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Russia-Ukraine: Is a diplomatic solution on the horizon?

Following the 15 August 2025 Alaska meeting between Presidents Vladimir Putin and Donald Trump, and the 18 August meeting in Washington between Presidents Trump and Zelenskyy, along with several European leaders, the prospect of a diplomatically negotiated end to the Russo-Ukrainian War is back on the agenda. Over the course of three and a half years of fighting, the two sides have been down this road several times before, and got nowhere. Is this time any different? Maybe.

While little of substantive detail was initially revealed during the Trump-Putin Alaska meeting, perhaps the most notable takeaway came a couple of days afterward, on 17 August, when US Envoy Steve Witkoff stated that Putin was prepared to concede on security guarantees for Ukraine. According to Witkoff, "We were able to win the following concession: That the United States could offer Article 5-like protection". Assuming Witkoff's understanding of the Russian position is accurate, this would indeed represent a major breakthrough. Yet there appear to be two key conditions associated with this, according to a Trump post on Truth Social.

The first is understood to be that Ukraine formally cede Crimea. While likely to prove a painful symbolic issue for Ukraine, the country was highly unlikely to regain the peninsula Russia annexed in 2014, and it is fair to say that this condition largely makes de jure a reality which already existed de facto. Consequently, this is unlikely to represent a hill to die on for Ukraine's negotiators.

The second condition is understood to be that Ukraine formally promise to give up its NATO accession aspirations. Based on Witkoff's comment, the thinking may be that in place of NATO membership, Ukraine instead agrees to an "Article 5-like" bilateral security arrangement with the US. This one may be quite difficult for Ukraine to accept, as it would effectively leave their security at the mercy of the US' leadership. Compared to the real Article 5, an "Article 5-like" bilateral guarantee would be far more prone to abuse of power and rent-seeking behaviour – both of which are a credible risk given the US President's transactional tendencies. Lest it be forgotten, Trump's administration effectively coerced Ukraine into agreeing to a minerals deal, by making further support conditional upon Ukraine signing. Under the terms of the deal signed on 30 April 2025, the US is to receive 50% of revenues from new licenses undertaken by extractive industries in Ukraine. While potential land swaps have also been floated by Witkoff, little hard detail is available at the moment. Without knowing exactly what Russia will concede, the conditions put forward by Trump look to favour Russia's position, insofar as they largely fulfil Russia's strategic goal of keeping Ukraine out of NATO, and legitimise at least some of its prior annexations. Should these conditions prove untenable for Ukraine, is there a third way? A brief glance at the alternatives suggests most may be worse, not least because many roads lead back to Trump, in one way or another.

While Ukraine has proven its ability to slow the Russian advance to a crawl, doing so depends entirely on the continued supply of military aid and intelligence support. Right now the US appears to be the only actor capable of meeting the requirements. Trump seems set on adding a peace deal between Russia and Ukraine to his presidential legacy, and has not been shy about pressuring Ukraine very publicly. As such, the idea that Ukraine could wait him out until January 2029, hoping for a friendlier president to enter the White House, seems far-fetched at best. If Ukraine is not seen to play ball by Trump's rules, he will likely suspend aid again, or take other measures to pressure Ukraine back to the negotiating table. Going more than three years without US support is not an option for Ukraine.

Could Europe stand up to Trump on this issue, and pressure him to commit to unconditional support? Probably not, given that most European leaders have thus far proven quite reluctant to challenge Trump directly, with some even going out of their way to kowtow to him. Hoping that Europe will grow a spine therefore feels like waiting for Godot. Could Europe at least replace US military aid? Europe has certainly improved its military production capacity since 2022, but all evidence suggests it still falls far short of being able to fully shoulder the US' burden – financial or industrial. Moreover, many key systems operated by Ukraine, such as PATRIOT, would necessarily remain reliant on the US. On top of this, Europe would likely find it difficult to substitute the US' intelligence sharing, especially in the space domain, where Europe possesses a fraction of the US' remote sensing capability.

In sum, short of the collapse of the Russian economy and their forces' unilateral withdrawal, a Trump-negotiated peace process, difficult to stomach as it may be, may represent Ukraine's only realistic route to securing peace with its sovereignty intact. In the current political environment, it is difficult to see what other viable choice exists.

Mark Cazalet

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Australian DoD selects Japanese Mogami class as its future general-purpose frigate

(pf) The Australian Department of Defence (DoD) announced on 5 August 2025 that it has selected an upgraded version of the Japanese Mogami-class frigate as the preferred platform for the Royal Australian Navy's (RAN's) future fleet of 11 general-purpose frigates to be procured under Project Sea 3000.

It is the first time the Australian DoD has selected a major Japanese weapon system and the first time Japan has exported such a platform.

The deal for the 11 frigates is understood to be worth AUD 10 billion (EUR 5.59 billion). The Australian DoD will now conduct detailed negotiations with the Japanese government and Mitsubishi Heavy Industries (MHI), which builds the Mogami class, with a view to agreeing a firm contract in early 2026.

"Following a rigorous and competitive tender process, Mitsubishi Heavy Industries' Mogami-class frigate was assessed as best able to quickly meet the capability requirements and strategic needs of the Australian Defence Force (ADF)," the Australian DoD stated.

The Mogami-class design had been competing against a bid by Germany's Thyssenkrupp Marine Systems, which had offered its Meko A-200 frigate design.

[Australian DoD]

Beyond the Mogami class' overall capabilities, key factors in the design being selected were a lower cost over the life of the programme and the ability of MHI to ensure the ships are rapidly delivered, with Australian Minister for Defence Industry Pat Conroy stating, "This decision comes months ahead of schedule, reinforcing our commitment to deliver of capability at speed and at a lower overall cost to taxpayers. It makes good on our commitment to deliver four times as many warships in the next 10 years compared to the plan inherited by the former Coalition government."

The Australian government under Prime Minister Anthony Albanese wants the first general-purpose frigate to be delivered to Australia in 2029 and to enter service in 2030, with the third entering service in 2034. In order to make this happen the first three ships will be built in Japan, with production then transferring to Austal in Western Australia.

Along with the six Hunter-class heavy frigates being built for the RAN by BAE Systems Australia, the 11 upgraded Mogami-class general-purpose frigates will replace the RAN's Anzac-class frigates, the first of which entered service in May 1996. Seven of the original eight Anzac-class ships currently remain in service.

The RAN will this be replacing an original fleet of eight Anzac-class frigates with 17 new frigates overall.

"Today, we are taking another step towards delivering a much larger and more lethal navy, with stealth frigates that will reassure our allies and deter our adversaries," Conroy stated. "The upgraded Mogami class frigate is the best option for our navy, boosting its capability to put to sea. It will take our general-purpose frigates from being able to fire 32 air defence missiles to 128 missiles, giving our sailors the cutting edge weapons and combat systems they need to prevail in an increasingly complex environment."

Australian Deputy Prime Minister Richard Marles stated, "The upgraded Mogami-class frigate will help secure our maritime trade routes and our northern approaches as part of a larger and more lethal naval surface combatant fleet."

The upgraded Mogami-class frigate offers a range of up to 10,000 nautical miles (18,520 km). Its weapon suite includes a 32-cell vertical launch system that can launch both surface-to-air missiles and anti-ship missiles.

Ever since the Second World War Japan had followed a self-imposed ban on the export of major military hardware and had only exported smaller platforms such as patrol boats, but this policy was relaxed on 1 April 2014 by the Japanese prime minister at the time, Shinzo Abe.

Japanese law has allowed co-operative development, facilitating, for example, the country's involvement in the US-led F-35 Joint Strike Fighter programme and more recently the UK-Italian-Japanese Global Combat Air Programme (GCAP).

Australia's selection of the upgraded Mogami class frigate, however, indicates not only the growing strategic co-operation between Australia and Japan, but potentially the Japanese defence industry's emergence onto the world stage as a significant player in the global defence market.

PURL funding for Ukraine starts to flow from European NATO countries

(pf) Denmark, Norway and Sweden confirmed on 5 August 2025 that they would fund a USD 500 million (EUR 430 million) package of equipment and munitions for Ukraine sourced from the United States under NATO's newly launched Prioritised Ukraine Requirements List (PURL) initiative.

The announcement swiftly followed the unveiling of the first package of artillery and ammunition worth more than USD 500 million on 4 August 2025 funded by the Netherlands. Together the contributions are valued at over USD 1 billion and represent the first two tranches of regular deliveries to Ukraine under the alliance's PURL initiative.

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The PURL mechanism allows European NATO countries and Canada to regularly fund the delivery of US-sourced weapons and technology through voluntary contributions. It was established following an agreement made by NATO Secretary General Mark Rutte and US President Donald Trump at the White House on 14 July 2025. Within the PURL framework a prioritised list of weapons and ammunition will be created based on Ukraine's requests, approved by NATO's Supreme Allied Commander Europe (SACEUR).

[NATO]

The NATO secretary general stated on 4 August, "I commend The Netherlands for taking the lead and turning this initiative into concrete support on the ground, building on the steps taken last week by Germany to deliver more PATRIOT systems to Ukraine."

The following day he stated, "Since the earliest days of Russia's full-scale invasion, Denmark, Norway and Sweden have been steadfast in their support for Ukraine. I commend these Allies for their quick efforts to get this initiative off the ground. This latest round of funding will deliver life-saving equipment and critical supplies to the front line, strengthening Ukraine's hand and helping them deter aggression as they pursue lasting peace."

UK and Türkiye sign MoU on export of Typhoons, bringing deal closer

(pf) The governments of the United Kingdom and Türkiye signed a memorandum of understanding (MoU) at the IDEF 2025 defence exhibition in Istanbul on 23 July that brings a sale of Eurofighter Typhoons to Turkey a significant step closer.

[BAE Systems]

The MoU was signed at IDEF 2025 by UK Defence Secretary John Healey and Turkish Defence Minister Yaşar Güler. Negotiations on the potential deal, which would be the first export order the UK has secured for the Eurofighter consortium since 2017, will now continue over the coming weeks.

Final production of Typhoons bound for Türkiye under a future deal would see final production take place at BAE Systems' site in Warton, Lancashire.

While Turkey has expressed an interest in acquiring 40 Typhoons for some time, the previous government in Germany, as one of the Eurofighter nations along with the UK, Spain and Italy, had resisted such a sale. However, the current German government, which came to power in February 2025, gave a green light for the exporting of Typhoons to Türkiye on 23 July following a positive decision by its Federal Security Council.

Speaking after the signing of the MoU in Istanbul, Healey stated, "Today's agreement is a big step towards Türkiye buying UK Typhoon fighter jets. It shows this government's determination to secure new defence deals, building on our relationships abroad to deliver for British working people. Equipping Türkiye with Typhoons would strengthen NATO's collective defence and boost both our countries' industrial bases by securing thousands of skilled jobs across the UK for years to come."

The UK Ministry of Defence (MoD) has taken on more responsibility for defence exports since 31 July 2025 under an initiative outlined in the UK Strategic Defence Review, published on 2 June 2025, to drive potential UK defence exports and enhance the country's economic growth. The SDR initiative moved responsibility for defence exports from the Department for Business and Trade, making the UK MoD the lead for securing deals for military equipment with UK allies.

Germany to supply Ukraine with two additional PATRIOT launchers

(pf) The German Federal Ministry of Defence announced on 1 August 2025 that in the following days it will deliver two additional PATRIOT air defence system launchers to Ukraine, with complete system elements to follow in the next two to three months.

In return, an agreement has been reached with the US Department of Defense (DoD) that Germany will be the first nation to receive newly produced, latest-generation PATRIOT systems at an accelerated pace, with the financing for these provided by Germany.

The move is a result of the US President Donald Trump announcing on 14 July 2025 that the United States would approve the transfer of both defensive and offensive weapons to Ukraine as long as NATO nations paid for them.

"Germany has always been willing to provide PATRIOT system components in support of Ukraine," stated German Defence Minister Boris Pistorius. "The prerequisite was that the US manufacturer would deliver new PATRIOT systems to us as quickly as possible so we can continue to meet our NATO obligations. That commitment from the US side has been secured."

[Bundeswehr]

"Highly efficient air defence systems like the PATRIOT system are in short supply, and the production of some components takes years. Germany has already delivered three systems to Ukraine, which play an important role in Ukraine's air defence," the German Federal Ministry of Defence stated.

"With the solution now agreed upon, Germany is taking the lead to quickly meet Ukraine's currently very urgent needs. We are once again taking the lead and are combining this delivery with an appeal to our partners to promptly provide additional systems," the ministry added.

In recent weeks Russia has intensified its aerial attacks on Ukrainian cities with both missiles and bomb-laden unmanned aerial vehicles (UAVs). On 31 July, for example, an aerial attack on Kyiv killed at least 31 people and injured around 159. That attack involved more than 300 UAVs and eight cruise missiles, according to Ukraine's air force.

Hyundai Rotem agrees sale of second tranche of K2 MBTs to Poland

(pf) South Korea's Hyundai Rotem has secured a major deal to supply a second tranche of 180 K2 Black Panther main battle tanks (MBTs) to Poland, South Korea's Defense Acquisition Program Administration (DAPA) announced on 2 July 2025.

