveraging a broad range of recent advances in technology, production methods and operational concepts."

The helicopter types currently in NATO nation inventories that are expected to be replaced by the NGRC effort include the Airbus (formerly Aerospatiale) Super Puma, Leonardo (formerly AgustaWestland) AW101, NH Industries NH90 and Bell CH-146 Griffon. The Sikorsky UH-60 Black Hawk has also been mentioned in this list, although the latest variant, the UH-60M, continues to be procured in significant numbers and the Black Hawk will not be fully retired for decades to come.

The UK will certainly have renewed interest in its participation in the NGRC effort, given that its much-delayed New Medium Helicopter programme, which was largely focused on replacing the Royal Air Force's ageing fleet of Puma HC2 helicopters, has been left with a sole bidder (Leonardo Helicopters UK, offering the AW149) and could well have fallen into abeyance.

In September 2020 the NSPA detailed a number of the attributes that the NGRC solution should feature. These included: a range in excess of 1,650 km (900 NM), a maximum take-off weight of 10 to 17 tonnes, a capacity for up to 16 troops in full combat gear or mission equipment, an endurance of more than five hours or up to eight hours with additional fuel tanks, and a combined internal and external payload greater than 4 tonnes, with at least 2.5 tonnes carried internally.

Additionally, the NSPA stated that the NGRC should be capable of being used as an "optionally unmanned/remotely piloted vehicle" and that maritime and land variants should use a common airframe with a footprint no larger than the NH90 or AW101, including a folding tail and main rotors. The intended cruise speed of the NGRC was given as "optimally 220 kt [407 km/h] or more but not less than 180 kt [333 km/h]", which is not as fast as that envisaged for the US Army's Future Long-Range Assault Aircraft (FLRAA). The winning solution for that programme, the Bell Textron V-280 Valor, which was selected in December 2022, has a cruise speed of 519 km/h (280 kt) and a maximum speed in excess of 556 km/h (300 kt).

Airbus

For its NGRC Concept Study Five effort Airbus has teamed with RTX's Collins Aerospace and Raytheon businesses along with European missile and systems house MBDA.

A conceptual image published by Airbus when it was selected for an NGRC Concept Study Five contract in July 2024 depicted a rotorcraft with a main rotor and twin lateral propellers accompanied by armed rotary-wing UAVs. [Airbus]

"Taking part in this NATO study for the next generation of military rotorcraft offers a unique opportunity to leverage our experience working with the different European armed forces," Bruno Even, CEO of Airbus Helicopters, stated in a 24 July 2024 company press release. "Our goal, together with our highly skilled partners, is to develop a European solution, a concept that would fulfil both the needs of the NATO armed forces while also guaranteeing industrial sovereignty for our European nations and maintaining key engineering competencies," he added. *"This project will be fully interoperable with other NATO means. With our experience in both civil and military helicopter design, we are convinced that we have the right cost-effective, high-performance, and operationally efficient solutions at Airbus Helicopters for the next generation of military rotorcraft."*

There was early speculation in defence media that Airbus' Racer high-speed helicopter demonstrator, which combines a traditional main rotor with lateral propellers and can cruise at up to 400 km/h, could form the basis of Airbus' NGRC proposals. However, an Airbus Helicopters spokesperson told *ESD* on 29 January 2025, "We won't develop a military version of Racer, but knowledge gained through the Racer project could be re-used for a military platform."

European armed forces have expressed a need for a long-range aircraft with speeds that would exceed the capabilities of a conventional helicopter. The technologies developed by Airbus can match these requirements.

The Airbus spokesperson added, "European armed forces have expressed a need for a long-range aircraft with speeds that would exceed the capabilities of a conventional helicopter. The technologies developed by Airbus can match these requirements."

He additionally noted, *"One of our priorities is to integrate our platforms into a multi-domain combat cloud where the helicopter will be a force multiplier: a mothership capable of deploying combat capabilities fast and at a long range. That is why we are working actively on crewed-uncrewed teaming. We have already developed and tested teaming capabilities with the H145M [a military version of the H145 light utility helicopter] and more recently with the European project MUSHER [a manned-unmanned teaming demonstration initiative launched by the European Commission in December 2021]."*

The Airbus spokesperson further added, *"Connectivity at large is a key element of our research on the next-generation rotorcraft. We are not only working on future platform concepts but also on a combat cloud that will integrate helicopters, unmanned aerial vehicles and other assets taking part in military operations. This is why Airbus Defense and Space is part of our NGRC team" and that "Working with RTX and MBDA, we are also making sure that our platform and systems will be fully modular and NATO integrated."*

Leonardo

On 29 February 2024 Leonardo announced that it had signed an MoU with US company Bell Textron to evaluate co-operation opportunities in the tilt-rotor technology domain. This co-operative effort began in earnest with work on NGRC Concept Study Five, in which Leonardo is taking the lead on a tilt-rotor design proposal with Bell in support.

Leonardo has teamed with Bell, manufacturer of the US Army's V-280 Valor FLRAA platform, to offer a tilt-rotor proposal for the NGRC effort. [Bell]

The Leonardo/Bell team thus combines Bell's experience with its V-280 Valor tilt-rotor, which was selected as the US Army's FLRAA platform in December 2022, with Leonardo's experience in developing the AW609 tilt-rotor. The Leonardo-led NGRC consortium additionally includes General Electric, Hensoldt, Leonardo DRS, MBDA Italia, NLR, Rolls-Royce and Safran.

"This co-operative effort between Bell and Leonardo reflects our shared vision that next-generation rotorcraft will be influenced by the speed, range and manoeuvrability only tilt-rotor technology can deliver," Lisa Atherton, president and CEO of Bell, said at the time of the teaming announcement. "We are proud to deepen our relationship with Leonardo as we continue to explore emerging vertical lift programmes in Europe and the United States."

Gian Piero Cutillo, managing director of Leonardo Helicopters, added, *"We're thrilled to evaluate new joint efforts for the next generation of rotorcraft technologies, based on our solid and shared view of the unique advantages of tilt-rotors. Leonardo has always firmly endorsed tilt-rotor technologies to meet evolving rotorcraft requirements, even more so as new needs emerge in the market."*

With regard to how its Concept Study Five work is progressing, a Leonardo spokesperson told *ESD* on 29 January 2025, "Activities proceed to schedule without criticalities. Interaction with NSPA is very good, allowing quick resolution of doubts and direction, if required. The team is ready to provide its contribution once the Study 5 phase is completed."

Sikorsky

Meanwhile, Sikorsky announced in July 2024, upon its selection for the Concept Study Five work, that technology derived from its experimental X2 compound helicopter, which features coaxial rotors and a pusher propeller, would form the basis of its NGRC effort. The X2 first flew on 27 August 2008; the SB-1 Defiant compound helicopter developed from it competed, ultimately unsuccessfully, for the US Army's FLRAA requirement.

"Years of investment and rigorous flight testing with multiple X2 technology demonstrators have proven its ability to change the future airspace," Andy Adams, vice president of Sikorsky Future Vertical Lift, stated in July 2024. *"Our X2 aircraft will bring to bear the strengths of Lockheed Martin along with input from our European Industry Group, such as digital thread, advanced manufacturing, sustainment, training, and weapon and mission system development, to provide NATO with an integrated rotorcraft system that combines speed, range, manoeuvrability, survivability and operational flexibility."*

Sikorsky's European Industry Group includes BAE Systems, ELT Group, ESG Elektroniksystem-und Logistik, GE Aerospace, Hellenic Aerospace Industry, Kongsberg, Liebherr-Aerospace Lindenberg, MAGroup, Malloy Aeronautics, Safran, Rheinmetall and Terma.

Sikorsky will use technology derived from its experimental X2 compound helicopter to address the NGRC Concept Study Five work. [Lockheed Martin]

With regard to Sikorsky's Concept Study Five work specifically, Adams told *ESD* on 31 January 2025, "The concept design study has challenged us to look at the art of the possible, which we are doing to define the best next-generation solution for NATO. The NATO study is progressing very well; we have completed our first quarterly programme review and are tracking to complete our conceptual study in September of 2025."

With more than USD 1 billion (EUR 0.96 billion) already invested in X2 rotorcraft, along with 15 years of testing and flying the X2 demonstrators, Sikorsky certainly had a firm basis for its NGRC Concept Study Five proposals.

However, given that all but one of the NGRC nations are European, with European rotorcraft industries to support and protect, an obvious question is to what extent the proposed NGRC solutions will be purely considered on their own capability merits above any European political or industrial considerations.

Asked by *ESD* if this is perceived as an issue by Sikorsky, Adams replied, "We remain in the conceptual study phase. As the programme progresses and NATO provides more detail, we will have a better understanding of what will be required."

Asked the same question by *ESD*, Heckel at the NSPA responded that, by awarding three Concept Study Five contracts, the NGRC effort will "ensure that diversity is maintained in the identification of possible concepts before exploring design activities".

The NSPA and NGRC nations, he added, "will initiate the writing of NGRC requirements and outcomes of the studies will be considered to draft these requirements. The objective is now to initiate a new competitive process to be able to identify a NGRC preferred solution by the end of 2027."

The dozen companies within Sikorsky's European Industry Group suggest, at the very least, that the US company will be able to develop comprehensive plans for European participation if it progresses further in the NGRC endeavour.

Outlook

The NSPA's efforts to kickstart the development of a next-generation rotorcraft are, of course, still in their initial stages, but the aim of ultimately producing a common aircraft type for multiple NATO nations that can successfully address all of their varying requirements is clearly no easy undertaking.

Salutary lessons can certainly be taken from the NATO Helicopter 90 (NH90) programme that began in earnest in 1992, which set out to address NATO requirements for a battlefield helicopter that would also be capable of being operated in naval environments. The NH90 programme stands as currently the largest military helicopter project in Europe and has delivered around 600 aircraft to the armed forces of 14 countries, but the programme was plagued with technical issues, delivery delays, maintenance issues and consequent low availability rates among multiple users. Two NH90 users – Australia and Norway – have withdrawn their NH90 fleets from service, while Sweden has also announced plans to withdraw NH90s.

The NGRC effort, meanwhile, will be hoping to avoid all those issues while still ultimately delivering a transformational rotorcraft capability for the 21st Century battlespace.

Protected patrol vehicle programmes: A survey

Sidney E. Dean

Protected patrol vehicles balance mobility with protection from mine and ballistic threats. While they come in various size, weight and protection configurations, the current trend is pointing towards prioritising enhanced mobility over heavy armour. What follows is a selected overview of currently marketed systems.

Protected patrol vehicles (PPVs) are versatile or multi-mission-capable vehicles. The British Army provides a concise profile, stating that PPVs "are used in combat, combat support and combat service support roles across the battlespace, including within the direct fire zone. Some have an organic self-defence capability which can be optimised to support offensive operations." They come in many iterations and in various vehicle types. During the initial phases of the Afghanistan and Iraq conflicts, Western armed forces rushed to procure thousands of protected platforms, many of them mine-resistant, ambush-protected (MRAP) vehicles, which subsequently formed the backbone of many PPV fleets. With the end of those conflicts, many services moved to divest or reduce their MRAP inventories, reasoning that they would have limited utility in future peer-warfare.

▲ The Foxhound is identical to the Force Protection Europe/GDLS Ocelot, but entered service as the Foxhound to align with the British Army's naming convention for MRAPs. [UK MoD]

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Streamlining inventories and simplifying logistics is another goal of several PPV programmes. The British Armed Forces' Land Mobility Programme (LMP), as one example, hopes to replace up to 11 currently operated vehicles with three platforms – one each in the following categories:

- LMP – Light Mobility Vehicle (LMV); an unprotected platform in the ≤3.5 tonne range.
- LMP – Light Protected Mobility (LPM; a lightly-protected platform in the ≤10 tonne range.
- LMP – Medium Protected Mobility (MPM); a medium-protected platform in the <20 tonne range.

Current PPV procurement programmes are placing greater emphasis on mobility and flexibility over pure armour protection as the primary survivability factor. That being said, PPVs continue to be acquired in various weight and size classes, from lightly- to heavily-armoured, from 4×4 to 6×6 configured vehicles. This continues to include some MRAPs, although the newer models tend to have a lower centre of gravity and improved mobility compared to early models. While the precise borders between weight classes are somewhat fluid, systems below 10 tonnes gross vehicle weight (GVW) are generally considered lightweight, with those up to 20 tonnes classified as medium weight. Mission spectrum and capabilities profile can factor into how vehicles which straddle two weight classes are categorised. As indicated above, PPVs are multi-capable systems which can be configured or dispatched in a variety of mission modes as required. Irrespective of vehicle weight class, sensors, weapons and other mission-specific equipment are major factors determining both operational capability and survivability.

GDLS Foxhound

The British Army introduced the Foxhound light protected patrol vehicle in 2011. Originally designed and produced by Ricardo PLC and Force Protection Europe (now owned by General Dynamics Land Systems; GDLS) as the Ocelot, it is lighter and more manoeuvrable than the service's heavier PPVs, making it particularly suitable for mentoring and partnering missions. The British Army's website describes the Foxhound as providing "unprecedented levels of blast protection for its size and weight (...) This is an agile and versatile vehicle that will be a mainstay in the Army for years to come." The 7,500 kg GVW vehicle accommodates six including the driver, and has an on-road speed of 110 km/h.

The current inventory is expected to serve until 2030. In July 2024, the MoD published a voluntary ex-ante transparency (VEAT) notice confirming the procurement of up to three Foxhound technical demonstrator platforms (TDPs) from GDLS. According to the VEAT, these will be used to assess whether the currently in-service Foxhound fleet could be modified to extend its use beyond 2030 or whether new-build Foxhounds could meet an extant vehicle requirement.

Arquus Scarabee

The Scarabee developed by Volvo subsidiary Arquus stands out among other PPVs due to its bold modern look, hybrid-electric propulsion, and unique capabilities profile. The air-droppable vehicle has a GVW of 8,000 kg, and at 5.25 m long, 2.1 m wide, and 2 m tall (without optional weapons mounts), presenting a comparatively low silhouette. Together with the ability to approach targets in electric drive mode (greatly decreasing its acoustic and thermal signatures), this boosts survivability as well as the suitability for covert operations. The four-wheel steering capability, which enables the vehicle to 'crab steer' sideways, further enhances the ability to make maximum use of urban, woodland or mountain terrain for surveillance and covert approaches.