[US Army]

Polish Defense Minister Władysław Kosiniak-Kamysz confirmed the news via his X social media account, stating on 2 July, "We have completed negotiations for the delivery of 180 tanks, 80 support vehicles, and we will sign contracts for a comprehensive package that has never been implemented before as part of K2 tank agreements.

"This is an extremely complex process due, among other things, to technology transfer and the localisation of production," Kosiniak-Kamysz added. "As a result, 60 tanks will be manufactured in Poland, and the main partner in carrying out this task will be the Polish company Bumar Łabędy."

The specific size of the contract will be disclosed at a later date, DAPA said in a statement, but Yonhap News Agency has reported that the deal to supply 180 K2 MBTs is likely to be worth about USD 6.5 billion (EUR 5.53 billion).

Poland initially signed a major USD 22 billion framework arms agreement with South Korea in August 2022, under which were purchased 180 K2 MBTs, 212 K9 self-propelled howitzers, 48 FA-50 fighters and 218 Chunmoo multiple rocket launchers (MRLs) (with another 72 MRLs bought in April 2024).

According to reporting by *The Korea Times*, negotiations for a follow-up deal had been underway but were delayed by political turmoil in South Korea following former president Yoon Suk Yeol's short-lived martial law declaration in December 2024, as well as disagreements between the two sides over contract terms.

Ukrainian intelligence specialists obtain secret details of Russia's latest SSBN

(pf) The Ukrainian Ministry of Defence's Main Directorate of Intelligence (GUR) asserted on 3 August 2025 that its intelligence specialists have obtained top secret documentation related to Russia's latest nuclear-powered ballistic missile submarine (SSBN).

The Project 955A Borey-A-class SSBN *Knyaz Pozharsky* (K-555) was commissioned into the Russian Navy's Northern Fleet as part of the 31st Submarine Division on 24 July 2025, in a ceremony at the Sevmash shipyard in Severodvinsk overseen by Russian President Vladimir Putin.

[GUR]

Publishing detailed documents to back up its claim, the GUR said it had obtained numerous details relating to the operation of *Knyaz Pozharsky* (and by extension its seven Project 955/955A sister boats), including:

- name lists of the submarine crew, including data on positions, qualifications and level of physical training;
- combat instructions for the crew;
- the combat scheme of the ship, as well as schemes of systems to ensure the survivability and organisational structure of the crew;
- crew regulations in cabins and cockpits, instructions for transferring wounded and cargo, procedures for towing and other job instructions;
- engineering documentation, in particular a report on the investigation of a deformed radio beacon indicating the members of the commission and enterprises that participated in the investigation;
- an extract from the submarine's schedule book: a "voluminous document [that] regulates the daily combat and everyday work of the vessel".

"The Project 955A Borei-A submarines are a key element of the Kremlin's so-called nuclear triad," the GUR noted. "The submarines have 16 launch pods for R-30 Bulava-30 intercontinental ballistic missiles, each of which can carry up to 10 warheads."

The GUR added that the information obtained by its intelligence officers "allows us to identify the features and technical limitations of not only the *Prince Pozharsky*, but also other Project 955A submarines, which are critically important for supporting the imperial myth of the aggressor state of Russia."

Russia's Borei-class SSBNs, which are 170 m long and displace 23,621 tonnes submerged, are the first Russian nuclear submarines to use a pump-jet propulsion system, leading a report by the Russian state news service TASS to claim that their noise level is five times lower compared to Russia's third-generation Akula-class nuclear-powered attack submarines, which first entered service in 1986.

CCG cutter inadvertently rams Chinese destroyer in South China Sea incident

(pf) Two Chinese naval vessels, a China Coast Guard (CCG) cutter and a People's Liberation Army Navy (PLAN) Type 052D-class guided missile destroyer, collided on 11 August 2025 in a bizarre incident involving a Philippine Coast Guard vessel in the South China Sea near Scarborough Shoal.

Footage of the incident filmed from Philippine Coast Guard (PCG) patrol vessel BRP *Suluan* (MRRV-4406) shows the vessel being pursued by CCG cutter 3104 as it attempts to water cannon the Philippine vessel. The PLAN Type 052D-class destroyer *Guilin* (164) then cuts across the stern of BRP *Suluan*, leading the CCG cutter to ram head on into the PLAN destroyer.

While the Chinese destroyer appeared to suffer moderate gouging on its port side, several metres of the CCG cutter's bow section were entirely stoved in.


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BRP *Suluan*, along with sister vessel BRP *Teresa Magbanua* (MRRV-9701), had at the time been escorting Philippine fishing vessels in support of the Kadiwa Operation: a Philippine government-led initiative designed to support and empower fishing communities in the country's western exclusive economic zone (EEZ).

[Philippine Coast Guard]

In response to the incident the Philippine Department of National Defense described the Chinese actions as "atrocious and inane behaviour" and pledged its support for the Philippine Coast Guard personnel operating in the South China Sea.

This was not the only incident of Chinese vessels harassing Philippine shipping as Beijing pushes to expand a claimed exclusion zone in the region. While Scarborough Shoal is a maritime feature located within Manila's EEZ, China also claims the feature under its ten-dash line assertion, which claims most of the South China Sea: a claim that has been rejected by a United Nations Law of the Sea tribunal.

However, China up to now has typically pressed its claims using CCG vessels, so this latest incident involving a PLAN destroyer could potentially signal an escalation.

Denmark to be become fourth European operator of the MQ-9B SkyGuardian

(pf) Denmark is buying four MQ-9B SkyGuardian unmanned aerial vehicles (UAVs), manufacturuer General Atomics Aeronautical Systems Inc (GA-ASI) announced on 23 July 2025.

The purchase, which includes three Certified Ground Control Stations, was aided and supported by the NATO Support and Procurement Agency (NSPA), which has added the MQ-9B to its portfolio of defence systems to contract on behalf of European nations with the goal of enhancing interoperability while facilitating training and joint operations.

Denmark thus joins a growing list of European countries that have selected the MQ-9B. The platform provides pole-to-pole satellite control as well as de-icing capabilities that enable missions in the harsh conditions of the Arctic in support of Denmark and its NATO allies. Additionally, the MQ-9B's in-house-developed detect-and-avoid System allows the MQ-9B to fly in unsegregated airspace for domestic civilian operations, making it highly versatile for operations from Denmark.

[GA-ASI]

On 29 April 2025 the MQ-9B (in the form of the Royal Air Force Protector RG Mk1 UAV) became the first large UAV to obtain a Military Type Certificate (MTC) from the UK's Military Aviation Authority, certifying its safe operation without geographic restrictions, including over populous areas.

"It's been a very productive year for our MQ-9B platforms," GA-ASI President David R Alexander was quoted as saying in a company press release. "First, we earned MTC and now we've added Denmark to the UK, Belgium and Poland as MQ-9B customers in Europe. I believe the extensive waters of the North Sea, Norwegian Sea and Baltic Sea of the Nordic countries make the MQ-9B a very effective tool for national maritime surveillance and security."

GMARS launcher conducts first live firing, proving its capability to launch GMLRS rounds

(pf) Lockheed Martin and Rheinmetall, as partners in the Global Mobile Artillery Rocket System (GMARS) programme, have successfully conducted the first live firing of the GMARS launcher, demonstrating its capability to launch Guided Multiple Launch Rocket System (GMLRS) rockets, Lockheed Martin announced on 4 August 2025.

GMLRS rounds are launched by the M270 MLRSs and M142 High Mobility Artillery Rocket Systems (HIMARS) of the US and various allied forces worldwide, reinforcing interoperability and supporting joint operations.

[US Army]

The live-fire demonstration, held recently at White Sands Missile Range in New Mexico, marked a significant milestone in the GMARS development programme, which aims to provide military customers with a highly mobile, survivable and versatile long-range precision fires capability tailored to and interoperable with existing allied platforms. The launcher can be armed with an enhanced loadout of two Army Tactical Missile System (ATACMS) rounds, four Precision Strike Missiles (PrSMs), 12 standard-range GMLRS rounds or 12 Extended-Range (ER) GMLRS rounds.

The GMARS launcher, based on the Rheinmetall HX vehicle series, offers a high degree of interoperability and interchangeability with fielded M270A2 and HIMARS launchers, making it an ideal solution for military forces operating in Europe, Lockheed Martin noted. The system's ability to launch current and future long-range and extended-long-range rocket fire missions provides a significant advantage on the modern battlefield, the company added.

The GMARS programme is a result of a partnership between Rheinmetall and Lockheed Martin that began in 2023, with the two companies combining their individual strengths to provide a launcher built for NATO allies that maximises combat-proven HIMARS and M270 components. GMARS provides the same munition capacity as the tracked M270 system on a wheeled platform, with opportunity to integrate allied nations' platforms and munitions.

Denmark finalises integration into CAVS programme and orders 129 vehicles

(pf) Denmark has now completed its integration into the Common Armoured Vehicle System (CAVS) programme by signing the three remaining agreements and ordering 129 Patria 6×6-based CAVS armoured vehicles, Patria announced on 14 July.

It was announced that Denmark had joined the CAVS programme – joining Finland, Latvia, Sweden and Germany – on 1 April 2025 by signing its Technical Arrangement, but

[Patria]

Denmark has now also signed the programme's R&D Agreement, the Frame Agreement and Life Cycle Management Agreement.

The first Danish CAVS vehicles will be delivered in 2025.

Within the CAVS programme the 6×6 armoured vehicle system development is led by Patria. The supply of vehicles to the CAVS partner nations is conducted by utilising the nations' local industrial capabilities, with every new nation inherently reinforcing the security of supply for the whole collaboration system.

Patria has already received orders for nearly 1,000 Patria 6×6 vehicles and has delivered more than 200 under the CAVS programme, which is open to countries with similar AFV requirements by mutual consent of the participating countries.

Royal Navy accepts into service new autonomous minesweeping system

(pf) The UK Royal Navy (RN) has accepted into service three sets of autonomous minesweeping systems, known as SWEEP, that allow it to safely clear sea lanes and defeat modern mine threats using unmanned platforms, the navy announced on 4 July 2025.

[Crown Copyright]

The SWEEP system – effectively the RN's first uncrewed minesweeper – was designed by Dorset-based TKMS Atlas UK (formerly Atlas Elektronik UK) under a GBP 25 million contract announced on 19 January 2021.

Each SWEEP system comprises an autonomous surface vessel that tows a sensor unit behind it. The unit uses magnetic, acoustic and electric technology to identify and neutralise different types of sea mines. The system is controlled by a portable command centre that can be based at sea or on land.

SWEEP's 'sense and avoid' capability works together with other similar autonomous systems, such as the Maritime Mine Counter Measures (MMCM) system and SeaCat uncrewed underwater vehicles, to sustain freedom of manoeuvre for RN and allied vessels.

The RN received its first serial-production MMCM system – an advanced suite of technologies designed to locate, classify and neutralise naval mines, operated either autonomously or via remote control – in February 2025.

Roketsan unveils five new advanced munitions and an SLV at IDEF 2025

(dy) Roketsan was a standout participant at the IDEF 2025 defence exhibition, held in Istanbul from 22 to 27 July, with the Turkish weapon manufacturer unveiling five new advanced munitions and a satellite launch vehicle (SLV) at the show.

The first of these was the Akata: a submarine-launched version of the Atmaca anti-ship missile currently in service with the Turkish armed forces. This will give the Turkish Navy a submarine-launched missile capability possessed by only a few countries worldwide. The Akata has a range exceeding 250 km and is armed with a high-explosive, fragmentation warhead, bolstering Turkey's Blue Homeland defence doctrine.

Also being debuted by Roketsan was the Gökbora beyond-visual-range air-to-air missile (BVRAAM). The Gökbora is designed to play a decisive role against enemy air targets from both manned and unmanned combat aircraft platforms. With what is described as a superior guidance system and a range exceeding 100 nautical miles (185 km), the Gökbora will become one of the air force's most powerful offensive assets, capable of neutralising all types of airborne threats.

Roketsan additionally debuted the Tayfun Block-4 hypersonic missile at IDEF 2025. This is a hypersonic variant of the Tayfun missile, which is already the longest-range ballistic missile developed indigenously in Turkey. With the Tayfun Block-4, Turkey is achieving new long-range capabilities and setting a record in domestic defence production. Weighing over 7 tonnes, the Tayfun Block-4, equipped with a multi-purpose warhead, can destroy strategic targets such as air defence systems, command-and-control centres, military hangars and critical facilities from hundreds of kilometres away.

Also making a first public appearance was the Eren high-speed multi-purpose loitering munition. Capable of being launched from unmanned aerial vehicles (UAVs), helicopters, land vehicles and other ground-based systems as well as naval platforms, the Eren is designed for use against slow-moving aerial targets, armoured and unarmoured ground targets and personnel. With advanced guidance capabilities, an extended loitering time and a range of over 100 km, the Eren addresses a critical Turkish operational need for such a munition.

[D Yaylali]

Roketsan also debuted the 300 ER: an air-launched ballistic missile system that can be integrated onto both manned and unmanned aerial platforms. Depending on release altitude and speed, the 300 ER can strike strategic targets at ranges out to more than 500 km away without exposing the launch platform to enemy air defences. The 300 ER will feature various guidance options and warhead types tailored to different target profiles. Its solid-propellant propulsion system enables rapid, high-speed and precise strikes.