▲ The Scarabee demonstrates its mobility. [Arquus]

In its baseline configuration, the Scarabee seats four including the driver. Depending on the mission, the Scarabee can be equipped with roof-mounted radar, visual sensors, or weapons including a 30 mm automatic cannon, or the Akeron MP ATGM. Other options include the Arquus Battlenet Battle Management System (BMS), NBC protection, and a radio controlled improvised explosive device (RCIED) jammer.

Joint Light Tactical Vehicle (JLTV)

The US and numerous other armed forces continue to acquire the JLTV, with the vast majority of vehicles being delivered to the ground forces. The 6.2 m vehicle has a GVW of approximately 10,200 kg, and can be transported by heavy-lift helicopter. The JLTV is designed to provide protection comparable to MRAP vehicles while being considerably more manoeuvrable and fuel-efficient. The basic protection level of STANAG 4569 Level 1 can be enhanced with additional modular armour kits as mission conditions dictate.

▲ Testing the new JLTV A2 variant. [AM General]

As defined by the US Army, the JLTV is intended to provide protected, sustained, networked mobility across the full range of military operations, while balancing payload capacity, performance, and protection. The combat tactical vehicle variant of the JLTV can be configured for general purpose, heavy gun carrier, and close combat weapon carrier missions, with corresponding mission-specific equipment packages.

Oshkosh Defense began producing the JLTV in 2015. Under a new contract, AM General will begin producing the newer JLTV A2 variant, with full-rate production expected to begin in summer 2026. AM General highlights the A2's improved fuel efficiency, an upgraded drive train and suspension, enhanced lithium-ion batteries, and enhanced corrosion protection. The A2 design also includes a simplified user interface to support future enhancements, upgrades, and integrations.

GDELS Eagle

The General Dynamics European Land Systems (GDELS) Eagle V tactical armoured vehicle is available in 4×4 and 6×6 configurations, with respective GVWs of 10,000 kg and 15,000 kg. Both configurations utilise the same chassis and drive train components to simplify logistics and maintenance. The De Dion suspension with its axle articulation and high wheel travel enhances off-road mobility and stability while minimising crew discomfort. The basic STANAG 4569 Level 1 protection package can be augmented by supplementary modular armour up to STANAG 4569 Level 3, and can include RPG netting. An RWS can be optionally mounted on the vehicle roof, with various user-defined armaments possible.

Both variants are highly versatile and can be configured for numerous roles. The 5.4 m long 4×4 vehicle has a 3 tonne payload and accommodates four combat-equipped soldiers including the driver and commander (2+2); while a fifth seat can be optionally integrated for non-permanent use. The high torque Cummins Diesel engine permits on-road speeds of 110 km/h and a range of 700 km. The 6.9 metre 6×6 offers a higher personnel-carrying capacity, allowing up to 12 including driver and commander (2+10) in the troop carrier configuration, as well as higher useful payload capacity of 5 tonnes.

Nurol Makina Ejder Yalçın

In September 2023, Nurol Makina presented the Ejder Yalçın 4×4 PPV at the UK's Millbrook Proving Ground in Bedfordshire (UK). The vehicle was marketed to the UK as the 'Dragon 4×4', and was being geared toward the British Army's LMP-MPM programme. At the Defence Vehicle Dynamics 2024 (DVD 2024) exhibition, Nurol Makina also announced the establishment of a British subsidiary, Nurol Makina UK (NMS UK), to market vehicles and services to the British Army and third countries, and signed a partnership agreement with NP Aerospace to provide vehicle integration and support services. Building on these initiatives, NMS UK acquired a manufacturing facility in Leamington Spa in September 2024, to allow UK domestic production.

▲ Nurol Makina has been promoting the Ejder Yalçın to the British Army. [NMS UK]

The Ejder Yalçın 4×4 has a GVW of 14,000 kg to 18,000 kg (depending on wheelbase and configuration) and is offered in numerous variants including armoured personnel carrier (APC), reconnaissance, command and control (C2) vehicle, anti-tank, air defence, mortar carrier, ambulance, and mine clearing. Ballistic protection is scalable, and Nurol Makina cites blast protection conforming to STANAG 4569 Level 4A/4B, which is equivalent to 10 kg of TNT under the body or under any wheel location. In terms of mobility, the vehicle is able to climb 60% gradients, navigate 30% side slopes, clear vertical obstacles 0.5 m tall, and ford water up to 1.1 m in depth without preparation. Options include CBRN protection, a central tyre inflation system (CTIS), protected fuel tanks, and engine-preheating for cold environments. The baseline variant seats up to 9 crew including driver and commander (2+7), while the extended wheelbase (EWB) variant expands the seating capacity to a maximum of 12 soldiers (2+10).

Arquus MAV'Rx

The newest PPV entry is the MAV'Rx (pronounced: 'Mavrix'), presented as a prototype at Eurosatory 2024. Arquus emphasises that the multi-mission platform has been designed for high-intensity operations, serving in roles ranging from personnel carrier to anti-tank platform, to command and control or medical evacuation vehicle. As described by the firm, the MAV'Rx is conceived as a well-protected vehicle that retains a high degree of mobility while accepting heavier payloads.

The 19,000 kg GVW, 6.98 m long vehicle features a large internal space capable of seating the driver, commander, and eight dismounts, who benefit from relatively generous headroom, interior climate control, as well as ergonomic seating and design. Electrically assisted doors and a rear ramp facilitate rapid exit and entry. The vehicle is fitted with a 298 kW (400 hp) engine and seven-speed automatic transmission, permitting speeds of around 100 km/h, while the independent suspension, CTIS and run-flat tyres preserve mobility and stability under many tactical scenarios.

▲ The MAV'Rx PPV prototype. [Arquus]

The useful payload capacity ranges from 2.5 tonnes to 4 tonnes (depending on the ballistic protection level selected), which is sufficient to allow the MAV'Rx to mount a turret armed with a medium-calibre weapon to provide a direct fire support for its dismounts. The vehicle demonstrated at Eurosatory 2024, featured a John Cockerill Defense SPWS Gen.2 turret, armed with a 25 mm automatic cannon. Other major operational systems include the Battlenet electronic architecture and battle management system (BMS) which connects the various on-board systems and enables networking with eligible friendly units. This facilitates the use of features such as on-board sensor fusion, monitoring vehicle health, video sharing, and blue force tracking.

Rheinmetall Fuchs Evolution

At the heavier end of the scale, and moving into dedicated wheeled APC territory, the Fuchs 6×6 family was introduced in 1979, with the Fuchs 2 being built by Rheinmetall MAN Military Vehicles (RMMV) since 2007. The Fuchs family has seen service with numerous users worldwide, and Rheinmetall is now offering the Fuchs Evolution as the latest family variant.

Testing of the Fuchs Evolution amphibious configuration. [Rheinmetall]

Like its predecessors, the Fuchs Evolution can be configured for a wide variety of roles including combat reconnaissance vehicle, APC, and ambulance. Technology upgrades promise to keep the Fuchs Evolution relevant for the coming decades. System attributes revealed by Rheinmetall include a digital electronic architecture, a 360° surveillance system with day and night cameras, and a nuclear, biological, chemical (NBC) filtration system. In terms of mobility, the vehicle is provided with an MTU 6V 199 TE20 turbocharged diesel engine developing 339 kW (455 hp), permitting a top speed of 100 km/h, and a range of 800 km. The vehicle remains amphibious up to weights of 22,000 kg, and can be fitted with rear propellers, permitting swim speeds of up to 10 km/h. Rheinmetall cites a maximum GVW of 25,000 kg, including up to 9,000 kg payload capacity. The hull offers up to 11.5 m3 of internal space in the high-roof variant (with an interior roof height of 1.60 m), and 10 m3 in the standard roof configuration (with an interior height 1.40 m).

In the combat reconnaissance vehicle configuration, the vehicle can carry the driver, commander, and 10 dismounts. This version was displayed at Eurosatory 2024, fitted with a turret armed with a medium-calibre automatic cannon, along with an optronic sight mounted on a telescopic mast. Additional options include laser warning receivers, acoustic gunshot detector, and obscurant smoke grenade launchers. Ballistic protection is scalable, from STANAG 4569 Level 2 to Level 4, depending on configuration and user requirement, though the vehicle remains amphibious only up to Level 2. Mine protection is likewise scalable from Level 2a/2b up to Level 4a/4b.

New armour solutions?

In general, lightly armoured vehicles tend to be the most agile. The obvious disadvantage is the greater vulnerability to hostile fire. New battlefield threats, including drones and loitering munitions, have added a new dimension to protecting military vehicles of all classes. Optional modular armour upgrades can address threat scenarios on a mission-by-mission basis, albeit at the expense of reduced mobility and range.

Innovative materials promise some relief here by enabling production of modular armour components which are lighter and less thick than current passive and reactive applique, while offering comparable protection. Technologies being researched include ultra-high molecular weight polyethylene (UHMWPE) fibre-reinforced composites, which have a favourable strength-to-weight ratio compared to many alternatives. Systematic development of these and similar technologies will significantly contribute to future PPVs' ability to sustain a balance between firepower, mobility, and protection.

Testing combat boots with a new upper material from W. L. Gore & Associates

André Forkert

December is generally a time for presents, yet this time they arrived at the beginning of the month in the form of four pairs of a new combat boot. Manufactured by the experts for alpine, sports and outdoor footwear as well as combat boots, Lukas Meindl GmbH & Co. KG. The test is less about the boot and more about the new upper material. That's why this test is really exciting. The four boots were distributed to friendly associated within the Bundeswehr and have since been intensively tested in a wide variety of missions, climatic regions and everyday service.

The new upper material is EXTRAGUARD from W. L. Gore & Associates. It is intended to be an alternative to leather in the future. Meindl and presumably other shoe manufacturers will officially present their combat boots with EXTRAGUARTD for the first time at Enforce Tac 2025 in Nurnberg, Germany (24-26 February 2025). The current test will run until then, and the final report will also be given at the trade fair.

Gore wants to revolutionise this market segment with the new EXTRAGUARD upper material for combat boots. The aim is to move away from full leather boots or leather-textile mixes in favour of EXTRAGUARD. The manufacturer of the new upper material promises many advantages during use.

Low water absorption and quick re-drying

Leather requires intensive cleaning and care if the material is to provide long and reliable service. Especially if the boots frequently get damp and wet. EXTRAGUARD, on the other hand, does not require this and can even be cleaned with a steam jet. It also dries much faster. An important aspect of today's combat boots is minimising weight. Gore promises a weight saving of around 40% in the leather content. Leather also becomes very heavy when wet, whereas EXTRAGUARD absorbs very little water, so adds barely any additional weight. According to Gore,

Meindl combat boots with the new EXTRAGUARD upper material from Gore. What looks like rawhide leather here is actually a synthetic material. [André Forkert]

▲ Here the Meindl combat boot is shown in a different colour variant, with the appearance of smooth leather. [SaSch]

▲ Meindl combat boot in the water test. One advantage is said to be the lower moisture absorption. [André Forkert]

moisture from the outside penetrates as far as the inner construction layer of the EXTRAGUARD upper and is kept out by it. This minimises the risk of heat loss, keeping feet dry and warm even in cold and wet climatic conditions.

The seams are also specially sealed/glued from the outside to prevent water from penetrating and keeping feet dry. According to the manufacturer, the drying time of GORE-TEX EXTRAGUARD combat boots is considerably shorter than that of boots made from conventional upper materials (leather, textiles or a combination of both).

Leather is already naturally flame-retardant. EXTRAGUARD wants to be on a par here too and offers flame retardancy in accordance with fire service standard 15025. In a leather-textile boot, both durability and flame retardancy are generally reduced by the textile component. EXTRAGUARD has been used in safety footwear for some time, for instance by the manufacturer ELTEN. Now the military boot market is following suit.

Further advantages: A leather boot usually has to be 'broken in' intensively. With EXTRAGUARD, this factor does not apply. In addition, leather boots usually expand greatly when they are frequently wet for a long time, whereas Extraguard retains its shape and strength. Gore therefore promises that they are comfortable right from the start, do not need to be 'broken in' and retain their shape.

Initial testing

One of the aims of the boot test is to verify this information from industry. Before there is a nasty surprise on an exercise or away from the barracks, the boots are of course run in and thus subjected to an initial test. In my case, this was two days of 30 km each, with a total of 1,400 m in altitude gain. In the end, I had no complaints about pressure points or blisters. The boots were comfortable from the first, and without any problems. What is also immediately noticeable, despite lots of leaves, mud and sludge on the hiking trails, is that it is really difficult to get the material dirty.

But before we went off-road, the boots were first weighed on the scales. In contrast to full leather boots, the boots are supposed to be lighter even when dry, with around 40% less weight in the (leather) upper material. The EXTRAGUARD pair weighs 1,867 grams in EU size 44.5. The heavy combat boot (Kampfstiefel schwer) supplied by the Bundeswehr weighs 1,963 grams in the same size – only 100 grams more. To be fair, however, it should be noted that the comparison with the heavy combat boot is perhaps also a little off. This is because the feel and look of the EXTRAGUARD boot is more like that of a heavy service mountain boot, and here a pair normally weighs 2,126 grams.

Meindl and most likely other manufacturers will be presenting their EXTRAGUARD footwear systems at Enforce Tac 2025 in Nuremberg. Experts from W. L. Gore & Associates will also be available to answer questions at stand 7A-537.

CBRN forensics: Proving an incident occurred and proving who did it

Dan Kaszeta

The issue of legal and procedural forensics does not come up very often in this publication. However, the collection, handling, storage, and exploitation of evidence of use of chemical, biological, radiological, or nuclear (CBRN) weapons and materials is actually an issue of vital importance. The idea that forensics is something that police and courts need to worry about but not soldiers and diplomats is outdated. The ability to establish the veracity of alleged use of CBRN weapons is important, as is the ability to identify perpetrators. These two tasks are the main purpose of CBRN forensics as an emerging discipline.

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Verification of claims and incidents

The first reason why proper forensics is needed in acts of warfare or terrorism is to actually establish if a CBRN material has been used. Suspected use of CBRN materials may be a war crime, the start of a war, an escalation to a war, or a dreadful terrorist attack. However, merely claiming or believing that CBRN materials were used is often not as easy as it may sound to the layperson. Gases, vapours, or aerosols may disperse. Smoke could be mistaken for a toxic attack. Various kinds of sickness could have natural or, at least, non-CBRN causes. Indications on CBRN detection instruments may be true or may be false indications. Malfunctions are not unknown. Even true indications on detection instruments may be false depictions of CBRN use. For example, Hydrogen Cyanide and Phosgene, both chemical warfare agents, might be produced in fires in residential or industrial buildings. A radiation reading could be induced by a natural source. Since CBRN use is such a provocation, it is rather important to establish what actually happened and provide some credible proof. This is where forensics come into play.

Pfc Pat Cook, 22nd Marine Expeditionary Unit CBRN specialist, retrieves a sample from a fire extinguisher, which was marked by the reconnaissance team as possibly being rigged with chemical agents or explosives, in a subway car during hazardous material response training at the Guardian Centers in Perry, Georgia, on 21 June 2013. [USMC/Sgt Austin Hazard]

The world has seen such scenarios in the past. Are reports of people having difficulty breathing after an artillery attack simply smoke? Or are they the result of chemical weapons? Are the civilian victims of a rocket attack dead from a nerve agent? Or is it a misunderstanding and they died from conventional means? These are serious questions asked in 2013 and 2017 in Syria and they need the sort of answers than can be reinforced by forensic science. In the current Russia-Ukraine conflict there have been some incidents of chemical use by Russians validated by evidence, but there have been many hundreds, if not more, claimed incidents that simply could be verified because of insufficient evidence.
The verification of use is especially important in an era of social media, misinformation, and disinformation. For every valid or plausible claim of CBRN use in recent conflicts, there have been false claims, both well-intentioned and malicious. Making the other side in a conflict appear to be en-

gaging in forbidden conduct is an old tactic that has gained more traction in the age of social media. Verification of what substance actually was used is also important. Appropriate medical treatment may rely on accurate identification of a substance. A lesser material such as tear gas may have been mistaken for something more dangerous. Indeed, this is one reason why putatively non-lethal tear gases are banned in warfare.

Attribution

As well as verifying that an incident actually happened, CBRN forensics has a strong role to play in identifying who the perpetrator of an incident was. This may be at the strategic level (identifying which side in a conflict did it), the tactical level (which unit did it), or even the individual level (what soldier or terrorist did it.) With instances of chemical weapon usage in the Syrian civil war, there were numerous claims as to who actually used various chemical weapons. The large majority of such claims were gradually proven false, but it was both chemical and non-chemical evidence that allowed for the attribution of attacks to, almost entirely, the Syrian regime (a Sulphur Mustard incident was attributed to IS, but the vast majority of chemical incidents were attributed to the Assad regime).

One critical aspect of attribution is that not all of the focus should be on the technical CBRN aspects of the collected evidence. Often, it may be non-CBRN elements of evidence that actually provide crucial details as to who perpetrated the attack. Finding a dead body at the scene of a terrorist incident with the nerve agent Sarin on its clothing and finding relevant chemical markers of Sarin in the blood of the victim is fairly useful in establishing that the victim died from nerve agent exposure. But that information does not easily reside in just the chemical agent itself. What if the evidence is on fragments of the device? Or on a smartphone of a victim, now covered in nerve agent?

▲ BioTesting Division Microbiologist Scott Jonas activates a party popper filled with Glo Germ dust within the Aerosol Simulant Exposure Chamber as three Soldiers from the Alabama National Guard's 690th CBRN Company wait in protective suits for the dust to disperse. [US Army/Jack Bunja]

The same type of logic applies to battlefield use. Who fired the artillery rounds with the Sarin? Who dropped the bombs? Analysis of shell craters or analysis of fragments of the munitions, not the chemical agent, is needed to develop a full picture of who may have performed the war crime. In both war crimes and terrorism, the analytical CBRN laboratory that identifies the chemical agent may not be able to analyse non-CBRN evidence. Fingerprints, fibre, and DNA evidence from a fragment of the device or munition may have evidentiary value. The smartphone of a victim could hold much useful information, but the criminology laboratory that could easily derive that information might not be able to safely handle nerve agents, or may not be legally allowed to process such evidence.

How does CBRN forensics work? Types of evidence

Forensic science in CBRN warfare and terrorism needs to follow the same basic approaches as forensic evidence in conventional criminology. CBRN forensics consists of collecting evidence from a potentially contaminated crime scene in a way that scientifically preserves the evidence in a way that protects the ability to extract information at some future point as well as doing so in a way that is resistant to administrative or legal challenge. It seems odd to some to talk about warfare and evidence using legal and procedural language, but use of chemical weapons is a war crime, war crimes can lead to tribunals, terrorism can lead to trials, and use of such weapons can be used as an excuse to start or escalate a war. So, it pays off in abundance to get the evidence right, from the beginning.

There are a number of broad categories of relevant CBRN evidence. For each category there are preferred tactics, techniques, procedures, and equipment that range from very simple to nearly esoteric. Gas, vapour, and aerosol samples are one category, and represent a difficult type of evidence. Finding the right point to collect a sample will be difficult, and due to environmental conditions, such samples are the most time-sensitive.

Solid and liquid samples are more straightforward. The two categories can often be found co-mingled. For example, soil or clothing samples could be soaked in a liquid agent. Surface swabs and swipes are useful for detecting very small amounts of material. Such samples were useful in the 2006 Litvinenko investigation and the 2018 Skripal investigation in the UK.

It is important to note that there is, potentially, a biomedical component to CBRN evidence. Some of the evidence may be in the form of dead people or dead animals; biomedical evidence from living or dead people or animals, in the form of hair, blood, urine, swabs from skin, and tissues has been revelatory in past investigations. In the Khan Sheikhoun Sarin attack in 2017, for example, necropsy of dead animals helped prove that Sarin was used in the attack, which killed at least 58 people. The biochemical processes and the 'biomarkers' that are the targets of such investigations are well-documented in the scientific literature.

Conventional evidence from an incident scene, possibly contaminated with CBRN material is yet another (and often overlooked) category, as discussed earlier. Finally, an investigation should not disregard electronic evidence. This may include video, social media posts, geolocation data from mobile devices, and actual physical exploitation of electronic devices found at an incident scene.

Integrity of evidence

Materials collected in an investigation need both physical and procedural integrity if they are going to be able to be processed in a way that yields information that is useful. Physical integrity means being able to keep the collected material (or virtual evidence, in the case of electronic evidence) in storage in a way that preserves it and protects it from cross-contamination, until it can be properly examined in laboratory conditions.

▲ A US Marine with 31st Marine Expeditionary Unit (MEU), monitors for hazardous materials during visit, board, search, and seizure training under exercise Noble Arashi, at Naval Base Guam, Guam, 19 March 2022. [USMC/Sgt Danny Gonzalez]

The best way to look at the CBRN forensics problem is to assume that a very good lawyer is defending the perpetrator in court and questioning every single bit of evidence, how it was collected, the tools used, and how the evidence was handled after collection. Good defence counsel already does this in murder investigations and drug cases. People who were likely guilty of crimes have been let go because of problems with the integrity of the evidence.

Several countermeasures can be taken to ensure the integrity of the evidence. All of the processes, tools, procedures, PPE, and containers involved need to be used in a way that minimises cross-contamination. As an example, using the same shovel to fill a hundred different bags at four different sites could really cause procedural problems through cross-contamination. Documented and verifiable sterility of containers and tools is a useful safeguard. So is the use of blank samples (items not used in the collection effort but submitted and processed as evidence) and control samples (similar materials to those collected but from outside a crime scene) are useful methods for protecting the integrity of evidence.

National and international efforts

Thirty years ago, there was a void in this space. Incidents such as the Tokyo subway Sarin attacks in 1996 and the Amerithrax investigation in 2001 pointed out the procedural voids between military CBRN detection and the needs of criminal investigation. Some countries have come a long way, and numerous countries field Sampling and Identification of Biological, Chemical, and Radiological Agents (SIBCRA) teams, and there are specialist NATO capabilities. In the civil sector, efforts very greatly. Some countries, like the USA (which has dedicated FBI teams for exactly this task) and the UK (police CBRN teams) have sunk much development effort into CBRN forensics. In some other countries, the situation is dire. Some

▶ A sampling team from 2nd Platoon, 51st Chemical, Biological, Radiological, Nuclear (CBRN) Company, 83rd CBRN Battalion assigned to Fort Stewart, Georgia during the ground collection practical exercise of the National Technical Nuclear Forensics (NTNF) Ground Collection Task Force (GCTF) Academics. [US Army/SFC Angel Martinez-Navedo)]

countries still manage to deal with CBRN incidents as only a public safety matter (vitally important) but neglect the legal aspects. Your correspondent has watched firefighters literally wash the fragments of a terrorist device down the drain during an exercise in an EU country.

One niche area worth mentioning is nuclear forensics. The US government has sunk great effort into this particular area. The Americans have been spending decades on devoting some of the vast nuclear weapon industrial infrastructure to an interesting technical question. The US now has labs and expertise able to examine the residue of a nuclear explosion, or failed or disarmed nuclear device (it is thought that improvised nuclear devices will have a high rate of failure) and determining the origin of the fissile material.

Some bilateral and international efforts have been underway to improve the situation. Interpol has spent several years (and had your correspondent serve on an advisory panel) developing and promulgating elementary guidelines. These guidelines for chemical incidents represent a good basis for development of local processes in countries that are years or decades behind in this subject. The European Union has fostered several projects in CBRN forensics, both within the EU (such as FP7's Project GIFT led by the Netherlands) and as part of the EU's efforts to spread knowledge through the EU CBRN Centres of Excellence (such as Projects 57 and 58). The International Atomic Energy Agency (IAEA) has also done work to spread knowledge on nuclear forensics.

Products and prosecution

Forensics is not a market segment that is particularly dense with specialist products. Much of the work can, in fact, be done with generic products as long as the various provisos of sterility, integrity, and chain of custody are observed. A glass jar is, at the end of the day, just a glass jar. However, this is not to say that there are not products or technologies available to help in this area. Saab (Sweden) has a well-regarded CBRN sampling kit designed as a ready-made technical solution in this area. HotZone Solutions (NL) produces 'The Identifier' sampling kit. Quick Silver Analytics (USA) has developed and sold similar kits in the US market. In all of these circumstances, these are, in effect, product bundles of fairly generic equipment items available from a wide variety of vendors and there is no practical obstacle to an end-user making their own kits. While field and portable CBRN detection instruments often do not represent a final step in CBRN forensics, they are crucial to processing a crime scene. However, these instruments have been well covered in several previous articles in this magazine.

Prosecutions and trials are rare in this arena, and the ones that have happened have tended to be ones involving breaking of sanctions. In such cases, financial evidence and paper trails were often the evidence. However, it is only a matter of time before it will happen. Indeed, with information coming out from Syria, it may happen sooner than anyone had expected; but we do not want to see situations where perpetrators escape justice due to faulty processes.

The Baltic: A 'strategic sea'

Dr Lee Willett

The Baltic Sea is becoming a significant geographic space in NATO-Russia naval rivalry. For NATO, its new Baltic member states – Finland and Sweden – add value in this context, bringing Baltic-specific capability, experience, and expertise to the contest with Russia in the region

The Baltic Sea sits centrally in the contemporary naval competition between NATO and its navies and the Russian Federation Navy. Here, these actors play significant roles on what has become a central stage in the wider Euro-Atlantic theatre's security balance. While the ongoing Russo-Ukraine war, which erupted in February 2022, has developed largely as a land-focused conflict, the Baltic Sea (towards NATO's northern flank) – and the Black Sea (on NATO's southern flank) – are maritime regions into which events surrounding the war have spilled.

At a military-operational level, the occurrence since the war broke out of four critical undersea infrastructure (CUI) security incidents in the Baltic indicates that hybrid, asymmetric warfare campaigns may be underway there, designed to undermine Western connectivity and economies.

In September 2022, two Nordstream gas pipelines were ruptured by explosions, off Denmark's Bornholm island. In October 2023, the BalticConnector gas pipeline and nearby communications cables, all running between Estonia and Finland, were damaged. In November 2024, the Arelion internet cable linking Sweden's Gotland island to Lithuania and the C-Lion 1 telecommunications cable connecting Finland and Germany were cut. In December 2024, the EstLink2 power cable plus several internet cables, again all running between Estonia and Finland, were damaged.

The Royal Swedish Navy (RSwN) *Koster* class mine-hunting vessel HSwMS Ven is pictured patrolling around Baltic Sea critical infrastructure. Recent infrastructure incidents underline the Baltic's strategic importance. [Royal Swedish Navy]

At a geostrategic level, Finland's and Sweden's rapid accession to NATO membership in the wake of the war breaking out means the Baltic Sea is now ringed by eight NATO member states (Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Sweden, and Finland) plus Russia.

AUTHOR

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In the last three cases, the damage has been attributed to ship anchors being dragged across the seabed. Chinese and Russian commercial ships, present in the areas and at the times concerned, have been cited in the resultant political and public debates as potentially being involved. Yet the density of shipping in the area and CUI on the seabed offers plausible deniability for any rogue actor targeting CUI with 'shadow fleets' in hybrid, asymmetric operations.

Following the EstLink2 incident, NATO Secretary General Mark Rutte said on social media that "NATO will enhance its military presence in the Baltic Sea." In response to the incident, but no doubt aimed at tackling the wider Baltic CUI threat, NATO announced in January 2024 the establishment of a new activity – 'Baltic Sentry' – designed to deter attempts by state or non-state actors to damage Baltic Sea CUI. The activity is led by Allied Command Operations, with Joint Force

Command Brunssum and NATO Allied Maritime Command (MARCOM) running the multi-domain maritime activity, based around NATO's standing naval forces at the tactical and operational levels.