Lastly Roketsan introduced the Şimşek-2 SLV. Following the planned first test launch of the Şimşek-1 SLV in 2027, Roketsan aims to advance Turkey's position in the space arena with the Şimşek-2. Developed to place 1,500 kg-class satellites into sun-synchronous orbits above 700 km altitude, the Şimşek-2 is a critical step toward enhancing the country's independent access to space.

Forging the Future of Defense: How Additive Manufacturing Transforms Mission Readiness

In today's defense landscape, the difference between mission success and failure can hinge on equipment availability, performance, and speed of deployment. Traditional manufacturing - casting, forging, and machining - often can't keep pace, facing long lead times, inflexible supply chains, and limited design adaptability. Additive Manufacturing (AM), also known as industrial 3D printing, is rapidly changing that equation.

Assuring Mission Readiness with AM – Spare part was designed, produced and installed with helicopter hangar door operational in less than 3 weeks than conventionally 40 weeks. [Credit: NAVSEA]

The AM Advantage

AM builds components layer by layer from digital models, eliminating the need for extensive tooling and enabling local, **on-demand production**. This results in **faster lead times**, lower costs for small batches, and boosts **supply chain resilience**, while legacy systems benefit from easily produced replacement parts using scans or design files. **Rapid prototyping** accelerates development, and AM allows for complex, integrated designs not possible with traditional techniques.

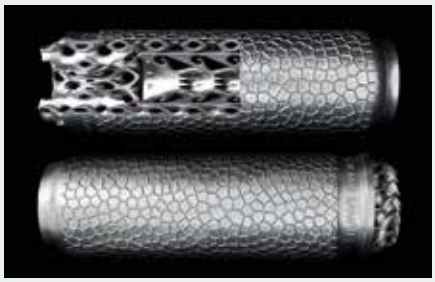
Real-World Defense Use Cases

- **3D-Printed Gripen Component for Battlefield Repairs:** In an operational scenario, a Gripen fighter received an exterior replacement part produced on-demand via AM. This expedient repair capability dramatically reduces aircraft downtime, enabling repairs at distributed bases or forward locations.
- **Assuring Mission Readiness for USS Halsey:** Mission-critical proximity switch bracket for helicopter hangar door, signaling door closure to prevent over-torque. The spare part was designed, produced, and installed with the helicopter hangar door operational in less than 3 weeks, whereas the conventional lead time is 40 weeks.
- **Next-Generation Suppressor Manufacturing:** Using AM enables complex internal structures, tailored acoustic profiles, and integrated mounting features, all in a single consolidated component. Delivering a performance gain and blow-back reduction by up to 80%. Rapid iterations allow to refine performance and adapt to platform-specific needs without expensive retooling.

A Multi-Material Advantage for Defense

The effectiveness of AM is directly linked to the range and quality of available materials. A material-agnostic approach, equipped with a portfolio of qualified materials, is crucial for addressing the diverse challenges across different defense domains — from sea to air and land. EOS supports a wide variety of metals and polymers, each offering distinct advantages for specific applications.
Key materials include:

- **Titanium (Ti64):** Lightweight and corrosion-resistant, ideal for aircraft components and drone frames.
- **Stainless Steel (316L):** Highly durable and versatile. Ideal for robust components for ground support equipment, to fixtures and fittings on naval vessels.
- **Pure Copper (CuCP):** Exceptional for thermal management systems due to its conductivity.
- **Copper-Nickel (CuNi30):** Optimized for marine environments, offering excellent resistance to saltwater corrosion and biofouling—essential for naval components like valve bodies, pump housings, and heat exchanger parts.



EOS Design Study for an Advanced AM Suppressor | Non-functional demo part [Credit: EOS]

Partnering for Success

With the Additive Minds consulting division, EOS supports defense organizations from initial part identification through design optimization, process industrialization, and qualification to defense standards. Our integrated approach helps mitigate risk, accelerate innovation, and embed additive manufacturing as a strategic capability.

With advanced technology, deep materials expertise, and collaboration within programs like Squadron 2020 of the Finnish Defense Forces, our defense partners are enabled to move faster, respond smarter, and maintain mission readiness in an increasingly complex and dynamic world.

Meet our experts at DSEI UK, Booth S9-362, and find out more on EOS.

Baykar completes acquisition of Italy's Piaggio Aerospace

(pf) Turkish unmanned aerial vehicle (UAV) specialist Baykar officially completed its acquisition of Italy's Piaggio Aerospace on 30 June 2025 with a signing ceremony in Rome.

The transaction, initiated by the Ministry of Enterprises and Made in Italy *(Ministero delle imprese e del made in Italy)* on 27 December 2024, has now closed with 'Golden Power' approval from the Italian Prime Minister's Office.

[Baykar]

The signing ceremony was attended by Minister of Enterprises and Made in Italy Adolfo Urso; Baykar CEO Haluk Bayraktar; and the Extraordinary Commissioners of Piaggio Aerospace – Carmelo Cosentino, Vincenzo Nicastro, and Gianpaolo Davide Rossetti.

Speaking at the signing ceremony, Urso highlighted the deal's importance for his country, stating, "With this operation we are safeguarding a strategic industrial asset for the country and laying the foundation for a concrete relaunch of the Italian aerospace sector. Piaggio Aerospace can once again play a leading role thanks to a solid industrial plan, new investments, and the enhancement of local expertise. This result demonstrates how the State, through the extraordinary administration and the Golden Power tool, can protect industrial sovereignty while attracting high-quality international investment."

Selçuk Bayraktar, Baykar chairman and CTO, stated of the acquisition, "It is a great honour for us to take responsibility for the future of Piaggio Aerospace: a symbol of Italian innovation and excellence. Our goal is to revitalise this historic brand by investing in its civil aviation capabilities, expanding production of the P.180 Avanti EVO [executive light transport aircraft], and enhancing [Piaggio's] role as a centre of excellence for aircraft and engine maintenance in Europe. We are committed to long-term growth, high-quality employment, and deepening industrial co-operation between Türkiye and Italy."

The acquisition represents a significant part of the broader industrial co-operation between Türkiye and Italy, including Baykar's joint venture with Leonardo to develop UAVs. Going forward, Baykar aims to stabilise the Piaggio and make the necessary strategic investments for its growth by developing a comprehensive industrial plan.

As well as reintroducing the legendary P.180 Avanti EVO to the global market with upgraded technological capabilities, the development plan for Piaggio also calls for producing Baykar's Bayraktar Akinci and Bayraktar TB2 unmanned combat air vehicles (UCAVs) at Piaggio's facilities to meet worldwide demand, and establishing a Europe-wide centre of excellence in aircraft and engine maintenance.

Leonardo to acquire Iveco Group's defence business for EUR 1.7 billion

(pf) Leonardo announced on 30 July 2025 that it has signed an agreement to acquire the Iveco Group's Defence division for a total enterprise value of EUR 1.7 billion, with the transaction financed through available cash resources.

Iveco Group's Defence business includes both Iveco Defence Vehicles (IDV), which produces special-purpose protected vehicles, and Astra, which produces heavy-duty trucks for extreme off-road conditions.

"This strategic acquisition marks a significant step in Leonardo's plan to strengthen its role as a leading, fully integrated original equipment manufacturer (OEM) in the land defence domain," Leonardo stated. "The acquisition further enhances the group's comprehensive portfolio of solutions for defence and security, covering both tracked and wheeled platforms."

[IDV]

The acquisition will also boost joint commercial positioning, leveraging the complementary nature of the two companies' sales networks and the ability to offer integrated solutions in high-potential markets.

"The acquisition of Iveco Defence represents a key milestone in the execution of our inorganic growth strategy and supports the full implementation of our Industrial Plan," Leonardo CEO and General Manager Roberto Cingolani was quoted as saying in a Leonardo press release. "This transaction reinforces Leonardo's position as a reference player in the European land defence market: a segment expected to experience sustained growth in the coming years."

The closing of the transaction is expected in the first quarter of 2026, subject to regulatory approvals.

The integration of Leonardo's electronic systems – including a complete suite of combat electronics sensors and next-generation turrets – with Iveco's range of military vehicles "will ensure the utmost effectiveness of the proposed operational solutions", stated Leonardo, adding that the highly specialised know-how in the two companies' respective verticals, combined with robust logistics

and manufacturing capabilities, "will drive greater operational efficiency and accelerate joint technological development, while also creating new opportunities for professional skill development and talent enhancement".

Leonardo, in collaboration with its partner Rheinmetall, will also evaluate potential opportunities in the heavy vehicle sector in relation to the Iveco acquisition. The two companies announced the creation of Leonardo Rheinmetall Military Vehicles (LRMV) in October 2024, although this joint venture is primarily focused on heavy tracked armoured vehicles.

Air Marshal Harv Smyth, former combat pilot, to be UK's new Chief of the Air Staff

(pf) Royal Air Force (RAF) Air Marshal Harv Smyth, a former combat pilot on multiple aircraft types who has also led UK space commands, has been appointed as Chief of the Air Staff (CAS) and Aide-de-Camp to His Majesty in the rank of air chief marshal, the RAF announced on 16 July 2025.

AM Smyth took up his CAS post in August 2025, succeeding Air Chief Marshal Sir Rich Knighton, who is being promoted to Chief of the Defence Staff: a role he is taking up in September 2025.

The Chief of the Air Staff is responsible for the strategic planning and delivery of all RAF operations, people and capability. The position is accountable to the UK defence secretary for the fighting effectiveness, efficiency and morale of the RAF as well as the service's development and sustainment.

Joining the RAF in 1991 as a direct entrant, AM Smyth then spent 15 years as a frontline Harrier pilot and weapons instructor, which included flying hundreds of operational missions over Bosnia, Kosovo, Serbia, Iraq and Afghanistan.

Through his subsequent career and increasingly senior appointments, AM Smyth retrained as a Tornado pilot and then as a Typhoon pilot.

Promoted to air marshal in 2022, AM Smyth was appointed as the RAF's Deputy Commander (Operations): a role that was transitioned to become the UK Air and Space Commander in 2023, responsible for all RAF air and space operations globally.

[Crown Copyright]

In April 2024 AM Smyth became the first RAF officer to hold the role of Deputy Chief of Defence Staff (Military Strategy and Operations), responsible for the provision of military advice to senior leadership across government including the UK prime minister, the development of UK military strategy and its integration with partners across government and allies, and the commissioning of UK military operations at home and across the globe.

Our partnership with industry is crucial to building Europe's defence

Rt Hon Maria Eagle MP

This year's DSEI comes at a crucial time for the European defence industry. Together our continent is standing steadfast in the face of the most perilous security situation Europe has faced for 80 years.

This new era of threat demands a new era for UK Defence and the Strategic Defence Review which we published in June set out our vision to make Britain safer, secure at home and strong abroad.

It outlined the biggest transformation in our defence posture for a generation and our commitments to industry to make it happen - Government and industry are working together hand-in-hand to ensure we can all meet this new era of threat.

At this time, where supporting NATO is more important than ever, we are re-affirming our support by committing to the largest sustained increase in defence spending since the end of the Cold War – hitting 2.6% by 2027 and the ambition to hit 3% in the next Parliament. Investing in the UK's defence is about strengthening all of Europe, bolstering the collective security of our whole continent.

That includes strengthening the Royal Navy with 13 new frigates, which will defend the North Atlantic for decades to come. We are broadening our contribution to NATO's nuclear mission with a new fleet of F-35A fighter jets for the Royal Air Force. We are investing in the British Army's armoured fleet, with more than 1,300 new vehicles rolling off the production lines in the coming years.

Together our Armed Forces play an integral role in contributing to Europe's collective defence. We frequently conduct exercises and operations with our partners in the Joint Expeditionary Force, protecting Northern Europe and the High North. Our continuous presence in the Baltics makes a vital contribution to NATO's defence of Eastern Europe from Russia's threat, and we are standing resolute with Ukraine, working alongside France, Germany and many others to ensure Kyiv can win a just and lasting peace.

In this new era of technologically-advanced warfare we are matching this political and security cooperation with partnerships which allow our defence industries to innovate and grow quickly. Our Defence Industrial Strategy sets out how we are going to facilitate deeper integration with European partners and our key allies,

The Rt Hon Maria Eagle MP. [UK MoD]

sharing costs and capabilities whilst strengthening our collective security. Our message to the European defence industries is clear: the UK is open for business.

Already, we are expanding the Lancaster House Treaties with France to build our capabilities with closer industrial cooperation, advancing procurement programmes such as Storm Shadow, as well as making it easier for our defence industries to do business together by enhancing reciprocal market access.

And in the Trinity House Agreement with Germany we outlined our shared ambition to develop and produce long-range conventional missiles to be used by our European allies. Our commitment to working together to boost exports of our joint capabilities will develop our industrial bases while strengthening our allies.

At DSEI we are showcasing our work with firms of all sizes, from established players to tech start-ups and experts in other industries to help us all stay ahead of evolving threats. Our long-standing partnerships with primes across Europe will enable us to deliver the ships, tanks and planes at the scale we need to keep us all safe.

Our new Office for SME Growth will give SMEs better access to the defence supply chain, making the UK one of the best places for cutting-edge firms to operate. We already have European businesses producing the latest AI-powered loitering attack drones, a vital weapons system to strengthen our friends, and we look forward to welcoming even more defence technology firms.