Alongside the CUI incidents, other at-sea developments also underscore the Baltic's military-operational importance, in a manner that in turn underlines its geostrategic significance. For example, in November 2024, MARCOM established a new anti-submarine warfare (ASW) exercise dedicated to Baltic Sea operations. Exercise 'Merlin' – conducted off Sweden, with 10 NATO countries participating plus MARCOM's North Atlantic-focused Standing NATO Maritime Group 1 (SNMG1) – is designed to enhance NATO's knowledge of the region's underwater operating environment and build its wider regional maritime situational awareness (MSA), while also demonstrating ASW presence and readiness to build collective deterrence and defence in the region.

'Merlin' illustrates how NATO was already enhancing its Baltic Sea military presence. The exercise's geostrategic importance is underlined by the fact that MARCOM now conducts an annual, high-level ASW exercise in each Euro-Atlantic theatre region, with 'Dynamic Manta' and 'Dynamic Mongoose' occurring in the Mediterranean and Norwegian seas, respectively.

A Royal Netherlands Navy (RNLN) NH90 helicopter takes off from the RNLN frigate HNLMS *Van Amstel* during NATO's 'Merlin' anti-submarine warfare (ASW) exercise in the Baltic in November 2024. NATO now hosts annual ASW exercises across the Euro-Atlantic theatre. [NATO Maritime Command]

This in turn underscores a point made by Professor James Bergeron (MARCOM's policy advisor) who said – when speaking in a personal capacity at the Royal United Services Institute (RUSI) 'NATO Allied Maritime Power' conference in London in May 2024 – that the Baltic and Black seas have become "strategic seas", regions NATO had not previously needed to consider as core maritime concerns.

In RUSI's annual Gallipoli Memorial Lecture, held in October 2024, Admiral Sir Keith Blount – a UK Royal Navy (RN) officer posted as NATO's Deputy Supreme Allied Commander Europe (DSACEUR), having previously served as Commander (COM) MARCOM – said "Sweden and Finland bring with them considerable military capability. Moreover, the Baltic Sea area looks very different with them as members .... [It] has become a formidable geographic cornerstone for the alliance."

Yet while NATO needs to support and secure Estonia, Latvia, and Lithuania as its Baltic State allies plus Finland and Sweden as new members, the Baltic is also a 'strategic sea' for Russia, which needs maritime access between Kaliningrad and St Petersburg.

Winds of change

One long-established NATO route for enhancing regional presence is joining national exercises. Following Finland's and Sweden's accession, NATO is already building Baltic presence this way.

In November 2024, two of MARCOM's four standing naval forces – SNMG1 and Standing NATO Mine Counter Measures Group 1 (SNMCMG1) – joined the Finnish Navy-led Exercise 'Freezing Winds 2024', in the eastern Baltic. 'Freezing Winds' is the navy's largest exercise, involving all its assets and personnel; participation included 15 NATO countries, 30 surface ships, plus maritime patrol aircraft (MPA) and marine forces.

"'Freezing Winds' is a crucial component of the alliance commitment to security in the Baltic Sea region," Commodore Janne Huusko – Finnish Navy Command's Chief of Staff – told the exercise's media briefing, onboard the Royal Norwegian Navy auxiliary ship HNoMS Maud, in port at Turku, southwestern Finland. "The Baltic Sea is now more strongly defended since Finland and Sweden joined NATO, increasing stability and security in the area."

"The objective of 'Freezing Winds 24' is to train for the execution of international naval operations in the circumstances of the Finnish coast and the Baltic Sea," Cdre Huusko continued. "*The exercise provides an excellent opportunity to highlight the presence, readiness, and partnership of participating countries in light of the current and future challenges related to joint, combined, and multinational operations, and within the framework of the international security architecture.*"

The exercise encompassed broad operational training, including amphibious warfare, maritime security, and sea lines of communication (SLOCs) protection. It tested and built participants' capabilities, readiness, and command and control (C2). Noting the exercise's wider impact on NATO operational output, Cdre Huusko said "Together, we will strengthen our capabilities to secure maritime trade routes, protect SLOCs, and uphold freedom of navigation in the Baltic Sea."

The importance of the opportunity presented for NATO to practice and demonstrate integration with one of its newest members in the challenging Baltic operational environment was underlined by the two NATO task groups' presence.

Standing NATO Mine Counter Measures Group 1 (SNMCMG1) practiced deploying uncrewed systems to secure CUI during the Finnish Navy-led exercise 'Freezing Winds', in the Baltic in late 2024. The exercise was designed to help enhance Finnish navy integration with NATO naval forces. [NATO Maritime Command]

"We are here to train integration of the Finnish Navy into NATO, and we will focus on advanced training to better prepare Finland's and NATO's ability to operate together," Commodore Thomas Stig Rasmussen – a Royal Danish Navy officer commanding SNMG1 – told the briefing. "By doing so, we will demonstrate our ability to defend Finland and other countries in the Baltic Sea region."

SNMG1 was deployed in the Baltic conducting naval surveillance operations, contributing to NATO vigilance activities. "We do this by patrolling the sea to observe and establish a clear picture of what is going," said Cdre Rasmussen. "We normally focus on the North Atlantic area, and for the time being we are patrolling in the Baltic Sea region. That is a very important strategic region for NATO."

"The Baltic region is not just a maritime domain: it is a key component of NATO's broad defence strategy," Cdre Rasmussen continued. "Our operational presence here underpins our commitment to maintain security and enhance deterrence, and is demonstrating NATO resolve to protect the territorial integrity of all our allies."

SNMG1's presence in and around the Baltic Sea for much of 2024 underlined the region's current strategic significance for NATO. SNMG1 – as MARCOM's North Atlantic-focused, destroyer/frigate-based standing naval force – has a vast geographic area of responsibility (AOR), covering the North Sea and Eastern Atlantic, the Norwegian Sea, the Arctic Ocean, and the High North. Yet, with the Russo-Ukraine war bringing greater strategic and operational focus on the central front ashore and the Baltic and Black seas as the conflict's maritime flanks, so SNMG1 is spending increasing amounts of time in the Baltic – including to quickly integrate Finnish and Swedish naval forces more fully into alliance operations.

"We still have a lot to do in the North Atlantic and elsewhere, but we are focusing on the Baltic, and training – especially with Sweden and Finland – is a key objective for us," Cdre Rasmussen told ***ESD***, onboard Maud. "So, we have increased focus on the Baltic, for good reason."

Exercises like 'Freezing Winds' enable NATO navies to practice integration in real-world operational environments. "[They do] help because we have to do it for real. It's only when we actually have ships at sea, aircraft flying, and people on the ground that we see all the tiny little bits that need to work together," Cdre Rasmussen told ESD. Such integration includes the different assets brought by NATO states, including those operated by the Finnish and Swedish navies that offer Baltic-bespoke capabilities. "The ability to operate fast patrol boats and mine hunters on the Finnish side together with the advanced frigates in SNMG1 is absolutely critical," Cdre Rasmussen added.

Total defence

Events in the Baltic and elsewhere across NATO's AOR are shaping Finland's and Sweden's defence plans. This is shown in Sweden's 2025-30 Total Defence Bill. Revealed in October 2024 and approved by parliament in December 2024, details of the Bill include increasing defence spending by 2028 to 2.8% of GDP (above NATO's 2.5% target). In a statement, Sweden's defence ministry described the Bill as adding "some muscles" to the "skeletal framework" provided in the two previous bills, helping "to accelerate the pace of rearmament" and meeting Sweden's ambition to be a "credible, reliable, and loyal ally".

The statement pointed to Russian activities in and around Ukraine, including its hybrid operations and targeting of civilian infrastructure. It highlighted several core capability developments for the navy, which underscore the Baltic naval threat. First, a mid-life upgrade on the five in-service ***Visby*** class

Close-up of a *Visby* class corvette docked near Karlskrona. [NATO]

corvettes, which will occur within the Bill period, will add an anti-air warfare missile capability. Second, Sweden will expand and re-organise its coastal missile capabilities – operated by its marine forces, and including anti-ship missile capability – into two units to improve availability. Third, procurement of the new *Luleå* class surface combatants will commence.

The Bill also underscored the importance of naval logistics and sustainability, with naval basing facilities to be established at Gothenburg (on the west coast), Karlskrona (in the southeast), and Haninge (south of Stockholm). Alongside supporting heightened readiness for Swedish forces, these bases will build naval ammunition stockpiles and provide maritime logistics support for NATO allies.

Overall, the statement noted, NATO's capability targets provide an "important starting point" for how Sweden will build its defence organisation and capability. The Bill's maritime elements reflect a wider re-think of Sweden's maritime strategy, which is taking place within the defence ministry in the context of reviewing how all elements of Sweden's society combine to deliver the country's 'Total Defence' construct.

"There are many reasons why a new maritime strategy has to be produced. Two of the main reasons are: the current security situation in the surrounding world; and our membership of NATO," Brigadier General Patrik Gardesten, the Royal Swedish Navy's (RSwN's) Deputy Commander, told ESD in a November interview. "We acknowledge the NATO '360' perspective," he added: "We will contribute to alliance tasks and meet the threats wherever they occur."

"We also bring to the table our military geography," Brig Gen Gardesten continued. "Sweden's territory together with Finland's territory is a real game changer for the alliance up in the Northeast flank, [including] to be able to defend it and sustain it."

Strategic SLOC security

Providing sustained defence of NATO's new geography in the Baltic includes securing SLOCs, part of which is the CUI network. The recent CUI incidents illustrate the complexity of the Baltic's SLOCs network (surface and seabed), NATO's increased focus on Baltic SLOC security at alliance and member state levels, and the competition between NATO and Russia over access to surface SLOCs.

For Finland, 94% of its trade travels by sea in peacetime. For NATO, in crisis or wartime, there may be a need to support or reinforce by sea various regional territories, including the Baltic States, Finland itself, or Swedish islands. For Russia, up to 60% of its trade is carried across the Baltic. So, especially in times of crisis, Baltic waters are congested and contested.

"Protecting SLOCs is vital for Finland. Finland is often described as an island from the import or export viewpoint. Maintaining the functioning of our society is heavily based on the maritime transport of goods," Cdre Huusko told the briefing. SLOCs security is a core task for the Finnish Navy, something it must tackle with national authorities and NATO allies, he added.
From Sweden's perspective, Brig Gen Gardesten explained, "The country is totally dependent on freedom of navigation in its surrounding waters, the SLOCs, and the functionality of our harbours and sea ports of embarkation." This applies to every country in the region, he added.

For NATO and its navies, Baltic SLOCs protection is an increasingly significant task. "We must train hard in a challenging and realistic environment to be able to defend our borders, our countries, and deter aggression if and when needed. To this end, control of the sea is very important for NATO in peace as well as in wartime," said Cdre Rasmussen. "We need to protect the SLOCs."

Baltic SLOC protection is challenging, due to the demanding operational environment and SLOC network complexity. The Baltic region stretches from the North Sea, through the Skagerrak/Kattegat straits, into and across the Baltic Sea, and up into the Gulf of Bothnia and Gulf of Finland. Baltic Sea waters are constricted in breadth and depth, congested with marine traffic (especially in Kattegat/Skagerrak), and cluttered in environmental noise. The western seaboard includes shallower, archipelagic regions, although there are deeper waters off Stockholm and Gotland island. The Baltic's brackish waters include varied seabed topography, ranging from flatter, sandier seafloors in the south to more mud and more rocks in the north.

RSwN *Visby* class corvettes are pictured leading ships under the Oresund Bridge. The bridge connects Sweden and Denmark at the southern end of the Kattegat Strait. The Skagerrak/Kattegat choke point is a crucial sea line of communication (SLOC) connecting the Baltic Sea and the North Atlantic region. [Royal Swedish Navy]

Integrated into this complex geophysical environment is an intricate CUI network. Broadly, CUI includes oil and gas resource pipelines and other installations; communications, data, and power cables; environmental and military sensors; wave and wind power structures; scientific research nodes, including oceanographic and hydrographic installations and instrumentation; and facilities for accessing sub-seabed critical minerals.

The Baltic's CUI risk is pronounced. As demonstrated in Ukraine, Russian wartime campaign strategy includes targeting civil energy and other infrastructure. The four Baltic CUI incidents underscore the MSA challenge in monitoring 'shadow fleets' in shallow, busy waters that mask their activities. These incidents underline the emerging, now enduring, risk to CUI that is economically significant for the region and more widely, and the consequent fact that Baltic Sea CUI is now a strategic SLOC.

The operational and strategic significance of this issue was underlined in January 2025 when six countries – Denmark, Estonia, Finland, Poland, Sweden, and the UK (under the auspices of the Joint Expeditionary Force maritime operational partnership, of which they are all members) announced plans – under Operation 'Nordic Warden' – to monitor 'shadow fleet' ships seen as presenting a risk in key CUI areas. 'Shadow fleet' ships are suspected of helping Russia circumnavigate oil export sanctions, and are central in NATO navies' focus on shipping that could be conducting Baltic CUI attacks. The decision to stand up the operation followed the EstLink2 incident; in December 2024, the six countries had already indicated they may start checking on 'shadow fleet' vessels transiting regional choke points like the Dover and Kattegat/Skagerrak straits. In late 2024, as reported in Western media, the Danish defence intelligence service warned that Russia could start assigning naval escorts to such shipping.

Baltic planning

The Baltic's growing importance for NATO strategy and operations was further underlined in October 2024, when the German Navy established a new tactical maritime headquarters, Commander Task Force (CTF) Baltic.

Responding to NATO's broader initiative to bring regional countries together to strengthen collective defence in regions across the Euro-Atlantic theatre, and alliance directives for member states to establish high-level tactical maritime headquarters, CTF Baltic will take on tasking on behalf of MARCOM in its maritime area; coordinate allied Baltic Sea naval activities; and conduct tactical control of maritime forces.

CTF Baltic is a German Navy national headquarters that can perform NATO tasks. Staff officers are drawn from Germany and other NATO allies (and not just Baltic member states). Its staff participated in 'Freezing Winds', engaging particularly in the integrated, tactical control of NATO maritime forces.

CTF Baltic's establishment illustrates the reciprocal learning process between NATO and regional allies. First, CTF Baltic illustrates how NATO is looking to improve coordination of regional member state naval activities, command of regional operations, and regional response plans now that Finland and Sweden are members. Second, its presence reflects the need for Finland's and Sweden's national defence plans to be aligned and integrated with NATO's, including the alliance's vigilance activities and wider regional response plans.