History teaches us that cooperation and collaboration are essential to robust defence and deterrence. The UK is dedicated to helping develop a Europe-wide modern warfighting readiness to ensure peace can prevail for decades to come. I look forward to you joining us.

AUTHOR

The Rt Hon Maria Eagle MP is the UK's Minister for Defence Procurement and Industry, and Member of Parliament for Liverpool Garston.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Desolate skies: Why GBAD matters

Mark Cazalet

While drones, tanks, and artillery have grabbed headlines, Ukraine's ground-based air defence (GBAD) has quietly achieved something remarkable: keeping Russian air power mostly out of the fight for over three years. Ukraine's experience in this sphere offers vital lessons for the future security of European NATO members.

Looking around at the bulk of NATO armed forces over the last few decades, a visible trend is the relative age and small numbers of GBAD systems in operation with many Allies. Concerns over this have been voiced at the highest levels, as during a 9 June 2025 speech at Chatham House, in which NATO Secretary General Mark Rutte stated that NATO needs "a 400% increase in air and missile defence".

IRIS-T SLM key system components viewed from above, consisting of the command post (left), transporter, erector, launcher (TEL; middle), and radar (right). This system forms the MRAD component of ESSI. [Diehl Defence]

AUTHOR

Mark Cazalet is the Editor-in-Chief of ESD. Previously, he worked for Janes as a Senior Analyst on the Land Warfare Team, and Editor of the Janes Artillery and Air Defence, and Janes Firepower, Survivability and Mobility yearbooks. Prior to that he worked at the International Institute for Strategic Studies (IISS), contributing to The Military Balance.

Neglecting GBAD has been a fairly long-running trend among many NATO Allies since the end of the Cold War, but it was not a particularly concerning capability gap during the era of the Global War on Terror, given the lack of aerial capability from the opponents of the time. Even the US could be credibly accused of slacking during this era, with its army broadly relying on PATRIOT for long-range air defence (LRAD), the Stinger-armed AN/TWQ-1 Avenger for very/short-range air defence (V/SHORAD), and the 20 mm Gatling cannon-armed Land Phalanx Weapon System for point defence of US bases, pretty much entirely in the counter-rocket, artillery, and mortar (C-RAM) role. There was little to speak of in the way of medium-range air defence (MRAD) during this period, with I-HAWK being retired, while initiatives such as SLAMRAAM were cancelled, and NASAMS was procured only in small quantities to defend government buildings in Washington DC; though on the other hand, this period also saw the original PAC-3 (now more commonly referred to as PAC-3 CRI) come to fruition.

Granted, in the US' case these gaps represented little in the way of meaningful weakness when considering that the country had, and continues to operate the two largest air forces in the world – the USAF and the US Navy. The same, however, cannot be said for its NATO Allies. Consequently, GBAD has represented a capability gap that European NATO members have begun scrambling to fix since Russia commenced its full-scale invasion of Ukraine on 24 February 2022.

In this vein, perhaps the most relevant current example of attempting GBAD procurement at scale is the German-led European Sky Shield Initiative (ESSI), which presently comprises 24 members. What is notable about ESSI is that the effort aims to steer users toward a procuring multiple systems with the goal of ensuring a multi-layer GBAD capability. The effort envisions Skyranger 30 in the VSHORAD role, IRIS-T SLM in the MRAD role, PATRIOT in the LRAD role, and Arrow-3 in the dedicated ballistic missile defence (BMD) role; all of which are systems Germany has selected for its own requirements. While this list lacks a 'true' dedicated SHORAD system, which should arguably also be part of any multi-layer system, the ESSI shopping list nonetheless covers most of the key areas. German industry stands to win significantly from this initiative, with the VSHORAD and MRAD components both

using German-origin systems, and may also benefit somewhat from the LRAD side, given that Germany plans to domestically produce PAC-2 GEM-T missiles for PATRIOT.

The move represents a significant tonal shift for Europe, whose GBAD purchases pre-Russo-Ukrainian War often consisted of low-quantity purchases to paper over the cracks, without the impetus to drive procurement of a proper, modern multi-layer air defence network. By now, it should be especially obvious to Europe that simply purchasing a couple of MRAD batteries and calling it a day is deeply insufficient. To understand why, one need only look to Ukraine.

Ukraine: Exemplifying the value of GBAD

The Russo-Ukrainian War represents an interesting and fairly unique case study in how near-peer/peer warfare looks when both sides field large, multi-layered air defence networks. At the opening phase of the war, Ukraine operated a significantly smaller and less modern air force compared to Russia, so consequently, a greater share of the task of contesting the Russian Aerospace Forces' (VKS') power would need to fall on GBAD systems. In many ways Ukraine's Soviet legacy helped it here, as the Soviet armed forces operated a very large and diverse fleet of GBAD systems covering many range and altitude bands, of which Ukraine inherited a substantial portion. Many of these older systems remained sufficiently effective against 4th-gen fighters, and were key to Ukraine preventing Russia from attaining air superiority in the opening phase of the 2022 invasion, as well as keeping Ukraine's airspace contested in the months and years that followed.

The effect over time was that these GBAD systems effectively prevented Russia from using its fast jets to full effect, largely forcing them to operate at very low altitudes for pop-up attacks, or employing less plentiful guided munitions from standoff distances. Initially, the latter typically comprised air-launched cruise missiles (ALCMs), and was later supplemented by gravity bombs fitted with UMPK glide/guidance kits. Alongside these, Russia also introduced the massed one-way attack (OWA) drones such as Shahed/Geran, and others, along with decoys into its aerial threat mix.

Pictured: a 5P85SM TEL from the S-300PM system. Despite being relatively old, many legacy SAM systems such as the S-300P family, nonetheless proved themselves to be a serious danger for 4th-Gen fighter aircraft. [RecoMonkey]

As Ukraine burned through its legacy missile stocks, and acquired new systems and munitions from allies, its GBAD gradually Westernised, with the country now operating a large and diverse mix of US and European designs, along with some hybrid oddities such as the Buk 'FrankenSAM' using RIM-7/AIM-7 missiles. While such systems were often effective, Ukraine's reliance on Western munitions introduced a vulnerability in supply – with perhaps the most concerning moments for the Ukrainian frontlines coming around February 2024, during which Ukraine's surface-to-air missile (SAM) depletion reached critical levels. In this window, some signs of limited, localised air superiority for the VKS rapidly began to emerge, with Russian President Vladimir Putin claiming "thousands of sorties" in the operation which culminated with the fall of Avdiivka on 17 February 2024. This window was not to last, as US Congress managed to pass a long-awaited USD 60.8 billion aid package on 20 April 2024. These deliveries saw a replenishment of Ukraine's SAM stocks, and consequently the ended the brief window in which the VKS had enjoyed localised air superiority.

In short, Ukraine has demonstrated the extent to which GBAD can influence the battlefield. While of course air-to-air exchanges have taken place, and manned aviation on both sides has played a role in air defence, it has not been the prime driver of the trends seen. With neither side able to employ air power in the typical desired fashion (persistent medium-altitude flight in close proximity to enemy positions, with emphasis on ground attack), the nature of the fighting was forced to become relatively static, positional, and attritional – an environment in which both artillery and small drones thrive. Both sides have nonetheless attempted to find alternative ways to employ their available air power, but GBAD has continued to prevent air power on either side from playing a decisive role.

All told, it would probably not be much of an exaggeration to argue that Ukraine's GBAD hindered the success of Russia's invasion more than any other single factor, due to its compounding shaping effects on the rest of the battlefield. While there are a number of shaping effects at work on the battlefield, artillery being an oft-cited example, this author would argue that there is a hierarchy of shaping effects. In the case of artillery – it is able to exert the shaping effects it does primarily due to the absence of persistent air power which under other circumstances could have located and destroyed it. Much the same could be said of drones; to my mind it is doubtful that this war would have seen the rise of small drones if Russian airborne ELINT and strike assets were free to roam Ukraine's skies, dropping KAB-250s on any emission signature even remotely resembling a drone ground control station. More to the point, in such a scenario, the war would likely have been over long before a domestic drone industry could arise.

How applicable are these lessons to NATO?

So, what can NATO members learn from the battlefield influence of GBAD in the Russo-Ukrainian War? As ever, one should be cautious about applying lessons from this war, as many observed operational realities exist due to Ukraine's unique circumstances vis-à-vis Russia, and may not necessarily apply in other scenarios, such as a hypothetical full-scale conflict between Russia and NATO. The latter is precisely the scenario the current wave of modernisation and rearmament is geared toward readying the Alliance for.

A Ukrainian Su-27P; the country operated an estimated 34 Su-27 aircraft prior to Russia's full-scale invasion. These were less capable than their equivalents operated by Russia. [RecoMonkey]

With that in mind, are large fleets of GBAD systems as necessary for NATO as for Ukraine? Arguably less so. For starters, air superiority over Russia was never a realistic goal for Ukraine, whose pre-war fast jet fleet largely comprised small-medium numbers of older Soviet-era 3rd/4th-gen aircraft. As such, GBAD had to shoulder the burden of keeping Russian aircraft at bay. By contrast, many NATO members operate significantly more modern, capable, and in some cases larger fighter fleets. As such, attaining air superiority should be a far more realistic goal for NATO than for Ukraine, and indeed would probably represent the Alliance's best chance for ending a war with Russia quickly. Consequently, given NATO's vastly superior air forces relative to Ukraine's, it is fair to question the likelihood that GBAD would play an equally-important role in the aforementioned scenario. In a time of budgetary pressures, it may therefore seem tempting to save on GBAD to free up funding elsewhere. Yet, as tempting as that route may be, there remain many good reasons for NATO members to invest in their GBAD capabilities.

To begin with, some context. Despite Russia's often poor tactical performance in Ukraine, and the superiority of NATO's air forces, the survival of sufficient numbers of NATO fast jets for long enough to attain air superiority in a full-scale conflict with Russia should not be taken for granted. In a scenario where it is fighting NATO, Russia would be expected to invest considerable resources into destroying the Allies' fast jet fleets on the ground, such as via ballistic and cruise missile strikes, along with using its GBAD and aviation to attrit NATO aircraft as they ventured into defended airspace to perform offensive counter-air, and suppression/destruction of enemy air defence (SEAD/DEAD). Alongside this, Russia would be expected to continue employing massed low-cost long-range precision strike means, such as OWA drones, against both military targets, as well as strategically-vital industrial and energy infrastructure. In this kind of environment, GBAD would provide a relatively low-risk form of persistent protection for strategic assets and ground formations.

First, the mere presence of larger numbers of GBAD systems, particularly long-range air defence (LRAD) systems such as PATRIOT, would restrict the freedom with which Russia's own air forces could operate in-theatre, likely forcing the VKS to either stay further back from the front lines, or dedicate more intelligence, surveillance, and reconnaissance (ISR) and strike assets to hunting down GBAD. This would also come at a time where they would be in very high demand for other tasks, such as locating key command and control (C2) nodes, or defensive counter-air. Likewise, the presence of GBAD could provoke the expenditure of precious high-performance munitions, either to ensure high-value targets were struck, or against the GBAD system itself.

Second, large fleets of GBAD systems would give Allies greater scope to devote fewer fast jets to the defensive counter-air role. This should not be understated – even leaving aside the cost asymmetries of using the likes of F-35 to down Shahed/Geran series OWA drones or Kalibr cruise missiles, dedicating a sizeable portion of the Allied fast jet fleet to conduct large-scale defensive counter-air also imposes an opportunity cost, insofar as these aircraft will not be usable for offensive action at the same time. Ultimately, the success of NATO attaining air superiority will hinge on the number of aircraft it is able to dedicate to offensive counter-air and SEAD/DEAD.

Russia is mass-producing Geran series OWA drones at an estimated rate in the thousands per month, with ambitions to scale this to 1,000 per day. Even if their wartime production is disrupted, their current estimated industrial output compared to observed expenditure suggests they likely have a not inconsiderable stockpile available. [TV Zvezda]

Third, there is a need for redundancy in case of losses. As seen in Ukraine, GBAD on both sides has suffered significant attrition, especially during the highest-intensity phase in the opening weeks of Russia's full-scale invasion. Ukraine's Western-built systems have thus far suffered fewer losses, however these have mostly seen action during portions of the war where hostile SEAD/DEAD was less of a risk, and Ukraine has also been more conservative with their positioning than with its Soviet legacy systems. That said, even Western systems have suffered losses during the relatively static phases of the war; most notably, Ukraine was visually confirmed to have lost part of a PATRIOT battery to a 9M723 Iskander-M strike in March 2024. What re-

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mains true for both sides, is that the relatively large GBAD fleets they started with meant they could absorb said losses without the situation turning truly catastrophic. Many NATO armies at present lack this level of redundant capability, meaning that any system losses risk leaving persistent gaps.

Fourth, there are some targets that fighter aircraft are simply unsuited to engaging – a case in point being ballistic missiles. At present, there is no real alternative to using ground- or sea-based systems for the ballistic missile defence (BMD) role. While not all GBAD is suited to the role, with SRBM interception typically being the domain of specialised LRAD systems, many V/SHORAD and MRAD systems nonetheless provide a level of capability against lower-tier threats such as artillery rockets or various types of precision-guided munitions, against which employing aircraft would be impractical, even though they may technically possess the requisite capability to engage such targets.

Fifth and finally, even when going up against an opponent with good SEAD/DEAD capabilities, there are a number of characteristics of GBAD systems which can make them a thorny problem to deal with effectively.

- GBAD systems can be difficult to locate, meaning an opponent needs to invest significantly in ISR to do so reliably, and often at considerable operational depths, particularly in a large theatre.
- Even when located, GBAD systems can often protect themselves against the very weapons which would typically be used to engage them. In the case of LRAD systems, these will often have V/SHORAD or MRAD systems protecting them.
- Even when engaged, GBAD systems represent quite complex targets, since they tend to operate as dispersed systems of systems comprising multiple vehicles. The system can usually keep functioning if a launch vehicle is destroyed, making total defeat of a GBAD system quite difficult. Furthermore, due to advances in networking technologies, some GBAD systems are now capable of using an allied asset's radar picture for target tracking and even fire control, making even the loss of a GBAD system's primary radar somewhat less of a dire prospect than in years past.
- GBAD systems exist primarily to protect other assets, so even in when they are successfully defeated, as long as the critical object or formation they are protecting survives long enough to achieve strategically-important effects, the GBAD has done its job.

A 9A317M transporter, erector, launcher, and radar (TELAR) vehicle from the Buk-M3 LRAD system. A less-discussed trend during the war in Ukraine has been the entry into service of more modern and capable air defence systems. [RecoMonkey]

In sum, large numbers of dispersed modern GBAD systems represent a genuine headache for even a well-equipped air force to deal with, and can exert considerable shaping effects on the battlefield over time if they are allowed to operate unopposed.

Doing things properly

When it comes to fielding a meaningful GBAD capability, there is a right way and a wrong way to do things. Perhaps the best exemplar of the former is Poland, which is currently in the process of procuring the following:

- 8 PATRIOT batteries, each comprising eight launchers (64 total) armed with PAC-3 MSE missiles (Range: ~120 km), under the Wisła programme. Deliveries to be completed in 2029.
- 23 EMADS (Narew) batteries, each comprising six launchers (138 total) armed with CAMM-ER missiles (Range: >45 km), under the Narew programme. Deliveries to be completed in 2035.
- 2 EMADS (Mała Narew) batteries, each comprising six launchers (12 total), armed with CAMM missiles (Range: >25 km), under the Mała Narew programme. Deliveries completed in 2023. It is unclear whether or not these will eventually be folded into Pilica+ batteries.
- 22 Pilica+ batteries, each comprising six SPAAGMs (132 total) armed with both twin-23 mm cannons and Piorun missiles (Range: 6.5 km); additionally each battery receives two separate launchers (44 total) armed with CAMM missiles (Range: >25 km), under the Pilica+ programme. Deliveries to be completed in 2029.
- 79 Poprad launch vehicles (split between eight formations and a training school), armed with either Grom (Range: 5.5 km) or Piorun missiles (Range: 6.5 km). Deliveries completed in 2021.
- Collaboration between MBDA and PGZ in the development of the CAMM-MR missile, purportedly slated to have a range of approximately 100 km. Planned to eventually enter service with Poland on both land and naval platforms.

As things currently stand, in 2035 Poland will possess probably the largest, and one of the most modern GBAD system fleets among all European NATO Allies. The fleet will be capable of combating a wide variety of threats, including small drones, cruise missiles and PGMs, modern fast jets, and SRBMs. This represents a remarkable turnaround in a relatively short span of time, especially considering the Polish Army had previously not procured any new GBAD systems, aside from man-portable air defence systems (MANPADS), since the Cold War.

Moreover, in a synergistic move Poland has opted for a common C2 system for its PATRIOT and its Narew batteries in the form of IBCS. This not only provides it with a modern, capable C2 system, but one which has already been integrated with F-35, which Poland is also procuring. This would in principle enable targeting data sharing across PATRIOT, Narew, and F-35. The most likely envisioned use cases would include, for instance, using F-35 radar data to enable PATRIOT and Narew batteries to conduct engagements below their own ground-based radar horizon, as may be required against very low-flying threats such as cruise missiles. This data-sharing capability would also enable redundancy in case of a ground-based radar being jammed or lost.

A TEL from Poland's Mała Narew system, using the same UK-designed CAMM missiles as the British Army's Sky Sabre system. The CAMM family will form the backbone of Poland's future MRAD capability. [Polish MND]

By contrast, the British Army is a notable example of chronic under-investment in GBAD, especially relative to the country's technological and economic potential. As with many countries, the UK's GBAD acquisitions were fairly limited in the decades following the Cold War, with the primary system for 27 years being Rapier FSC, a SHORAD system which served from 1995 until its retirement in January 2022. Rapier was formally replaced in service by Sky Sabre, which is the service name for the UK's specific configuration of EMADS, equipped with CAMM missiles. Although often referred to as SHORAD, it would more accurately be described as sitting at the lower end of the MRAD band. While Sky Sabre is a modern, capable system which represents a substantial improvement over the old Rapier FSC system, the UK's overall GBAD picture nonetheless does not look particularly rosy. The two key problems here concern quantity and diversity.

At present, 16th Regiment Royal Artillery is understood to operate just four Sky Sabre batteries, each with three launchers (for a total of 12). On the V/SHORAD front, IISS' The Military Balance 2025 publication cites a figure of 38 FV4333 Stormer vehicles in service with the UK, which can be armed with Starstreak (Range: 5.5 km) or LMM missiles (Range: 8 km). Aside from some MANPADS, that is effectively the sum total of the British Army's GBAD at present. Based on a rough calculation, the British Army's current capability results in a theoretical maximum defended footprint similar to just the organic GBAD available to two Russian tank divisions. While this is admittedly a somewhat flippant example, as different systems have varying typical deployment distances between launchers and command posts which can influence the real defended footprint greatly, it nonetheless serves as a rough litmus test of capability. All told, things could be better.

Regarding diversity, the Army currently fields only V/SHORAD and MRAD systems; it has neither LRAD, nor BMD capability. As things stand, this leaves the UK with no answer to the likes of 9M723 Iskander-M or Kh-47M2 Kinzhal, both of which have been commonly used by Russia in Ukraine. Through the Royal Navy's Type 45 Destroyers, the UK does have Aster-30 missiles, which in theory would be capable of dealing with the aforementioned threats – although reports from Ukraine

A 9P78-1 TEL of the Iskander-M system, with two 9M723 SRBMs shown raised to the launch position. At present, specialised GBAD is the only realistic solution to such threats in the context of a land war. [RecoMonkey]

in early 2025 suggested otherwise. In any case, being ship-based, these would be of limited utility in the context of a land war occurring deep into the European continent. As things currently stand, the UK's main options for force protection in a NATO-Russia scenario would seem to comprise: relying on Allied GBAD to plug the Army's gaps, and/or dedicating at least some of its fast jets to a defensive role. Thus far, the MoD has signalled it is pursuing the latter approach in the 2025 Strategic Defence Review, stating: "The RAF combat air force provides the core of UK IAMD 'effect' capability, with Typhoon and F-35 providing the UK and NATO with air defence against air and cruise missile attack."

Filling the gaps in the UK's GBAD would require substantial investment, but there have been some small signs that the MoD intends to consider the issue more seriously. Among these is the UK-led DIAMOND initiative, which according to an MoD statement aims "to integrate NATO's missile defences, while also pledging to develop new long-range, cutting-edge missiles, improving the Alliance's collective air defence and offering opportunities to the UK defence industry". However, until hard figures are revealed by the MoD in its 2025 'Defence Investment Plan', slated for publication at some point in the autumn, it is difficult to assess the extent of the UK's ambitions in this field.

An oppressive layer

In general, it is fair to say that GBAD has not enjoyed quite the same level of attention or credit for its role in the Russo-Ukrainian War as many other weapons. This was especially the case during the first two years, where the main references to it consisted of mocking calls of 'what air defence is doing?' on social media.

Some of this was due to poor public understanding of GBAD. Strikes on positions happen, so people assume air defence doesn't work. GBAD system components get destroyed, so people assume they're useless. Few confirmed kills are posted on social media, so people assume targets aren't being intercepted. Additionally, there's the problem of attrition inflation in the public imagination – mainstream press are used to dealing with single-vehicle systems such as tanks, whereas many GBAD systems are multi-vehicle systems. The result has been that media will be far more likely to report something like 'two S-400 systems destroyed' rather than the more accurate 'two 5P85TM launchers destroyed' – which would be just a portion of an S-400 battery. This isn't helped by the myriad variations in air defence system sizes among different systems and users, with terms such as 'fire unit', 'battery', to the Russian 'divizion' and 'polkovoi komplekt' – all of which can be confusing.

Attitudes did start to change somewhat as the war dragged on, especially as Ukraine's air defenders began to regularly post regular interception reports on social media, and increasing insight into the nature of the fighting began to drip-feed into public discourse. However, perceptions of GBAD's importance are difficult to shift, and fundamentally this comes down to GBAD being a low-propaganda value weapon, unsuited to the information war for several reasons.

For starters, given the massive area in which aerial targets could fall after being downed, many GBAD successes become confirmed only much later, such as when one side captures an area where an aircraft wreckage landed – yet this could take weeks, months, years, or in some cases might never happen. Such was the case with Bayraktar TB2 – the flurry of TB2 strikes published to social media led to it being hailed as a wonder weapon in the public imagination, even having a song written about it. However, the reality on the ground looked quite different – by the fourth week of Russia's 2022 invasion, new clips of TB2 strikes had dried up almost entirely. Then, only many weeks later as Russian ground forces gained ground in some sectors, they began posting photos of TB2 wreckages they had found to social media. Since the opening weeks, there have been only a small handful of new clips of TB2 strikes, broadly restricted to portions of the Black Sea.

Next, aside from some very kinds of short-range engagements such as those against small drones, most engagements (especially those against the highest-value targets) will tend to happen beyond visual ranges, sometimes even beyond the range of a system's optoelectronic sights (if present), meaning they can only be seen on radar. Simply put, video footage of a track on a radar screen losing altitude doesn't make for compelling sharable social media content in quite the same visceral manner as a first-person view (FPV) drone strike.

A selection of copter-type small drones of various weight classes in use with Ukraine. Along much of the front line, this is effectively what air power has been reduced to. [Ukrainian MoD]

Yet the effects of air defence in the Russo-Ukrainian War become fairly evident when looking for notable absences on the wider battlefield. Are fast jets regularly flying at medium-high altitudes close to the front lines? Are drones in the medium-altitude long-endurance (MALE) or similar class being observed in use? Are deployments via parachute being carried out? Are attack helicopters being used in offensive operations? After the high-intensity opening phase of fighting, the answer to all of these broadly became no. In this capacity, GBAD has served as an invisible, oppressive layer hanging over the battlefield in Ukraine, greatly limiting the utility of manned aviation for over three years. Within this kind of environment, both sides began to understand that regular flight along the frontline would only be possible by going small, cheap, and unmanned.

Next-Generation Energy Storage for Modular Military Power Supply

ESM hybrid brings the "Modular Grid" system to market readiness

Modern armed forces face a complex challenge: the power requirements of military systems have increased significantly. Air defense radar systems require continuous power for command posts and launcher modules. Electronic warfare, reconnaissance, and communications systems further drive up consumption. Added to this are basic operational requirements: quarters must be heated and illuminated; medical facilities supplied with life-saving equipment. What is routine in garrison becomes a critical logistical challenge in deployment.

VINCORION's Modular Grid technology provides flexible solutions to these power challenges. "The true innovation lies not in the technology alone, but in the operational advantages it creates," explains Sascha Brüning, Vice President Business Development & Sales at VINCORION. "Close collaboration with users and procurement agencies has provided valuable operational insights."

Battery Storage as Key to Efficiency Central to this innovation is the ESM hybrid energy storage module, which works in conjunction with PGM low emissions generators. The intelligent battery storage systems with 28 kilowatt-hour capacity from Futavis (part of Deutz) enable diesel generators to operate at optimal efficiency while handling peak loads. The ESM is available in configurations ranging from one 28-kW battery to nine batteries.

Thanks to an integrated ventilation system for heating and cooling, the energy storage units operate reliably in a temperature range from minus 32 to plus 55 degrees Celsius. In many deployment scenarios, the generator can be completely shut down while the storage handles base load requirements. In combined PGM and ESM operations, fuel savings of up to 33 percent are achievable. This not only reduces consumption but also minimizes acoustic and thermal signatures.

System Scalability and Integration Daniel Zeitler, Head of Product Management at VINCORION, outlines the system's development stages: "In 2023, we first introduced the Modular Grid concept, 2024 saw our first new PGM 50 kW generator, and now in 2025, we're presenting the new ESM hybrid battery storage with innovative energy management. The system's modular design enables it to integrate virtually any energy source – from conventional generators to solar arrays and fuel cells."

▲ Sascha Brüning [VINCORION]

▲ Daniel Zeitler [VINCORION]

The advantages are evident in operational scalability. The different power classes of the PGM series with 20-, 50-, and 200-kW units can be combined with corresponding ESM modules and expanded according to mission requirements. A unified interface controls all components and automatically determines optimal energy distribution.

Long-term Support Guaranteed Beyond technology, VINCORION provides comprehensive lifecycle support. The company has invested in new testing and maintenance facilities. "We've built a new multi-generator test stand and invested systematically in our PCB manufacturing capabilities," reports Brüning. "This enables reliable repairs and significantly reduces turnaround time."