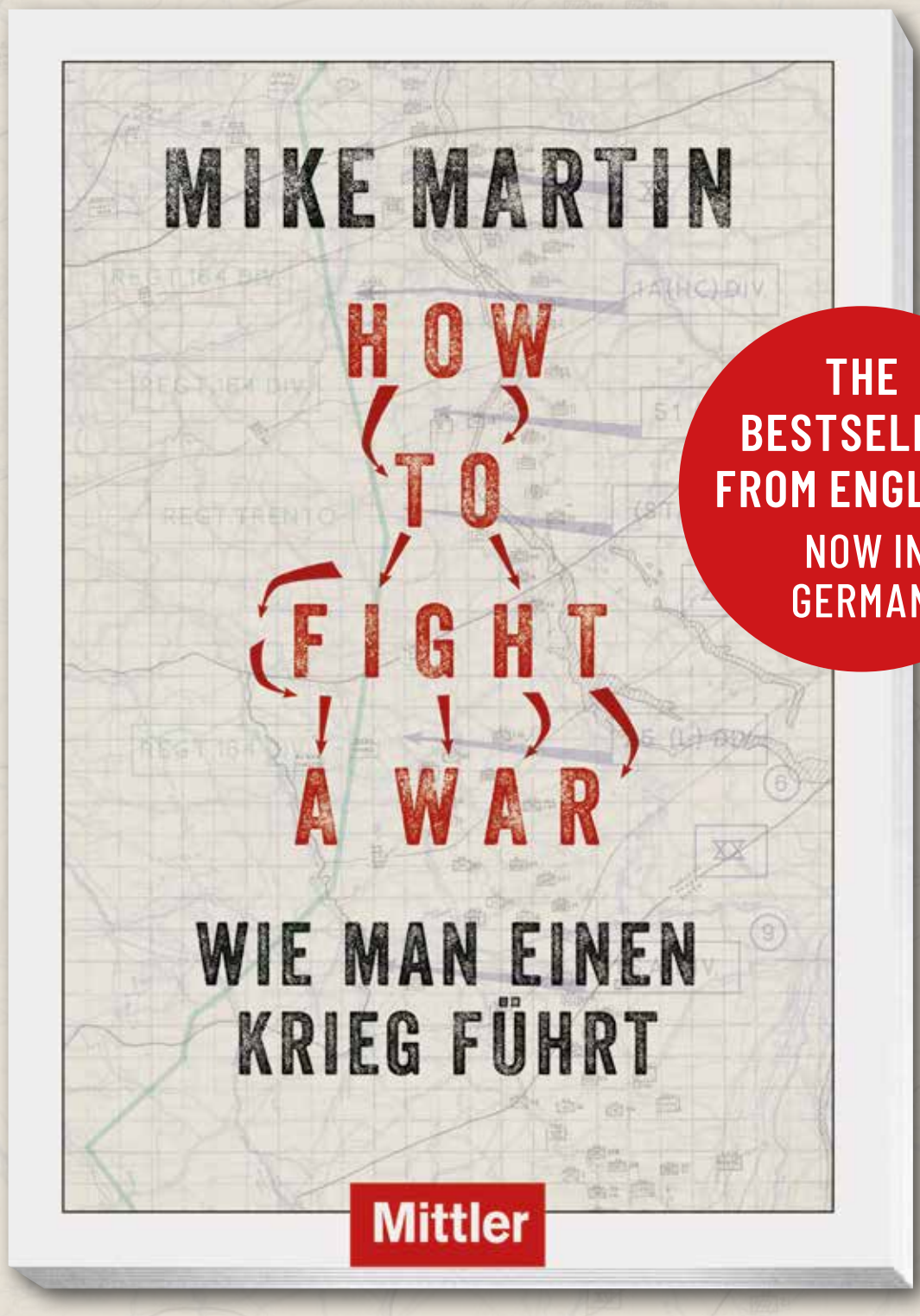
Operating capabilities such as the *Visby* class corvettes (pictured), the RSwN brings long-established and detailed knowledge of the Baltic's operating environment and maritime picture. [Royal Swedish Navy]

Since the Russo-Ukraine war erupted, NATO has bolstered its vigilance activities and reviewed and renewed its regional response plans. In the Baltic, development and execution of such activities and plans will be enhanced by input from the Finnish and Swedish navies.

"As Sweden is now a NATO member, we are included in and can affect the regional planning," said Brig Gen Gardesten. "We can affect that using our experience in the region; our territory, for instance how we use our archipelago for protection or how we use our naval bases for logistics; and our expertise, for instance in the subsurface domain."

"From the NATO perspective, with Finland's and Sweden's territory and capabilities being part of NATO's capabilities and assets, we have to take that into account in the regional plans," he added. "From the Swedish perspective, we have to see the possibility that our forces, capabilities, and territory can be used, for instance to ensure reinforcement of [NATO] states."

Noting that maritime infrastructure security in Sweden is a civil sector responsibility, as well as the broader fact that Sweden – as previously non-aligned – has developed full, society-wide responsibility for national security under its 'Total Defence' concept, Brig Gen Gardesten said that ensuring freedom of navigation in its waters, for example, is more than just the RSwN's responsibility. The 'Total Defence' approach might thus be something Sweden could bring to the table for NATO to consider in developing future defence plans, he added.



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Collective value added

The Finnish and Swedish navies add value for NATO in the Baltic in several ways, including: bringing expert understanding of the operational environment; building a detailed recognised maritime picture (RMP) and wider MSA; and exploiting these two with Baltic-focused operational capabilities.

As regards understanding the Baltic, "This environment is unique .... We know the environment, we know the weather, we know the geographical features in the area. So, this is what we can provide for our allies when they are operating in this part of the world," Cdre Huusko told ESD. "At the same time, when our allies come here, we are able to join together what we know, so we are even stronger based on that cooperation." As regards building the surveillance picture, Cdre Huusko told the briefing: "Our normal tasks have demonstrated that we have done the right work in Finland, during peacetime." Explaining that RMP and MSA building was a long-established national naval task, Cdre Huusko said "Now, we have seen the value of that: we know quite precisely what is happening around us." Since joining NATO, the navy has become busier, working daily with the alliance, working with task groups, learning tactics, techniques, and procedures (TTPs), and sharing (especially receiving) much larger amounts of information. However, Cdre Huusko said, the navy's basic task – building the surveillance picture – "has been quite correctly held". Building this comprehensive picture is crucial to countering the CUI threat. "We know what is normal, what is not normal," he told ESD.

Brig Gen Gardesten reiterated the impact the regional navies' sustained at-sea surveillance presence has for NATO. "To have a credible RMP, like we have today, we really, really need to be out at sea every day and to establish MSA, to have it nationally but also to contribute to MARCOM's regional MSA," he said.

Yet maintaining this surveillance presence while supporting NATO taskings may require the navy to reconsider its force structure size, Brig Gen Gardesten continued. "The Swedish Navy needs more hulls. We need them because we have to be able to continue our sea surveillance operation, and we have to be able to conduct naval operations in several directions – not only in one direction, like we have been for many years."

For the RSwN now as a NATO member, one such new direction may be out into the North Sea. The new ***Luleå*** class surface ships will enhance the navy's capacity and capability to operate there.

As regards capabilities, the two navies have built Baltic-focused outputs. For the Finnish Navy, this includes its mine counter-measures (MCM) vessels. For the RSwN, in ASW it provides Baltic-optimised capability for hunter and hunted: its ***Visby*** corvettes bring stealth and high speed; its A19 ***Gotland*** class diesel-electric submarines (SSKs) are highly manoeuvrable, and extremely quiet at low speed.

Hunting submarines in the Baltic is challenging, due to the operational and environmental conditions. The RSwN brings significant regional expertise in both operating and finding submarines. [Royal Swedish Navy]

On 'Merlin', SNMG1 exercised with the RSwN and one of its A19s. "To find submarines in the Baltic is very demanding, because of the conditions," Cdre Rasmussen told ESD. "We saw, however, that our frigates – together with the Swedish corvettes, helicopters, and MPAs – were a good match against the submarine."

NATO SNMG1 and RSwN ships sail together during 'Merlin'. Leading (right) is the Royal Norwegian Navy auxiliary ship HNoMS Maud (SNMG1 flagship), with the RSwN Visby corvette HSwMS Helsingborg completing the line of ships. [NATO Maritime Command]

The RSwN's knowledge of the operating environment enhances its operational capability, and NATO can draw on both together. "They are experts in this field," Cdre Rasmussen told ESD. "We came [to 'Merlin'] and learned a lot from the RSwN about doing ASW operations in this … area; it is different from blue-water ASW operations, where we are experts." With the RSwN already well-versed in NATO TTPs and continuing to prove its capabilities, "Right now, we are talking about very few technical issues that we have to get hold of to achieve full connectivity, but we are almost there," said Cdre Rasmussen.

Reflecting this point, Brig Gen Gardesten said that, with Sweden having been working closely with NATO for several decades including (since 1994) in the 'Partnership for Peace' programme, it has good understanding and use of NATO TTPs, leaving broader connectivity as the most significant hurdle remaining. "It's all about connectivity. We have to, together with our allies, develop common communications systems, and we have to develop our ability to share information," he said. "We do that today, but we have to be better at sharing information in other systems in order to be able to conduct combined operations, and not just coordinate operations." Improved information sharing will also improve regional MSA, he added.

Both the Finnish and Swedish navies plan to deploy ships with the standing naval forces in 2025. The addition of two more member state navies deepens the platform pool available to MARCOM to fill these forces.

▲ **The Finnish Navy mine-hunting vessel Vahterpää (foreground) works with SNMCMG1 in the Baltic in April 2024. The navy brings MCM expertise for the Baltic region. [Finnish Navy]**

Both navies are also building new – larger, and more capable – platforms that will add further value for NATO in the Baltic, and more widely. For Finland, four ***Pohjanmaa*** class multi-role surface combatants, being acquired under the 'Squadron 2020' programme and scheduled for delivery by around 2029, will provide anti-surface, anti-submarine, anti-air, and mine-laying capabilities. For Sweden, its four new ***Luleå*** class surface ships, scheduled for delivery in two pairs (before 2030 and before 2034), are designed to enhance RSwN capacity to support NATO requirements. The navy will also receive two A26 ***Blekinge*** class SSKs in the 2029-30 timeframe, with more maybe following.

Balancing act

As the Finnish and Swedish navies and NATO learn more about each other, future operational developments seem likely to involve balancing generation of presence and capability in the Baltic and more widely across the Euro-Atlantic theatre. The Russian threat in the Baltic underlines the need to maintain deterrence and defence there, while NATO navies operating 'out of area' in other regions of the alliance's AOR demonstrates wider cohesion.

"Today and in the future, our development and procurement will have the main focus of being able to conduct operations in our region … but I also believe in the necessity for us to be part of the alliance in other areas, because that sends a strong signal of unity," said Brig Gen Gardesten.

Such wider presence could add more value for NATO. "We can bring something to the table in other areas," said Brig Gen Gardesten. "For instance, in the future, Swedish MCM capabilities could be useful in the Black Sea and waters in that area." Such capability, he continued, could include operational concepts, personnel expertise and advice, and physical presence of MCM vessels (including within MARCOM's Mediterranean-based MCM standing force, SNMCMG2).

However, such ideas and options will need to be balanced against Baltic commitments, where RSwN presence and expertise will be paramount. "It's always about priorities," said Brig Gen Gardesten. "Now that we are NATO members, we are around the table when these priorities and these decisions have to be made."

Yet bringing Baltic-specific capabilities and expertise and contributing to NATO operations more widely both add value for the alliance, Brig Gen Gardesten explained. "When we contribute and exercise together, we make NATO stronger because we contribute with capabilities that no other country, in some ways, has. We also send a very strong signal to Russia that we, every day now, increase our capability to conduct operations together, within the framework of NATO," he said. "So, we learn, we integrate, we increase interoperability, we work on better connectivity – but we also send a signal that 'stronger together' is something for Russia to count on."

Interview – Admiral Naveed Ashraf, Chief of the Naval Staff, Pakistan Navy

ESD recently secured the opportunity to interview Admiral Naveed Ashraf, the Pakistan Navy's Chief of the Naval Staff, about his ambitions and expectations for the fleet's development under his leadership. His answers paint a vision of a modernised PN working in partnership with friendly navies to achieve regional stability. The interview was conducted by Conrad Waters.

ESD: What were your primary ambitions for the Pakistan Navy when being appointed Chief of the Naval Staff in October 2023? Which of these objectives have been achieved and which are still to be realised?

Pakistan Chief of the Naval Staff (PCNS): My main objectives included; first, the professional development and well-being of the men and women serving in the Pakistan Navy (PN) through various professional military education and welfare related initiatives; secondly, boosting the navy's combat readiness through the optimal utilisation of resources and completion of ongoing projects within relevant financial constraints; thirdly, preparing our navy to counter both the conventional and non-conventional threats that are being presented to us; and lastly, strengthening Pakistan's role as a key maritime player, capable of contributing to regional stability.

I am able to report with satisfaction that the majority of our major equipment projects have either been completed or are near completion. These including the MILGEM class corvettes, *Yarmook* class offshore patrol vessels and Embraer jet long-range maritime patrol aircraft. In addition, the *Hangor* class submarines will soon become part of our fleet. Moreover, our ships are active in maintaining presence across the region. Through regional maritime security patrols (PMSPs) and our participation in the Combined Maritime Forces (CMF) we ensure a credible deterrence against both traditional and non-traditional threats. The PN's proactive international engagement is also demonstrated through multilateral forums and exercises such as AMAN and the AMAN Dialogue. It is my utmost endeavour to make Pakistan a key maritime player for regional stability.