VINCORION maintains spare parts inventory and technical expertise for up to 30 years. Specialists from German facilities in Wedel, Altenstadt, and Essen support not only current systems but also legacy platforms – crucial for obsolescence management.

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▼ The animation illustrates how PGM low emissions generators could appear in operational use. [VINCORION]

Trade-offs in air defence system design

Dr Sidharth Kaushal

As modern warfare increasingly features overlapping missile, drone, and cruise missile threats, air defence planners face critical decisions about whether to optimise systems against specific threats or pursue costly multifunctional capabilities. Recent conflicts from Ukraine to the Middle East reveal how these choices can determine mission success or failure.

The design of air defence networks in a context where a number of overlapping threats will characterise the operating environment will pose a number of considerations as planners and defence industrial specialists attempt to balance the imperatives of managing the problems of mass and complexity. Among these are the questions of to what extent capabilities should be optimised against particular parts of the threat spectrum as opposed to being multirole and the trade-offs between coverage and magazine depth. In addition, the ways in which the demand for a broader range of sensors must be managed will pose its own challenges.

Optimisation or multifunctionality?

The choice regarding whether to build systems that are optimised against parts of the threat spectrum or not is one of considerable strategic importance, particularly in a context where multiple threat types converge. To build solutions weighted against individual parts of the threat spectrum is to risk having multiple lines of effort, each of which is poorly-resourced. Equally, the desire for multifunctionality can result in systems which are functional against many threats but perform sub-optimally against parts of the threat spectrum.

One solution might be to build systems biased towards a particular threat type. This does not mean exclusive focus, but relative weighting. The case of the Iranian attacks on Israel over the course of 2024 and 2025 are instructive in this respect. In April 2024, Iran commenced an attack which was in many respects a defence PowerPoint diagram come to life, combining unmanned aerial vehicles (UAVs), cruise missiles and ballistic missiles. The challenge that this posed, however, was that rather than reinforcing one another, the different elements of the threat spectrum undermined each other. Shahed one-way attack (OWA) UAVs provided Israeli air defenders with nine hours of warning, which in turn eliminated any hope of operational surprise when Iran's ballistic missiles were launched. It is perhaps unsurprising, then, that during its attacks in both October 2024 and July 2025 Iran opted for purely ballistic attacks (UAVs were used in July 2025, but there was no attempt to coordinate them with ballistic missiles and they had very limited utility).

A Shahed 136 OWA UAV on display. Iran's decision to add such threats into the mix for its April 2024 attacks proved less effective than it might have hoped. This was partially due to their launch increasing the warning time, but also because the air defence means to deal with Shahed tend to be much simpler than those required to deal with ballistic missiles, meaning there was no real synergy between the two to overwhelming a particular class of defensive system. [FARS Media Corporation/Behrouz Ahmadi, via Wikimedia Commons (CC-BY-4.0)]

Particularly at medium and intermediate ranges, some capabilities are considerably more concerning than others. Cruise and ballistic missiles which have the payloads to destroy high-value targets and the penetrating capacity to leak through air defences in meaningful numbers pose a considerably more potent threat than UAVs. Moreover, while there are opportunities to use the two threat types in mutually-reinforcing ways (for example using ballistic missiles with submunitions to trap aircraft for a follow-on salvo of cruise missiles), the differences in speed makes convergent attack unlikely. Such would likely characterise Chinese attacks on US airbases in the Pacific. Instead, one capability is often likely to act as a breaching capability and force multiplier for the other. For example, if Iranian ballistic missiles had proven more effective at shutting down bases such

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as Nevatim in October 2024 and July 2025, arguably cruise missile salvos would have proven more effective against a reduced defensive counter-air (DCA) challenge.

When one enjoys the advantage of medium to intermediate ranges from an opponent, then, it is arguably useful to optimise against specific high-value threat types even to the partial exclusion of others. For example, the Russian system as constituted has a specific focus on big-wing enablers such as tankers and airborne early warning and control (AEW&C) aircraft (against which the 40N6 of the S-400 was optimised), as well as on cruise missiles, which are to be engaged both by surface-to-air missiles (SAMs) and by aircraft such as the MIG-31BM, which was equipped with a Zaslon radar purpose built for this role – something which was arguably well-suited to Russia's pre-war needs.

Operating without depth

The erosion of a nation's strategic depth, however, can change this dynamic considerably since the range of threats which can strike a target increases exponentially.

Again, the Russian case is illustrative, particularly in light of the change in Russia's borders with NATO after 2022. The changing boundaries of the Alliance makes it possible to strike operationally or strategically significant targets with missiles which might have previously been considered tactical. From Finland, for example, a short-range ballistic missile (SRBM) such as the PrSM can reach a number of targets that the Russians would dub 'strategic', such as Severomorsk and Olenya Guba. Many of these systems can be launched from otherwise 'tactical' systems, such as M142 HIMARS and M270 MLRS.

The challenge Russia will face is not that it cannot defeat each threat type. In the ballistic missile defence (BMD) role, systems such as the S-300V can engage tactical ballistic missiles (TBMs) and SRBMs, while S-500, although notionally optimised for engaging medium-range ballistic missiles (MRBMs) and intermediate-range ballistic missiles (IRBMs), can also play a supporting role against lower-tier threats through its sensor coverage, or the provision of lower-tier interceptors. Meanwhile air-breathing threats can be engaged by Tor, Buk, S-300V4, S-400, among others. Similarly, systems such as Tor and Pantsir can play a counter- rocket, artillery and mortar (C-RAM) and counter-precision-guided munition (C-PGM) role. However, each individual system is vulnerable to the threats against which it is not optimised. For example, despite the 9M96M missile (now more typically employed on the S-350, but can also be used with S-400 if required) being of utility against tactical ballistic targets, it does not have a hit-to-kill warhead or a Ka-band seeker. This could either reflect a design focus on air breathing targets or potentially that the Elbrus-800 computer on S-400 is marginally too slow to enable hit-to-kill solutions (something which is often compensated for with seeker frequencies that enable wider sweeps but preclude hit-to-kill solutions). In either instance, the effective operation of an S-400 against a large number of tactical threats becomes dependant on the availability of ballistic missile defence (BMD) capable systems, increasing the cost and complexity of the air defence in an area but also forcing geographical clustering to enable mutual reinforcement.

The changing dynamic has also turned Russia's BMD strategy inside-out. Systems such as the S-500 and A-235 were procured with a view to defence against more limited numbers of IRBMs and intercontinental ballistic missiles (ICBMs). As more nations field SRBMs like PrSM, Russia will have a choice to make. It can deploy the S-500 against SRBMs (albeit almost certainly using interceptors other than the 77N-6 which is a high endoatmospheric capability). However, if employing the S-500 against lower-tier threats such as TBMs/SRBMs, it will necessarily have lower coverage compared to when it is configured against the MRBM/IRBM threats it was primarily designed for – due to the shorter-range missiles' lower apogee. Additionally, this would impose a degree of resource strain, since the limited numbers

Russia operates a diverse array of air defence systems, providing coverage against a variety of threat types. The 9A331M transporter, launcher, and radar (TLAR) shown here is part of the Tor-M2 system, optimised for short-range air defence (SHORAD) against air-breathing threats, along with and the C-RAM/C-PGM roles. [RecoMonkey]

A 9A83M transporter, erector, launcher, and radar (TELAR) of the S-300V4 system. The continuous wave illumination radar for the track-via-missile (TVM) guidance system can be seen folded over the rear deck, under the missile containers. [RecoMonkey]

of S-500 will be needed to defend key strategic targets against intermediate-range targets like submarine-launched ballistic missiles (SLBMs). Moreover, close to the front the S-500 is vulnerable to a range of air-breathing threats, necessitating the use of 'gate guardian' systems to protect it. The system itself is expected to carry a range of interceptors but dedicating launchers to shorter-ranged interceptors would limit its capacity against those parts of the threat spectrum which only it can defend against. Alternatively, Russia can turn to systems such as the S-300V4, but the X-band semi-active radar homing (SARH) seeker on the 9M82 likely provides limited granularity (which is traded for range) and a lower integration rate for returns, which potentially explains the modest claim of 0.5 probability of kill (Pk) against TBMs. This does not mean that defence becomes impossible, but the need to layer capabilities likely makes it more spatially concentrated.

This conundrum is not necessarily a uniquely Russian challenge and it raises two possibilities. The first is that forces, particularly in the land environment, will have to cluster in ever narrower areas both to enable mutual reinforcement of air defence system types, but also to allow for shorter-range air and ballistic missile defence systems which can be used in larger numbers, to be better leveraged given the limited coverage of these systems. Consequentially, both covered areas and the portion of a military force which is usable (in terms of having sufficient air cover to muster for an attack) will be relatively small at any given time and hard choices between the defence of frontlines and rear areas will have to be made.

Integration as an enabler for optimisation

An intermediate point between these two positions might suggest that the answer to the question of whether to optimise or aim for a balanced and integrated system (with consequentially limited coverage) is a function of one's ability to offset elements of the threat through means other than active defence. Integration in its broadest sense – the use of passive defence and offence in tandem with active defence – may thus be the determinant of one's ability to optimise.

It is of some note that the fact that Israel found itself facing a purely MRBM threat was a function of its previous success against Hezbollah, which removed the latter's rocket, artillery, and mortar (RAM) and TBM/SRBM threats from the mix to a considerable extent. Although despite this, Hezbollah did destroy or damage elements of the Israeli air defence system with capabilities such as Spike derivatives on several occasions. In effect, optimising the offence against a particular part of the threat spectrum (RAM and TBMs from Lebanon) narrowed the air defence challenge down to what in effect amounted to BMD.

In other circumstances, the situation may be reversed and longer-range threats may be more easily eliminated by means other than defence. In Europe, for example, Russia is likely to have a limited number of launchers for IRBMs such as Oreshnik for some time, incentivising 'left-of-launch' solutions.

Other elements of the threat spectrum may be better managed through passive defensive solutions including camouflage and hardening – something particularly true of many UAVs, which have small payloads and limited sensor loadouts. This is also true of older cruise missiles, many of which can be diverted off course by capabilities comparable to the digital radio frequency memory (DFRM) decoys used on naval vessels.

To the extent that an air defence system can be optimised against a threat type, it can more efficiently provide coverage over a wider area for longer (simply because of the efficiencies that focusing time and resources on a simplified problem creates). This will in turn depend on other parts of missile defence including suppression and passive defence.

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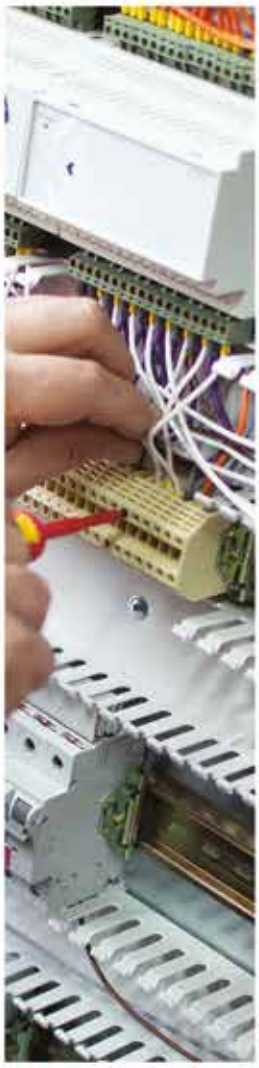

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Countering small drones: A big challenge

Doug Richardson

What began as a commercial technology is in the process of transforming the modern battlefield. As drone technology proliferates, and production scales toward the millions of units annually, the urgent question facing militaries is not whether they can afford sophisticated counter-drone systems, but whether they can afford not to deploy them.

While the funeral in Vatican City of Pope Francis on 26 April 2025 involved many traditional features, such as Swiss Guards dressed in their traditional Renaissance-style tricoloured uniforms, and armed with swords and halberds, it introduced one defensive measure never before seen at a papal funeral – soldiers from the Italian special forces armed not with rifles or other small arms, but with infantry-portable anti-drone weapons. Although a 'no-fly' zone had been imposed over the entire area of Rome and the Vatican in order to keep the sky clear of unauthorised aircraft and helicopters, the security forces were ready to deal with pilotless intruders.

Although no drones disturbed the funeral, small drones with multiple rotors and ranges of up to around 10 km have changed the nature of front-line combat. They are already reported to be responsible for around two-thirds of the total combat casualties suffered by both sides in the current conflict between Russia and Ukraine.

Both countries are understood to be using around 10,000 drones each month. Given that Ukraine's target for drone production through 2025 is 4.5 million, and Russia is reported to be planning to produce between 3–4 million, the rate of drone use seems set to increase, perhaps by an order of magnitude or more.

Radio links versus jammers

One inherent problem in creating effective anti-drone defences is that the process is largely reactive. Drones and drone tactics continue to evolve, particularly during conflicts, and upgrading of defences is the inevitable response to this.

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Known as first-person view (FPV) drones, the most common variant harassing Russian and Ukrainian front-line forces over the last year or so are typically controlled in real time via a video feed sent via a radio link to the operator who can use electronic goggles to display imagery from the drone's onboard camera, and use commands sent by radio to steer the aerial vehicle. Since these two-way radio communications can be jammed, many drone systems use frequency-hopping to try to maintain the two-way linkup.