The Pakistan Navy's new MILGEM type corvette PNS Babur is the first of four vessels of the class ordered from Turkey. Two of these are being built by Karachi Shipyard & Engineering Works (KSEW) as part of efforts to expand indigenous construction capabilities. [Pakistan Navy]

Admiral Naveed Ashraf NI(M) T Bt

Admiral Naveed Ashraf assumed command of the Pakistan Navy on 7 October 2023 as its 23rd Chief of the Naval Staff. Commissioned into the navy's operations branch in 1989, he was awarded the Quaid-e-Azam Gold Medal on successful completion of his initial training in Pakistan and Germany. His subsequent naval career has encompassed numerous command and staff appointments, including serving as commanding officer of a gunboat, minehunter, three destroyers and the 18th and 25th Destroyer Squadrons. He is a graduate of the Pakistan Navy War College Lahore, the National Defence University Islamabad, the Naval Staff College in the United States of America, and the Royal College of Defence Studies in the United Kingdom. His awards and decorations include Pakistan's Nishan-e-Imtiaz (Military) and Tamgha-e-Baslat.

The Pakistan Navy's PNS Alamgir (background) pictured operating with the United States Navy cruiser USS Shiloh (CG-67) in the Arabian Sea. Admiral Ashraf sees working with partner navies to achieve a secure maritime environment in the region as key to the navy's vision. Alamgir was one of his previous commands. [US Navy]

ESD: The Pakistan Navy is currently in the middle of a major programme of equipment modernisation, including procurement of new vessels from Chinese, Dutch and Turkish companies. Please describe the main elements of these projects and the new capabilities that they will provide?

PCNS: The induction of modern platforms and other force multipliers has been a major area of recent focus. At the same time, we have been emphasising indigenisation and the maintenance of diversified supplier options so as to mitigate external dependencies.

To date, we have inducted state-of-the-art Type 054 frigates supplied by China, offshore patrol vessels built in Romania [interviewer's note: built by the Dutch Damen group's shipyard at Galați] and the first of a class of MILGEM type corvettes ordered from Turkey. We are still in the process of inducting the remainder of the MILGEM class frigates, two of which are being constructed indigenously at Karachi Shipyard & Engineering Works (KSEW). In addition, *Hangor* class submarines that have been contracted with China will form part of the PN soon.

The Pakistan Navy's underwater flotilla will soon be supplemented by new Hangor class submarines of Chinese design as part of a process of ongoing force modernisation. [Pakistan Navy]

ESD: Pakistan has been steadily enhancing its indigenous warship production capacity, notably at KSEW. Please explain how you plan to develop this capability further, for example through your developing partnership with Turkish naval industry?

PCNS: We believe that collaboration with international partners is the best way ahead to ensure the robust development of our capabilities. In this regard, we have collaborated with both Turkey and China to develop warship construction and these partnerships are expected to grow further in the future.

ESD: The arrival of new equipment will inevitably give rise to management challenges in areas such as crew training and logistics. What steps are you taking to ensure your new vessels are being operated as efficiently as possible?

PCNS: Ensuring well trained and highly skilled human resources is at the top of my list of priorities. The challenge of training and educating the future generation of PN personnel is being addressed through optimising the navy's professional military education institutes. This includes the integration of the latest technology, including the use of simulators and application-centric (outcome-based) learning.

ESD: The Pakistan Navy is well-known for its active participation in multinational maritime security operations, for example through its frequent leadership of the CTF-151 anti-piracy mission off the Horn of Africa. How has the navy benefitted from these activities and are they an ongoing priority?

PCNS: The PN's active participation in CTF led operations has provided Pakistan with an opportunity to observe, learn and apply some of the best practices being used by major navies around the world. It has also increased the PN's global outreach, leading to improvement in relations and collaboration with both regional and extra-regional partners.

ESD: What is your vision for the Pakistan Navy's role and capabilities within the context of the broader Pakistan Armed Forces a decade from now?

PCNS: The Pakistan Navy will need to be capable of ensuring good order across the Arabian Sea and adjoining areas, working in partnership with like-minded countries to achieve this goal. In this way, a safe and secure maritime environment will be achieved. Such an environment will assist the development of trade, helping to achieve economic prosperity throughout the region and beyond.

ESD: Thank you, Admiral, for your informative responses. We wish you well in realising your vision.

Admiral Naveed Ashraf pictured shortly after his appointment as the Pakistan Navy's Chief of the Naval Staff. Ensuring the development of well trained and highly skilled personnel has been at the top of his priority list. [Pakistan Navy]

US helicopter training – In a spin?

Trevor Nash

The US DoD trains thousands of military helicopter pilots each year and these are produced by the US Army, Navy and Air Force to different standards using unique training pipelines and utilizing different training aircraft. All three services have, or are in the process, of adopting new training syllabi to address a number of shortfalls. This feature looks at those processes and asks – can current costs be sustained and is it time for change?

Training provided to military helicopter pilots can be considered under the three broad headings of primary, type conversion and tactical. Increasingly, much of this training is conducted by commercial contractors to provide a blended learning environment that frequently features aircraft, synthetic training equipment, instructors and supporting resources such as classrooms, maintenance facilities and accommodation. Although this model is growing in popularity, there is no 'one size fits all' solution and rotary-wing syllabi therefore vary accordingly.

The integration of synthetic training equipment with rotary-wing training is vital. This example is for the USN's TH-73A Thrasher and provided by Frasca International. [Frasca]

AUTHOR

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The key driver for this training market is the military's adoption of frontline helicopters. Spotting trends and forecasting requirements to plan for training in the future and therefore, the number of pilots required, is however, a challenge. For example, a study of eight extant forecasts for future military helicopter sales from companies such as Forecast International, Spherical Insights and Mordor for the next six to seven years vary wildly from USD 10.2 billion to USD 89.4 billion. Compound Annual Growth Rates (CAGR), the difference between sales in 2023-4 to 2030-2 stretch from 2.1 to 9.31%.

Forecasting helicopter procurement is not made easier when programmes are cancelled or delayed. Here, the US Army's Future Attack Reconnaissance Aircraft (FARA) and the UK's New Medium Helicopter (NMH) initiatives provide examples. The delayed NMH programme and its impact on the UK's rotary-wing training pipeline has also been exacerbated by the Government's decision to scrap the 17-strong Puma fleet along with 14 Chinook HC2 aircraft.

Although over USD 2 billion had already been invested in FARA, all is not lost for the US Army. The organisation continues to progress its Future Long Range Assault Aircraft (FLRAA) programme as a UH-60 Black Hawk replacement. Unsurprisingly, the market forecasts all identify the US as the biggest military helicopter market over the next few years and currently, with over 3,500 military helicopters, the lion's share of this market is held by the US Army. Unfortunately, all is not well with rotary-wing training in that organisation, as it grapples with defining a new training strategy to address key shortfalls.

Go Army

The US Army conducts rotary-wing training at the Army Aviation Center of Excellence (USAACE) at Fort Novosel in Alabama (formally known as Fort Rucker). Students currently undertake an Initial Entry Rotary-Wing (IERW) basic flying phase using the LUH-72 Lakota (a variant of the Eurocopter H145) before moving on to undertake type training on the UH-60, AH-64 or CH-47 during the Advanced Graduate Flight (AGF) Training phase. In theory, the flight training process takes between 12-18 months.

This type or conversion training for the three frontline helicopter types is undertaken by CAE under the Army Advanced Helicopter Flight Training Services contract. This is due to expire in 2027. Highlighting how CAE has benefitted from its close relationship with the US Army over recent years, 2026 will see the company deliver new CH-47F and UH-60M flight

▲ **The US Army currently uses the LUH-72A (pictured) and LUH-72B but are looking to replace these helicopters under a re-vamp of its rotary-wing training pipeline. [US Army/Staff Sgt Austin Berner]**

simulators to Fort Novosel as part of the US Army Flight School Training Support Services contract.

Unlike many military forces, the US Army does not conduct fixed-wing training prior to IERW. All US Army pilots start with rotary-wing training and those selected for fixed-wing training to fly aircraft such as the C-12 Huron undertake additional training conducted by CAE at Dothan, Alabama that features the Grob 120TP and Beech King Air.

US Army rotary-wing training is currently suffering a hiatus due to a number of factors. The first of these is the number of Class A accidents; or 'mishaps' in US DoD parlance, that have occurred between FY20 and FY24. During this period and according to the US Army Combat Readiness Center, there were 49 mishaps that resulted in 45 fatalities. A Class A mishap is defined as an incident resulting in; 'total cost of property damage [of] USD 2,500,000 or more; an Army manned aircraft...destroyed, missing, or abandoned; or an injury and/or occupational illness [that] results in a fatality or permanent total disability.'

"We've seen a troubling trend with our accident rates," said MG Walter Rugen, Director Army Aviation during in a press briefing in April 2024. This has resulted in the US Army undertaking increased training but perhaps more importantly, take a much closer holistic look at how it conducts its training. According to Rugen, this means, "more training [and] more focused training."

Increasing emphasis has centred on the LUH-72 Lakota, primarily on its operating costs and the complexity of this twin-engine helicopter. Paradoxically, after the LUH-72 first entered service in 2015, the US Army said it was 'almost too easy to fly'. This question of complexity as a training platform has not been raised by nations that operate the H145 aircraft in this training role and that is because in most cases, pilots will have conducted initial training on the less-complex H135 or the Bell 206B prior to flying the H145. The other focus has been on the current training syllabi contained within the IERW including the integration of classroom training and the use of synthetic training equipment.

The current situation is serious and focussing minds in Washington. On 15 November 2024 the US Government posted a RFI; to "inform the Army's analysis and development of options to transform Army IERW Flight Training at Fort Novosel, Alabama, including the potential replacement of the current IERW helicopter (Lakota LUH-72) to reduce costs, gain efficiencies, and maintain or increase aviation training quality."

As the RFI highlights, the current IERW course operates, "with inefficiencies from years of change and multiple disparate contracts" due to numerous changes of industry providers. Known as the IERW Training Next Generation, an industry day was held in late October 2024 and responses were submitted in early December. Bearing in mind this RFI is only the beginning of the procurement process, it will be a number of years before any real changes are made.

USAF training

To put the USAF's helicopter pilot training requirement into perspective, of the 1,350 fixed- and rotary-wing pilots trained in 2023, around 90 graduated as helicopter pilots. This is much smaller than throughput for the US Navy and US Army but one common denominator is the USAF's inability to attract military pilots. All three services are now suffering a pilot shortage.

To address this pilot paucity, the USAF has altered the way that it approaches rotary-wing training over recent years.

▲ **Following training at Dothan, USAF helicopter pilots move to Fort Novosel to fly the TH-1H Huey II. [USAF/Airman 1st Class Juliana Todd]**

From the early-nineties the service re-introduced a fixed-wing initial training phase on the T-6 before moving to Fort Rucker (aka Fort Novosel) for rotary-wing training on the TH-1H Huey II. This training was conducted by 23rd Flying Training Squadron (23 FTS) in preparation for pilots joining the USAF's UH-1N Huey, HH-60G Pave Hawk, and CV-22 Osprey fleets.

Following-on from the USAF's Pilot Training Next (PTN) studies that were designed to streamline all pilot training to address its pilot shortfall by reducing the time that the undergraduate pilot spent in the training pipeline, specific changes have been made to the rotary-wing training process. The result was that the service introduced Helicopter Training Next (HTN) in 2020. The approach removed the fixed-wing T-6 Texan training phase, thereby freeing this valuable training resource to be used solely for the fast-jet and multi-engine pilot training pipelines. The first seven officers graduated from HTN in June 2021. The USAF estimates that by cutting the T-6 phase it will reduce the cost of rotary-wing training by 37%, improve efficiency and provide "better continuity for training".

CAE provides basic helicopter flight training to the USAF using a fleet of six Bell 505 helicopters from its training centre at Dothan, Alabama. [Bell Helicopter]

Expanding HTN, in 2023 the DoD awarded CAE an initial USD 44.5 million contract to provide the USAF with rotary-wing Introductory Flight Training (IFT-R). As part of this programme, worth a maximum of USD 110.6 million over the total contract term, CAE will use a fleet of six Bell 505 Jet Ranger X helicopters that have been configured specifically to USAF training requirements. Live flight training will be supported by three Bell 505 training devices: a Level 5 Flight Training Device (FTD) and two H1000 Advanced Aviation Training Devices (AATD) supplied by Spanish company, Entrol.

The Safran Arrius 2R-powered Bell 505 is increasingly being used as a training helicopter with 10 now in service with the Royal Jordanian Air Force at the King Hussein Air College in Mafraq. Three Bell 505s are in-service with the Royal Bahrain Air Force and other military training helicopter customers include the Montenegro Air Force, Republic of Korea Army and Republic of Korea Navy. The CAE team providing IFT-R includes Bell Textron, Alpha 1 and Navigator Development Group working together to support areas such as flying operations, synthetic training and classroom training.

Prior to flying the T-6, rotary-wing cadre students used to undertake fixed-wing training having flown the Diamond Aircraft DA-20 at Pueblo, Colorado as part of their IFT received during basic officer training. This has now also stopped. "As of 2020, the USAF rotary- and tilt-rotor student pilots no longer participate in fixed-wing training at Pueblo," Benjamin Faske, the Director of Public Affairs at 19th Air Force told ESD. "Students self-identify their desire for rotary/tilt-rotor training slot at their source of commissioning and are sent directly to Dothan for IFT-R. The program consists of 55 training days which lasts about two-and-a-half months. After graduation they have a short break before reporting to Undergraduate Helicopter Training (UHT) at Ft. Novosel."

USN approaches

Unlike the US Army and USAF, the US Navy currently retains the use of a fixed-wing phase of training for its helicopter pilots using the T-6B Texan although this approach is undergoing transition. Within the Advanced Helicopter Training System (AHTS), rotary-wing training was provided by the TH-57 Sea Ranger helicopter but in 2021 it was decided to start replacing this platform with the Leonardo TH-73A Thrasher.

This approach is now beginning to change as the US Navy trials its new rotary-wing training pipeline. If successful, this new approach could be in place by mid-2025 and replace AHTS. The US Navy's Chief of Naval Aviation Training (CNATRA) has said that the new system can reduce the overall rotary-wing training pipeline by 13 weeks.