Developed by the Australian company Droneshield. the Dronegun Tactical uses·directional antennas to deliver RF energy intended to disrupt control, video, and navigation signals across multiple frequency bands, and to prevent the target from using satellite navigation. [Droneshield]

Jamming of the radio signals passing between the drone and its operator was a viable solution for dealing with first-generation threats. Jammers transmit a large amount of radio frequency (RF) energy towards the drone. This can disrupt the commands being sent to the drone, and video signal being transmitted back to the controller. They can also be used to jam any on-board GPS system that the drone may be using for navigation.

While anti-drone jammers are available in fixed-site and vehicle-mounted configurations, as the hardware being used to protect the Papal funeral in April 2025 showed, RF jammers are also widely available in man-portable form.

Early drone jammers operated on specific frequencies known to used by commercial drones. More modern systems use improved RF detection subsystems capable of precisely iden-

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tifying the specific frequencies used by their target, tailoring the jamming to match the threat, while minimising the risk of interference with friendly RF-based systems. However, RF jammers require regular updates in order to cope with changes on the download and control frequencies being used.

By the end of 2024, more than 70% of the radio-controlled FPV drones being used by Russia and Ukraine were being successfully countered by jamming, even though newer types of Ukrainian drone operating at many different frequencies had made Russian jamming operations increasingly difficult.

The fibre-optic revolution

Fibre-optic drones get around the jamming problem by carrying a storage spool and a dispensing system for a long optical fibre. Since all communications between the drone and its operator are transmitted through the fibre rather than via radio links, these drones are more difficult to detect, and immune to effects of defensive jammers. Fibre-optic technology offers much higher bandwidth than is possible using RF links, so delivers higher-quality imagery to the operator.

▲ A Ukrainian drone manoeuvres after launch to demonstrate the release of its trailing optical fibre. [Ukrainian MoD]

The weight of the fibre-optic storage spool and the dispensing system reduces the operational payload of a drone. Maximum range is limited by the total length of fibre being carried, and currently sits at around 10–20 km. While the presence of the fibre does place limits on the degree to which the drone can be manoeuvred, it does allow flight at much lower altitudes than are required in order to maintain radio links. Additionally, as long as the fibre is unbroken, the drone could be landed to await the arrival of a suitable target – thereby permitting ambush-type attacks.

If the use of fibre-optic drones destroys a large portion of the enemy's RF jamming systems, this can restore the viability of radio-controlled drones, which are less expensive than their fibre-optic guided counterparts.

Protective netting

According to a recently-published US Army document, gunfire is seen as a potential counter to hostile drones flying close to a tank. The proposed procedure for a training exercise 'React to Unmanned Aircraft System While Mounted – Platoon' calls for tanks threatened by a hostile UAV to "engage with all machine guns or 120 mm canister rounds". US tanks have no fire-control system able to target such threats, but the document recommends that when faced with a crossing fixed-wing threat, gunfire be aimed "one-half football field in front of nose", while an approaching quad-copter be tackled by aiming slightly above its fuselage.

Such a simplistic approach has not found favour with other armies. Recent conflicts have seen tanks equipped with protective screening intended to detonate incoming warheads. In its most basic form, these are mounted above the turret in order to counter attacks from above, but drones are now able to fly at very low altitude when attacking, and recent imagery has shown some Russian tanks totally enveloped by protective screens.

Armoured fighting vehicles (AFVs) and other vehicles on the move behind the front line are potential targets for attack, as are groups of soldiers. In 2023, Russia was reported to be using lamp posts to support panels of netting stretched across major roads around Bakhmut. These panels seemed to be repurposed camouflage netting, and were intended to counter drones attempting at fly at shallow approach angles while chasing and attacking vehicles. Likewise, Ukraine has also taken a similar approach, by hanging fishing nets above commonly-used roads. This thin netting is often difficult to detect on an FPV's camera, and make it likely that FPVs diving targets on these roads would find themselves immobilised in the process, their propellers snagged in the netting.

▼ A Ukrainian 'drone tunnel' in Donetsk Oblast. Such is the density of FPV drone threats that both sides have opted for covering up commonly used routes with anti-drone netting. [jana_skhidna X Account]

In mid-2024, the Russian TASS news agency recorded that the vehicle routes in the Kupyansk area of the front line were being fitted with protective nets made from plastic and fabric mesh held in position by wooden poles positioned along the route. If the netting is installed both overhead and on both sides of the road, the result is the creation of what is intended to be an anti-drone tunnel.

In February 2025, a 2 km tunnel of nets was reported to have been installed near Chasiv Yar in the Donetsk region. These road-protection schemes are reported to be effective, but involve a significant investment in man-hours both to install the supports and netting, and then to maintain them. It remains to be seen for how long such protective nets will remain a practical solution.

Small SAMs for the anti-drone role

One early attempt to create a low-cost surface-to-air missile (SAM) able to engage small UAVs was the Raytheon Coyote. This was originally developed in piston-engined form, incorporating folding wings, and stored in a pneumatic box launcher. It formed part of the ground-based air defence (GBAD) counter-UAV system developed for the US Marine Corps. This teamed the missile with an RPS-42 S-band radar, a Modi electronic warfare (EW) system, and visual sensors. In this initial form, Coyote was 600 mm long, had a 1.47 m wingspan, weighed 5.9 kg, and was armed with a 1.8 kg warhead.

Selected by the US Army for use in the counter-UAV role, the Coyote Block 1B version was equipped with a RF seeker and a proximity-fuzed warhead, and operated in conjunction with Raytheon's Ku-band Radio Frequency System (KuRFS) radar. To increase the missile's speed and maximum range, Raytheon then developed the Block 2 variant. Launched by a rocket booster and powered by a small turbojet engine, this had a flight endurance of up to 4 minutes, giving a range of 10-15 km, and the ability to re-attack a target in the event of an initial miss.

▼ A US Army Bradley Fighting Vehicle launches a Coyote LE SR during Project Convergence-Capstone 5 (PC-C5) at Fort Irwin, California, on 12 March 2025. [US Army/Sgt Marita Schwab]

In February 2021, Raytheon was awarded a US Navy contract to develop what was originally known as Coyote Block 3, but was later given the designation Coyote Launched Effect Short Range (Coyote LE SR). Compatible with a TOW missile launcher, this version has no wings or strakes, but features three rear-mounted pop-out grid fins.

Aside from the more common explosive payloads, non-kinetic options are also becoming available. In this vein, in August 2021, Raytheon announced that during an air-intercept test, a Coyote Block 3NK (non-kinetic) missile launched from a US Army Fixed Site-Low, Slow, Small UAV Integrated Defeat System (FS-LIDS) had used its non-kinetic warhead to defeat a swarm of ten drones.

The palletised FS-LIDS is one of two configurations of the Raytheon's LIDS family, the other being the Mobile-Low, Slow, Small UAV Integrated Defeat System (M-LIDS) variant. Both integrate Raytheon's KuRFS radar and Coyote missiles with Northrop Grumman's Forward Area Air Defense Command and Control system (FAADC2) and the Counter-Small UAV Electronic Warfare System Direction Finding (CUAEWS DF) direction finding and electronic warfare (EW) system made by Syracuse Research Corporation.

M-LIDS Increment 2 comprises a pair of Oshkosh M-ATV 4×4 protected patrol vehicles, one of which is fitted with a Moog Reconfigurable Integrated-weapons Platform (RIwP) remote turret, armed with a launcher housing two Coyote munitions, and the XM914E1 30 mm automatic cannon; while the second vehicle is equipped with the CUAEWS DF, along with a remote weapon station (RWS) fitted with a M2 12.7 mm heavy machine gun (HMG), paired with the Ballistic Low Altitude Drone Engagement system (BLADE) specialised C-UAV sight. Two key capability differences between the two configurations include the fact that M-LIDS has both cannon-based and HMG-based effectors while FS-LIDS lacks these, and that FS-LIDS' Coyote launcher houses four rounds, while the M-LIDS' launcher houses two.

In 2019, the USAF revealed that its BAE Systems AGR-20 Advanced Precision Kill Weapon System II (APKWS II) air-to-ground 70 mm guided rocket had been successfully tested in the air-to-air role. In late 2023, the service announced the

▼ Raytheon's palletised FS-LIDS launches the company's Coyote Block 2 missile. [Raytheon]

impending delivery of a new APKWS II proximity-fuzed warhead intended for use against drones. Early in 2025, the USAF reported that the APKWS II had been successfully used by F-16 fighters to engage hostile drones launched by Ansar Allah (Houthi) militia forces in Yemen. In this role, the APKWS II had served as a low-cost alternative to the AIM-9X Sidewinder.

Laser-guided 70 mm rockets also form the armament of L3Harris Technologies' Vehicle Agnostic Modular Palletized ISR Rocket Equipment (VAMPIRE), a modular system able to arm light tactical vehicles or even non-tactical vehicles. Based on a pallet that can be installed in about two hours on any vehicle with a cargo bed, it combines a mast-mounted WESCAM MX-10D RSTA independent stabilised sighting system with a launcher for APKWS or other laser-guided munitions. Developed and field-tested in 2021, this surface-to-air system underwent further tests in the following year, and a batch of 14 were delivered to Ukraine by mid-2023.

Even smaller and cheaper SAMs

Many small drones of the sort being widely used in the Russo-Ukrainian war would not make suitable targets for SAM defences on technical or cost grounds. Even engagements by cannon-based defences may prove surprisingly expensive if long bursts are fired. If SAMs are ever going to become a widely-deployed counter to swarms of drones, they would have to be cheap enough to be mass-produced at a unit cost similar to that of their target. Although such a goal may seem impractical, several companies not currently associated with missile development and manufacture seem determined to attempt it.

The Latvian company Frankenburg Technologies has set itself the goal of developing "missile systems that are ten times more affordable, a hundred times faster to produce, and in quantities far exceeding current industry capabilities". In December 2024, it announced a plan to start testing of hardware in Ukraine during 2025. No technical details of the hardware have been published other than a maximum engagement height of 2,000 m. A photograph of what seems to be a test launch shows a wingless missile with cruciform tail fins, but other photographs released by the company show a model with cruciform wings and tail fins, and indicate a length of less than 1 m. A predicted unit cost of around USD 2,000 is in a similar price category as many of the drones it is intended to counter.

In March 2025, the Swedish company Nordic Air Defence (NAD) announced the development of the Kreuger 100 anti-drone missile. Compatible with handheld or mobile launchers, it uses what the company describes as battery-powered pulsed propulsion, and is guided by an infrared (IR) seeker, which according to the company is built from "commercially available components", and "designed to function effectively in various weather conditions, day or night". Currently the missile flies at speeds of up to 270 km/h, but significantly higher speeds are expected from a planned military variant. It is understood to lack a warhead, however this has not been confirmed.

Drone versus drone

An alternative to these proposed missiles is already in service in the form of interceptor drones. Guided by real-time data from ground-based radar or optronic systems, these take direct physical action such as detonating a warhead, colliding with the intruding drone, or delivering some form of disabling payload such as a net.

Ukraine is already using Win_Hit interceptor drones developed by Ukrainian company ODIN to engage Russian Shahed/Geran and Gerbera long-range one-way attack (OWA) drones. Win_Hit is vertically launched and powered by four propellers mounted at the tip of the drone's cruciform wings. Once launched, it has an endurance of 7–10 minutes, and cruises at 200–220 km/h, transitioning to 280–300 km/h during its final attack.

This screengrab shows a test launch of the Mark I anti-drone missile being developed by Latvian company Frankenburg Technologies. This version, featuring cruciform wings and tail fins, is more likely to be representative of the eventual production model than the wingless configuration which has also been shown in company graphics. [Frankenburg Technologies]

The vertically launched ODIN Win_Hit interceptor drone is already in Ukrainian service. [ODIN]

Adapting multi-domain counter-UxS systems for cost-effective protection against drones

Dominik König

Hardly any other area of technology is currently as much in the spotlight as drone defence. The war in Ukraine demonstrates daily how rapidly the potential threats posed by drones are evolving and increasingly influencing the battlefield: fast advancing technologies and significant increases in production, combined with low manufacturing costs for drones, are constantly enabling new attack scenarios. The use of unmanned systems is no longer limited exclusively to the air but is also increasing significantly on land and in water.

Field-proven C-UAS systems for successful multi-domain operations

For several years, the German Armed Forces have been using ASUL, the defence system against unmanned aerial vehicles developed by HENSOLDT, for effective drone defence. The container-based C-UAS system relies on a complex mix of multi-sensors and multi-effectors.

The modular design, based on HENSOLDT's Elysion Mission Core software, allows the continuous expansion of the system. Both sensors and effectors are integrated modularly and can be changed or expanded at any time. An adaptable multi-layer approach, consisting of various soft-kill and hard-kill measures, does not only enable targeted protection against enemy drones, but also leads to lower costs for C-UAS systems and the defence measures themselves.

C2 software as a core element of cost-efficient extensions, adaptations and networking

Future-proof C2 software in the context of software-defined defence, such as the Elysion Mission Core Software, is the basis for the integration of other sensor-effector mix options.