The US Navy uses the Leonardo TH-73A Thrasher as its advanced training helicopter, which is primarily operated from Whiting Field in Florida. The Navy has 130 TH-73As on order with the final delivery set for later in 2025. [US Navy]

After initial selection, Student Naval Aviators (SNA) report to NAS Pensacola, Florida for medical screening and ground school. This is followed by approximately 10 hours of introductory flight in a light fixed-wing aircraft before SNAs move to a commercial training provider, The Helicopter Institute in Fort Worth, Texas. Flying the Bell 206, SNAs basically undertake a FAA Part 141 Private Pilots Helicopter certificate course where they log around 50 hours flight time.

Known as Contract Operated Pilot Training – Rotary (COPT-R), as of 7 January 2025, 80 student pilots had undergone this training in Texas. US Navy Reserve Cdr Spencer Allen said that; "Students complete their training...months earlier than their peers, with each student representing a cost savings of approximately [USD]30,000 for the Navy."

The US Navy's COPT-R programme sees students undertaking basic rotary-wing training in Fort Worth,Texas on the Bell 206/TH-57 prior to flying the TH-73A Thrasher. [Helicopter Institute]

The next phase sees them move on to Training Air Wing 5 at Whiting Field in Florida to carry out Advanced Helicopter Training (AHT) for 12 weeks on the TH-73A (a variant of the Leonardo AW119 Koala). AHT sees students complete 81 hours ground training and 50 flight hours The US Navy is to receive 130 TH-73As with the last delivery set for 2025. According to the US Navy, "the TH-73A improves pilot training and skills by using current cockpit technologies and modernized training curriculum that reflect the capabilities in the current Navy, Marine Corps and Coast Guard inventory."

In terms of simulation for the TH-73A, FlightSafety Defense provides Contractor Instructional Services (CIS) and maintenance for 18 Frasca Level 6 and Level 7 FTDs each featuring Aechelon visual systems. Eight of these devices are new builds and 10 are modified TH-57 devices. In addition to the FTDs, Frasca has also supplied seven Part Task Trainers (PTT) and 15 Desktop Avionics Trainers (DAT) under a contract from Booz Allen Hamilton. According to John Frasca, President of Frasca, "the combination of DAT, PTT, and high-fidelity FTDs enable students to reach higher levels of proficiency in fewer actual flight hours, [thereby] accelerating training."

It may surprise many that the US DoD does not rationalise its rotary-wing training to provide a common core syllabus covering primary-basic training. This idea is not new, and various US DoD, Congressional and General Accountability Office (GAO) studies have recommended this approach since the 1960s. In 1977 for example, in its 'Consolidation of Helicopter Pilot Training' report, the GAO opined that; "all services' helicopter pilot training should be consolidated into a single program conducted by the Army. A single training syllabus applicable to all services can be developed, and large annual savings can be achieved."

Putting things into perspective

There is no doubt that the US Navy, Army and Air Force have their own entrenched ideas when it comes to rotary-wing training. The main reason for this is that all three services believe that their employment of helicopters is unique and special cases demand special training. Although this is partly true, these differences could be addressed during advanced or conversion training phases after the provision of a tri-service initial or basic training phase, using a syllabus akin to the current USAF model that uses the Bell 505. If this solution were to be adopted, the savings would be significant.

Countries where helicopter pilot training is centralised, such as Canada and the UK, seem to be reaping cost savings, but in fairness, the scale of training demanded in these countries is clearly much smaller in comparison to the US.

One thing that is clear in the US is that all three helicopter training pipelines are undergoing major changes at the present time. The numbers of students going through those training pipelines are significant and their uninterrupted flow is not helped by the US procurement system that sees commercial companies made responsible for discrete elements such as the provision of training aircraft, training services, flight and ground instructors, aircraft maintenance and general logistics.

These contracts generally run for five years and are renewed every year, meaning that the training pipeline is disjointed and this precludes long-term planning; a process made worse if a losing company 'protests the award'.

With the Pentagon having failed its latest audit, the DoD is now firmly in the sights of the Department of Government Efficiency (DOGE) and its boss, Elon Musk. Change may be forced even in the face of individual service desires.

Security in the Middle East – SITREP

Robert Czulda

The Middle East enters 2025 burdened with multiple conflicts and tensions, all of which are contributing to significant geopolitical shifts. It is difficult to optimistically anticipate a peaceful year ahead.

Certain dates in international politics hold both symbolic and transformative significance. For instance, 1989 marked the end of the Cold War, bringing fundamental changes to the global system. The year 2001 signalled the start of the global war on terror, a pivotal moment for the world. Similarly, 7 October 2023, will be remembered as a landmark date; Hamas's shocking attack on Israel acted as a catalyst for changes that have reshaped the political, social, and economic landscape of the Middle East. Throughout 2024, the region commanded unparalleled global attention, overshadowing other events, including Russia's aggression against Ukraine.

Even with things quietening down in the wake of two important ceasefires between Israel and militant groups, the security situation will not see a great improvement, as the Middle East remains plagued by ongoing issues, including the unresolved question of Palestinian statehood (a vision currently more distant than in the past). The main factors presently contributing to the region's overall instability include: the collapse of the Assad regime in Syria and its internal and regional consequences, tensions between Israel and Iran, internal crises in Lebanon and Yemen, the economic and political weakness of all countries in the region, societal discontent, and the strength of radicalism. Stability is further hindered by the absence of a regional 'policeman' in the Middle East capable of resolving conflicts and disputes.

Ceasefires signed, but will the conflict stay frozen?

The Israel-Hamas ceasefire went into effect on 19 January 2025, and the first phase is set to last until 3 March 2025. The agreement marked a pause in Israel's prolonged and bloody campaign in Gaza and beyond, with repercussions far beyond its borders. Thus far, Gaza suffered over 47,300 deaths, according to Gaza's Hamas-run Ministry of Health, devastation of its infrastructure, and famine before the eyes of a world which seemed powerless to stop the fighting.

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The conflict also spilled into Lebanon, seeing large-scale bombardment of much of the south of the country by the Israeli Defence Forces (IDF), along with devastation of Hezbollah's leadership. The conflict culminated in a ceasefire which went into effect on 27 November 2024, and was originally set to expire on 27 January 2025. Yet on 26 January, on the day Israeli forces were supposed to have withdrawn from southern Lebanon under the agreement, they had not withdrawn. In response, Lebanese residents protested this and attempted to return home by breaching Israeli roadblocks, but this move was contested by the IDF, who opened fire, killing 24 and injuring 134. Consequently, according to a White House statement, a new deadline of 18 February for Israeli withdrawal has been agreed by Israel and Lebanon.

▲ US forces are present in Syria, with the official goal being to ensure the complete defeat of ISIS. According to an official announcement, however, when it comes to US forces in Kobane, there is currently no plan to establish a permanent base there. [US DoD]

Risk of escalation with Iran

The risk of a military confrontation between Israel and Iran looms large. While both actors have long been adversaries, tensions between the two became particularly intense over the past year. Previously confined to cyber warfare, propaganda, and proxy engagements, the rivalry escalated in 2024 with direct confrontations in April and October. This marked a new level of escalation, heightening tensions significantly.

Iran's armed response has been particularly notable. Historically operating below the threshold of open war, Tehran conducted direct strikes on Israel to restore its deterrence. However, this effort yielded mixed results. While Iran demonstrated its military capability and willingness to strike, its successes were limited, and it does not appear that Israel has been successfully deterred. As a result, Iran has been pushed into a defensive position, making it unlikely to regain its standing in 2025.

The fall of Syria

The lightning offensive by various opposition militant groups, including Jihadi fighters, against Assad's forces caught many by surprise. While the weakness and low morale of government forces were well-known, few anticipated that the regime would collapse so quickly, leading to President Bashar al-Assad fleeing the country within days and ending his 24 year rule (or his family's 54 year rule). Consequently, a previously stable – albeit authoritarian – state

The overthrow of the Assad regime gives Ankara hope for increasing its influence in Syria. Erdoğan is expected to intensify actions against Kurdish groups. [Turkish Armed Forces]

near Europe has vanished, leaving behind a chaotic vacuum. In 2025, Syria is expected to endure internal conflict and sustained violence rather than progress toward establishing a stable and effective government.

Alarmingly, power now rests largely with militant groups, particularly Hay'at Tahrir al-Sham (HTS), an Islamist and jihadist organisation. Its leader, Abu Mohammad al-Julani, formerly headed the Al-Nusra Front, a Salafi-jihadist group responsible for numerous atrocities in Syria. Despite al-Julani's recent attempts to present himself as a moderate, it is unlikely his ideological views have fundamentally changed. In late December 2024, he explicitly ruled out free elections in the foreseeable future, signalling plans to rebuild Syria under an authoritarian, militarised model reminiscent of Assad's regime.

Even if the new Syrian authorities prove to be relatively moderate and allow religious minorities, including Christians, to participate in governance, a fundamental problem will remain: how to lift Syria out of complete economic collapse? The dire economic situation was the primary cause of social discontent against Assad's regime at the turn of 2010 and 2011. The starting point would have to be the lifting of European and American sanctions imposed on Assad. An open question remains whether the Syrian authorities will have a strategy to persuade the West to lift these economic sanctions. Gaining international legitimacy will be one of the most significant challenges.

Geopolitical implications for Iran

The fall of Assad's regime is a significant blow to Iran, whose geopolitical position in the Middle East is now far weaker than in 2024. Iran's network of alliances, known as the 'Resistance Front', has been severely undermined, alongside its reputation as a leader of the anti-Western and anti-Israeli bloc. Key Iranian allies have suffered devastating losses, including the assassinations of Hassan Nasrallah (Hezbollah) and Ismail Haniyeh (Hamas), along with dozens of other military and political leaders. These setbacks represent a profound humiliation for Iran, leaving it struggling to recover.

Assad's Syria was often referred to as Iran's '35th province', serving as its only state-level strategic partner in the region. Syria's existence was a cornerstone of Iran's resistance front; without it, Iran faces significant challenges: moreover, its logistical networks are now severed, cutting off direct access to Hezbollah in Lebanon and thereby to Israel. This also threatens Iran's ability to support Hamas and Islamic Jihad, as alternative routes via the Red Sea, Sudan, and Egypt have been blocked in recent years.

Former leader of Hamas' political wing, Ismail Haniyeh, shown here with Ayatollah Khamenei, was a key collaborator for Iran. His death represents a significant weakening of Hamas, and therefore also of Tehran's influence, for whom the current geopolitical situation is challenging. [Office of Iran's Supreme Leader]

In December 2024, pro-Turkish militias and the Turkish Air Force clashed with the US-backed, Kurdish-led SDF coalition near the Kurdish-majority city of Kobane. [Turkish Armed Forces]

The loss of Syria dramatically reduces Iran's capacity to exert influence over Israel, while Israel retains its ability to strike Iran. This development also casts doubt on Iran's previously ambitious vision of reshaping regional security and order in the Middle East. Efforts to solidify its leadership of the global Shia community have faltered, pushing the entire Shia bloc into a defensive position.

The collapse of Assad's regime in Syria and Israel's unchallenged elimination of key pro-Iranian leaders have made Yemen's Ansar Allah (the Houthis) more critical to Tehran. Yemen, a failed state, continues to impact regional security architecture. Despite years of engagement by Arab forces and numerous US-led aerial strikes, the pro-Iranian Houthis remain a potent force, capable of effectively targeting commercial shipping in the region. In 2025, intensified Israeli aerial campaigns are anticipated, aimed at degrading Ansar Allah's long-range strike capabilities.

Winners and losers

As 2025 begins, Russia finds itself significantly weakened in the Middle East. The Kremlin had been directly involved in Syria since September 2015, launching an air campaign to bolster Syrian, Iranian, and Iranian-backed ground forces. This intervention successfully preserved Assad's regime and established relative stability, with a relatively modest military contingent (around 7,000 to 8,000 troops) at the time of Syria's collapse. However, the fall of Assad's government deals a severe blow to Russia's reputation and geopolitical standing in the region, diminishing its capacity to project power in both the Mediterranean and Africa.

In return for supporting Assad, Russia gained access to two critical military facilities. The Khmeimim Air Base served as a cornerstone for Russia's operations in Africa, including its growing influence in the Sahel. These efforts not only bolstered Moscow's position on the continent but also allowed it to exert strategic pressure on Europe, such as through the manipulation of migrant flows. Losing Khmeimim disrupts Russia's logistical network, complicating supply chains and the export of resources; particularly mining contracts essential for Russia's economy and the private military contractor (PMC) Wagner Group. The Tartus Naval Base supported Russia's Mediterranean task force, comprising a range of naval assets, including *Grigorovich* class frigates, Kilo class submarines, and supply ships. Its loss leaves Russia without a secure Mediterranean warm-water foothold, forcing reliance on more distant facilities in Crimea and reducing its regional and global power projection capabilities.

While Russia's influence wanes, Türkiye's power in the region grows. The overthrow of Assad and the rise of Islamist factions in Syria represent a major victory for President Erdoğan, who has successfully expanded Ankara's influence across the Middle East and into Africa. If Türkiye maintains its hold over Syrian rebels, it will gain substantial leverage in its dealings with Europe and the United States. This could lead to further crises within NATO and increased use of migration as a tool of political pressure against Europe. Additionally, Türkiye's policies toward Syria are expected to intensify its campaigns against Kurdish groups. These actions are likely to resonate negatively in countries like Germany, which hosts large Kurdish and Turkish populations, potentially heightening domestic tensions. An example would be the military campaign launched in early December 2024 by pro-Turkish militias and the Turkish Air Force against the US-backed Kurdish-led coalition known as the Syrian Democratic Forces (SDF) near the Kurdish-majority city of Kobane.

Despite its growing influence, Türkiye is unlikely to push for the formal disintegration of Syria. Such a scenario could reignite Kurdish independence movements, which Ankara views as a significant threat to its territorial integrity. In 2025, Türkiye plans to allocate a record USD 47 billion to military spending, signalling its intent to solidify its regional power. However, this military buildup will likely focus on maintaining control and countering Kurdish aspirations, rather than promoting the fragmentation of Syria.

What's next?

The year 2025 promises to be one of profound uncertainty for the Middle East, marked by volatile developments and shifting power dynamics. The future of post-Assad Syria, which includes the role of external players, and the trajectory of political struggles remains uncertain. However, it is highly likely that Syria will be plagued by bloody conflict and dominated by Islamist factions. This instability will have a ripple effect, threatening an already fragile Lebanon and even the previously stable and peaceful Jordan. The latter, a pro-Western, but economically struggling monarchy, faces increasing internal pressure from opposition groups dissatisfied with both the monarchy's policies and the nation's economic situation. In the long term, the potential spillover of violence into Jordan represents a significant regional risk.

▲ Under Trump, Israel is expected to receive increased military aid from the US, emboldening Prime Minister Netanyahu to escalate military operations. [IDF]

Another unknown major variable is the direction of US policy in the Middle East under President Donald Trump. One certainty is Trump's aversion to involving the United States in any new wars in the region. Nevertheless, stronger support for Israel is anticipated. Alongside political backing, Israel is expected to receive increased military aid from the United States, emboldening Prime Minister Netanyahu to escalate military operations. Having crossed a point of no return, Netanyahu may feel compelled to undertake bold – albeit fruitless – steps to ongoing challenges, particularly concerning Iran.

However, further escalation also poses risks for the US, such as undermining the Abraham Accords, one of the Trump administration's signature achievements in the Middle East. Increased Muslim radicalisation or an outright war between Israel and Iran would also have negative consequences for the White House. While a softening of US policy toward Iran seems unlikely, a return to 'maximum pressure' appears more probable. This approach eliminates any realistic prospects of reviving the Joint Comprehensive Plan of Action (JCPOA), designed to ensure that Iran's nuclear programme will be exclusively peaceful, which the first Trump Administration unilaterally withdrew from in 2018. It leaves Iran, battered economically and politically isolated, in an increasingly precarious position. Deepening its partnership with Russia seems the most probable response, as both nations face growing Western pressure.

Simultaneously, a thaw in US-Saudi relations appears likely, marking a departure from the strained ties during Biden's presidency, which once vowed to make Saudi Arabia a "pariah". A rapprochement under Trump could pave the way for normalised relations between Saudi Arabia and Israel, though unresolved issues surrounding Palestine remain a significant obstacle. Even if progress is made in 2025, neither side is likely to publicly celebrate such developments.

Nevertheless, optimism for an improved regional security environment is limited. The region's conflicts remain fundamentally unresolved, except for a tentative warming of relations between Iran and Saudi Arabia. Despite the pause in fighting, the Gaza crisis remains a pivotal issue which will continues to impact the Middle East profoundly. The Israeli leadership's reluctance to pursue peace, coupled with the possibility for future military strikes against targets in Gaza, Lebanon, Syria, Iraq, and even Yemen, is likely to stymie diplomatic efforts. Moreover, extreme factions within Israel, advocating for the forced expulsion of Palestinians and the expansion of Jewish settlements in the West Bank, further exacerbate tensions.

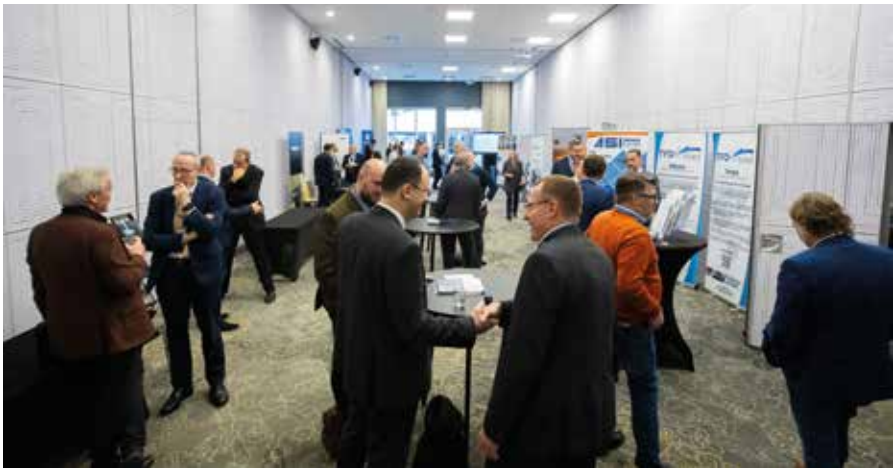
The Gaza crisis has far-reaching consequences, catalysing radicalisation across the Middle East. Many in the region perceive Israel's actions in Gaza as acts of genocide and ethnic cleansing. The longer these actions persist, the more they inspire young individuals frustrated by economic conditions, to join extremist groups. This dynamic also widens the gulf between dissatisfied Arab populations and their often-authoritarian governments, straining social cohesion.

Despite growing frustrations, Arab states remain unwilling to confront Israel directly. During a joint summit of the Organization of Islamic Cooperation (OIC) and the Arab League in Riyadh in November 2024, calls were made for international support to expel Israel from the United Nations and establish an independent Palestinian state with East Jerusalem as its capital. Yet, these proposals are unlikely to translate into decisive action against Israel. However, with the relative unpredictability brought by a Trump presidency and, intra-party tensions within the Israeli government, and the dissatisfaction of many Israeli citizens with the government, Netanyahu's position is not unassailable, and the year ahead may yet yield some unexpected results.

The 20th Life Cycle Management in NATO Conference and Exhibition

Manuela Tudosia

Mittler Report Verlag, in cooperation with the NATO Life Cycle Management Group (LCMG), hosted the 20th edition of the LCM in NATO conference and exhibition on 21 and 22 January 2025 in Brussels. Bringing together government and industry representatives, and marking 20 years of NATO LCM, the conference offered a unique setting to exchange about the latest developments and challenges in this field.



The 20th LCM in NATO Conference and Exhibition was attended by a diverse pool of government and industry LCM experts [MRV]

A rapid technological pace enabled by digital transformation and the challenge of a changing environment is driving adaptation and transformation both in NATO and in industry. It is perhaps the most significant transformation in 20 years by its scale and depth, coming with its own opportunities and difficulties. The rich conference programme provided numerous occasions to take stock of where we are, but also to reflect upon challenges and their possible solutions. Honoured with the presence of Rear Admiral N.J. Wheeler (Director NDS) as guest speaker at the conference dinner, today's needs and rationale for a data-driven organisation were placed in the wider context of Multi-Domain Operations and Digital Transformation.

Interoperability and standardisation remain the cement that make it possible for both Nations and NATO industries to jointly operate complex systems-of-systems, while constantly adapting to times and rapid technological change. Participants found out from the Chair of the AC/327 LCMG how this pivotal NATO committee continues to provide the means to optimise the defence and security capabilities of NATO, Member Nations and Interoperability Platform Nations in terms of performance, interoperability, sustainability and cost. Cooperation with industry as well as with other standards-developing organisations enhances coherence and provides the opportunity to embrace technological change at scale.

Whereas the changing operational environment prompts ever-faster adoption of new technologies, it is critical not to lose sight of the operational, capability and regulatory requirements. The ACT representative explained the high relevance and the challenges of through-life requirements traceability, a process that NATO has been developing for common funded capability development. End-to-end traceability between and across capabilities can also support, among others, digital transformation, which is seen as inevitable for NATO.

Compared to the past, today's particularly dynamic context can also trigger evolution in requirements, but traceability needs to be maintained as to why they are evolving. It is important to understand how and when requirements need to be changed, and also when the requirement is enduring, but the solution should evolve new means of delivering results.

The case of fast digital transformation, and its potential impact on requirements management, was illustrated during the conference by an example from a NIAG Study focused on the 'digital thread and the importance of configuration management (CM) to data quality and traceability'. Still ongoing, one of the study objectives is to look into how CM policies, standards and processes may provide assurance of digital thread for NATO with respect to through-life management.

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In a keynote speech, the representative of the NATO Support and Procurement Agency (NSPA) explained how this lead organisation for multinational acquisition, sustainment and support addresses the challenge of the changing environment. Through innovative sustainment enabled by the exploitation of emerging and sustainable technologies, the Agency can innovate and transform its procurement, sustainment and operational support activities. The project 'Repository for Additively-manufactured Products In a Digital environment' (RAPID-e) was an illustrative example of this. Its long-term objective is to provide a NATO-wide marketplace for additive manufacturing.

The conference also featured a diverse mix of industry and government representatives who informed about the latest innovative trends to support optimisation of key LCM processes, but also shared many lessons learnt from the implementation of complex programmes and contracts. Many key themes emerged from the presentations and the highly interactive sessions that followed them.

Experience and lessons learned from ongoing projects

Insta ILS shared their experience as a strategic partner of the Finnish Defence Forces to support security of supply and LCM, providing examples from the sustainment of the F/A-18 Hornet fleet acquired by Finland in 1992 and explaining the benefits of involving the local industry in this process since the beginning.

Featuring decades of experience in vehicle life cycle services, Patria ISP shared experiences about the organisation of multinational life cycle management within the Common Armoured Vehicle System (CAVS) programme started in 2019 as a multinational cooperation initiative between Finland, Latvia, and Sweden, with Germany formally joining the programme in early 2025. The Patria 6x6 was selected as the common vehicle platform for this programme.

A conference presenter shares his experiences on the management of complex programmes. [MRV]

The aforementioned experiences were complemented with meaningful examples and lessons learned from multinational and government-industry collaboration in the context of high-intensity war, provided by ILIAS Solutions.

The presentations fostered important discussions on data availability, data sharing and data trustworthiness in the context of such multinational endeavours, where LCM of complex systems-of-systems is involved and where interoperability is of the essence for mission success. Not only does rapid change require nations to agree smoothly and without delays on the rules of joint programmes or initiatives, but contracting also needs adaptations to keep up with the necessity of providing services much more rapidly during wartime.

Enabling adaptation and transformation

Recognising many of the aforementioned challenges, several presentations addressed solutions to address them through available technology and through adaptation of contracting.

Deloitte showed how digital enablement can empower military organisations to navigate the complexities of modern deployments with greater agility, efficiency, and resilience. In particular, Digital Engineering facilitates the shift from paper-based records and document-centric approaches to digitally-hosted and model-based authoritative sources of truth for system data, technical specifications and configuration management. It provides a means to enabling the data flow through the asset's life cycle, allowing optimisation of asset development for the operational sustainment of the asset through-life. However, commercial barriers, access to data, and capturing of data legacy remain challenges that can only be addressed by the people and the organisations involved.

Two conference presenters addressing the opportunities presented by Digital Engineering. [MRV]

Eurostep AB addressed how to enable product definition life cycle continuity in collaborative environments. Whereas timely access to product data is more important than ever to make informed decisions about system performance and management, experience shows that this is still scarce when diving into many of the business applications downstream the product life cycle. This is despite the existence of numerous standards, considered to be the 'historical solution' for the acquisition and collection of product data. From the presenters' perspective, among the key root causes of such data 'shortages' in the defence context is the lack of contracting and product data supply chain processes and tools. The solution proposed is 'SMART' contracting for information: Semantics of what is being asked must be clearly defined; enforceable data quality KPIs must be set to make it Measurable; precise specification of information asked must be provided to make it Accurate; only what is necessary must be asked to be Reasoned; and, it must be stated when data is needed to make it Timely.

Progress in life-cycle cost estimation and optimisation

NCIA representatives shared insights from a comparative study analysing different models for cost analysis using available data from various types of US fixed-wing aircraft.

Systecon highlighted the importance of integrated modelling and analysis (M&A) capabilities as a key source of decision support throughout the life cycle. While presenting the Opus Suite and using scenario-based examples, they showed how M&A can be used to evaluate, influence and optimise aspects in mission, system, and product support engineering.

Sirius Analysis presented the pros and cons of various cost-estimating methodologies, stressing the advantages of adopting an end-to-end approach to cost estimating, which is an integrated process that covers all life cycle stages and that includes data integration, real-time updates, and comprehensive analysis. Cost estimation is a continuous process throughout the entire life cycle, that must be performed both during the procurement and the in-service phases of a system. The benefits of employing digital twins, machine learning (ML) and artificial intelligence (AI) were also thoroughly explained.

▲ The exhibition featured several decision support tool solutions to optimise product support and life cycle cost analysis. [MRV]

The topics revolving around cost estimation also opened the opportunity for meaningful discussions on the applicability of data in the context of traditional support regimes versus the context of new/emerging systems (for instance, drones) that may require different support arrangements. They also revealed that the process of integrating and using new standards is progressive and can be long, whereas discontinued standards can stay around for some time after termination.

Sustainability and the environment as emerging LCM considerations

Prompted by the impact of climate change, and encouraged by increasing availability of solutions to reduce carbon footprints, sustainability considerations are an emerging trend in life cycle management decisions. It may become an irreversible trend that will also impact the adaptation of contractual requirements. The 20th NATO LCM conference was an opportunity to find out how industry is responding to these trends by studying and developing tools and processes to support environmentally-responsible decisions while reducing costs, and without affecting system safety and reliability.

Gabe Batstone (Contextere) provided informative insights into the environmental cost of AI but also about the costs of not adopting AI. Based on findings from ongoing case studies, the presentation showed how the use of AI can also be optimised through the adoption of Small Language Models in certain contexts. A 'blended sustainable AI pipeline' approach was proposed that combined permanent online presence with intermittent and offline access to information solutions, depending on requirements.

▲ A speaker addresses sustainability aspects. [MRV]

TFD Europe shared equally-relevant insights from the application of life cycle and supportability modelling, as well as analysis on all options available for alternative propulsion methods in the context of designing a lightweight training aircraft that could potentially replace the current system which utilises an AVGAS-fuelled, internal-combustion powertrain. The presentation was a compelling illustration of how supply chains for various options can be modelled from concept to in-service, and of the variety of factors that must be considered to arrive at sound comparisons to support informed decisions.

Delivering operational availability in a fast-paced environment

NATO and NIIG representatives concluded the two-day conference by reminding the challenges of the changing environment and acknowledging the valuable updates and case-study illustrations offered by NATO representatives and participating industries alike. While working on the implementation of digital transformation, it is important not to forget about the real world and the many lessons learnt from real-life cases.

Delivering operational availability remains an overarching and pivotal goal of NATO life cycle management, and each presentation contributed a piece to this complex endeavour. What is key is to integrate this goal from the very start of requirements definition, including from a contractual point of view. Operational availability is also facilitated by the standards and guidance produced by the AC/327 LCMG, which industry was encouraged to use.

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