Ever-changing threat scenarios and the associated changing requirements for drone defence make it necessary to continuously develop and expand C-UAS systems. The development of completely new systems leads to high personnel and administrative costs. Extensions and adaptations of existing C-UAS systems are therefore a decisive factor in making these systems future-proof and more affordable.

Supporting human resources as effectively as possible with software

The required number of military personnel is often not available and training them is associated with high costs. With the help of comprehensive assistance and support functions, as well as an intuitive operating concept tailored to the target user group, personnel and training costs can be significantly reduced. A high degree of automation through C2 software has a positive effect, allowing drone defence systems to be operated by only one operator using the human-in-the-loop principle.

ASUL: Mission-proven C-UAS – scalable and future-oriented [Bw/ Dahlmann]

In addition, the scalability of C-UAS systems is becoming increasingly important. When multiple drone defence systems are interconnected with each other, C2 software such as Elysion Mission Core Software allows a single operator to control multiple C-UAS instances.

Flexible integration options in multi-domain scenarios

Drones in the air are only the first step in deploying unmanned systems on the battlefield of the future. Systems on land as well as on and underwater (e.g. unmanned underwater vehicles (UUVs) in the maritime sector) are becoming increasingly important. Cost-effective deployment can only be guaranteed if C-UAS systems can be extended to other dimensions and scenarios, such as land-sea scenarios.

The ASUL system's solution approach with Elysion Mission Core software demonstrates how existing capabilities can be integrated into other configurations: on tripods, in containers, on vehicles or as fixed installations.

Success criteria for C-UAS systems

Multi-domain operations require agile multi-sensor, multi-effector solutions for successful drone defence. This involves comprehensive connection of all levels of ground-based air defence in real time in order to deploy existing reconnaissance and weapon systems efficiently and effectively, thereby ensuring maximum protection. With its targeted, cost-efficient and scalable range of solutions featuring high-performance hardware and software, HENSOLDT demonstrates its exceptional capabilities, which have proven themselves in various operational scenarios over many years.

On 3 July 2025, Ukraine and the US company Swift Beat signed a memorandum covering drone production. Swift Beat is to expand its production capacity, and give priority to supplying Ukraine with drones under what was described as "special terms and at cost price". In addition to interceptor drones, the agreement also covers quadcopters for reconnaissance, surveillance, and fire-adjustment, as well as "medium-class strike drones for engaging enemy targets". The US company had already conducted drone tests on Ukrainian territory.

Elsewhere, following an initial series of trials conducted in Israel during October 2024, around 20 counter-drone technologies underwent operational trials testing by the Israel Ministry of Defense (IMOD) Directorate of Defense Research & Development (DDR&D) in February 2025. While some involved gun systems, solutions using interceptor drones were demonstrated by Israeli companies, Airobotics, Elbit Systems, Elisra, Israel Aerospace Industries, Rafael Advanced Defense Systems, Robotican, and Xtend.

Directed-energy weapons

The US Army's Directed Energy Maneuver-Short Range Air Defense System (DE M-SHORAD) is based on the General Dynamics Land Systems (GDLS) Stryker wheeled infantry combat vehicle, and is armed with a high-energy laser (HEL) and radar system configured by Leonardo DRS. This includes a 50 kW class laser intended to melt the plastic or metal structure of a hostile drone, damage its optical sensors, cause it to catch fire, or even to prematurely detonate the explosive payload.

During a meeting held in June 2025 to review Russia's planned state armament programme for 2027–2036, President Putin declared that the country needed "new approaches and non-standard solutions" to the problem of countering drones. Within days, officials revealed that eight HELs of varying power levels had recently been tested. These included mobile units and higher-powered stationary systems, and the trials were expected to allow the start of serial production and subsequent deployment.

In the spring of 2025, Russia's TASS news agency reported the development of a "laser rifle" able to attack hostile drones at a range of up to 500 m. Based on Ytterbium-laser technology, the hardware was tripod-mounted, and connected by cable to a separate power supply. According to TASS, a similar weapon was already in Ukrainian service. However, the only laser weapon that Ukraine has revealed so far is the Tryzub (ENG: Trident). A video released in April 2025 showed what was probably a trials version installed on a mounting carried in the rear of a vehicle. According to Col Vadym Sukharevskyi, commander of Ukraine's Unmanned Systems Forces, Tryzub can engage fixed-wing aircraft, helicopters, and large reconnaissance drones at ranges of up to 5 km, or tactical strike drones and cruise missiles at up to 3 km.

High-power microwave (HPM) devices are another form of directed-energy weapon (DEW), and are intended to generate an electromagnetic pulse (EMP) powerful enough disrupt or destroy the electronic circuitry in drones by inducing damaging levels of voltage and current. In April 2025, the UK MoD announced that during the largest counter-drone swarm exercise the British Army had conducted to date, soldiers had

During a trial conducted early in 2025, the UK-developed RF DEW system used high-powered RF energy to defeat a swarm attack by drones. [Crown Copyright 2024]

successfully tracked, targeted and defeated swarms of drones using a newly developed system dubbed 'RF DEW'. This used high-frequency radio energy to disrupt or damage critical electronic components inside the drones, causing them to malfunction or crash. Installed on a truck, the system is intended to defeat airborne targets at ranges of up to 1 km, and become an effective counter to UAVs that cannot be countered by electronic warfare. According to the MoD, the estimated cost of each shot of RF energy was about GBP 0.10.

Last-ditch defence

Today's Russian and Ukrainian front-line soldier knows that while newspaper articles and defence magazines may talk of next-generation lightweight SAM systems, and of DEWs based on HELs or HPMs, these are unlikely to become available in large numbers deployed close to his current position. Meanwhile, the soldier lives under skies swarming with hostile drones – knowing that if a drone just spotted by a comrade has locked onto him, his life expectancy could be dramatically shortened. Inevitably, front-line soldiers facing frequent drone attack would like to see some form of anti-drone defence deployed at platoon level, or even made available to every soldier.

One potential candidate is a shotgun, which can be effective against all types of small UAV, including these guided by fibre-optics. Ukrainian and Russian forces are reported to be using shotguns as last-ditch anti-UAV weapons, and manufacturers in other countries are developing anti-drone shotgun rounds, and even offering specialised shotguns.

Italian firearm manufacturer Benelli Arm's M4 gas-operated 12-gauge weapon is already in service by the US as the M1014 Joint Service Combat Shotgun, by the UK as the L128A1, and by at least 14 other countries. The manufacturer has now developed the M4 A.I. Drone Guardian variant. This features a long choke inside the barrel which is intended to enhance the ability to hit drones at greater distances that are possible with the standard barrel.

Benelli's M4 A.I. Drone Guardian shotgun features a long choke to allow drone engagements out to 100 m, with the manufacturer citing optimal effectiveness from 0 to 50 m. [Benelli]

Swedish ammunition manufacturer Norma offers the AD-LER, a 12-gauge shotgun cartridge that releases a payload of 2.7 mm No 6 tungsten shot at a velocity of 405 m/sec and a maximum effective range of 100 m. According to the company, the shot has a "high impact force against drones and other small aerial targets".

Payloads intended to end a drone's flight by tangling with or even damaging its rotor blades can be fired from shotguns or various forms of hand-held, shoulder-launched, or turret-mounted launcher. They can also be launched from a defensive drone, or hung below the latter and manoeuvred into contact with the target.

Florida-based company ALS has developed the ALS12SKY-Mi5, a 12-gauge anti-drone round intended for use against commercially-available drones used for illegal or military purposes. The payload has a velocity of 251 m/sec when fired, and a maximum effective range of about 90 m. It takes the form of five tethered segments which separate by centrifugal force in order to create what the company describes as a 'capture net' about 1.5 m in diameter.

Russia's Tekhkrym company is developing an anti-drone shotgun cartridge that fires a Kevlar net instead of traditional shot. Reported to be still under development in 2024, this will create a fully-deployed net at a range of about 30 m.

The smallest and most man-portable net-launcher is probably the hand-held Mitla developed by Ukrainian company Teneta. This single-use launcher is only 200 mm long and 40 mm in diameter, and weighs 365 g. A built-in 7.62 mm pyrotechnic cartridge provides the propulsive force for the net, which measures 3.5 x 3.5 m when fully expanded. Due to the force of the recoil, users are advised to hold the device with both hands when firing. Since the maximum range is only 25 m, this is very much a 'last ditch' weapon for an individual soldier who finds himself under attack.

Russian company Ingra has developed the Rosyanka adaptor that converts a standard GP-25 Kostyor 40 mm under-barrel grenade launcher mounted on AKM and AK-74 assault rifles into a single-shot 12-gauge shotgun with a reported range of 15–30 m. In 2024, Ingra claimed that testing of the Rosyanka adaptor had been completed, and that a pre-production batch was being manufactured. However, given that not all Russian infantrymen are equipped with the GP-25, the scale of any deployment of the Rosyanka will be limited, while its tactical effectiveness will be restricted by a slow reloading process that requires the device to be removed from the grenade launcher, the spent cartridge case extracted, a new cartridge loaded, and the adaptor reinstalled into the grenade launcher.

A cluster of barrels (probably intended to fire shotgun ammunition) and a row of rifles form the armament what is probably a Russian improvised anti-drone vehicle, but there is no sign of an optical sight or other aiming system. [Russian MoD]

Shotgun-type weapons and machine guns have formed the armament of several Russian improvised anti-drone vehicles first seen in 2024. The ZVeraBoi incorporates a turret fitted with two 7.62 × 54 mm PKT machine guns, a six-barrel array intended to fire shotgun-style cartridges, and a thermal imaging sight. A second turret is armed an array of with six coaxial AK-12 5.45×39 mm assault rifles.

In late 2024, video sequences released by the Russian defence ministry showed a counter-drone vehicle armed with a cluster

When mounted on a rifle, Israel's SMASH 2000L fire control system is intended to give the front-line soldier the ability to engage incoming UAVs.

of 24 barrels that may be intended to fire shotgun-like ammunition, as well as six AK-series infantry rifles positioned on a single mount. Both of these multi-barrel systems are steerable, but it is not clear how they are aimed. Another Russian short-range anti-drone weapon created for use on a vehicle features a tripod-based mounting carrying a four-barrel Yakushev-Borzov YakB-12.7 rotary machine gun, a thermal-imaging camera, and probably a laser rangefinder.

Ukrainian defence forces have used FPV drones armed with shotguns to attack enemy UAVs. The Ukrainian company Varta has developed DroneHunter, a payload that can be used to arm small drones, allowing them to engage small and medium-sized opponents. It weighs 2.3 kg, and consists of two 12-gauge barrels able to fire electrically initiated anti-drone charges with a range of 5-20 m. Its recoil-suppression system is based on the principle of simultaneous counterfire. A similar system based on four 12-gauge barrels and able to fire more powerful ammunition with a maximum range of 50 m was reported to be under development in mid-2025. The first application of the twin-barrelled system was the Chief-1 UAV, which Ukrainian Ministry of Defence cleared for operational use in June 2025.

Rifle fire versus drone

In June 2024 Ukraine released a video showing how a Yak-52 training aircraft could be used in the anti-UAV role by carrying a marksman close enough to a UAV to allow the latter to be engaged by rifle fire. However, full-automatic rifle fire from soldiers on the ground will rarely be effective against UAVs if standard ammunition is used.

Ukraine has developed a 5.56 mm calibre anti-drone round which is now in front-line use. Known informally as the Horoshok, it is reported to fire five sub-projectiles rather than a solid bullet. These are reported to have an initial velocity of more than 800 m/s, higher than that of the pellets released by anti-drone shotgun cartridges. Yet to have a realistic chance of downing a drone, the soldier must fire a burst of between five and rounds while continuing to track the target. Maximum range is reported to be around 50 m.

The soldier can rapidly reconfigure his personal weapon for use against drone targets, but the Horoshok cannot be fired while the weapon is fitted a suppressor or some types of flash hider. These rounds are reported to be already in service with some Ukrainian units, but production is expected to ramp up to allow more widespread deployment.
Postings on Russia's Telegram chat service in 2024 have shown attempts by Russian soldiers to improvise anti-drone payloads for the standard 5.45x39 mm rifle cartridge. One example showed how the standard projectile could be removed from the cartridge and replaced by a series of seven ball-bearings contained in a plastic shrink-wrapped sleeve. This improvised payload is smaller in diameter than the original projectile, so will have a low accuracy when fired, while the effect that ball bearings and the remains of the plastic shrink wrap will have on the barrel of the rifle are unlikely to be good.

An alternative approach is to add a sophisticated fire-control system to a rifle used to fire standard ammunition. The Israeli company Smart Shooter won a contract from the US Army to supply their Smash 2000L optical system for small arms and rifles to the US Army. It is intended to team artificial intelligence and assisted-vision technologies to allow individual soldiers to accurately engage moving targets including small drones. Smash 2000L uses image processing to recognise the target, predict its movements, and remain locked on the target despite its subsequent movements, and changes of position by the user. Maximum effective range is 250 m by day, and 100 m at night. The potential of giving the individual soldier the ability to engage small drones has not gone unnoticed by other nations, and the Israeli system can be integrated into any type of assault rifle. The British Army has procured a version of the system for use on its SA80A3 rifle.

Coping with the evolving threat

As the deployment of front-line anti-drone systems increases, the greater the training problem. Ukraine reports that a growing number of its soldiers need to be trained in their use. At first, their success rate may be low, but as individual soldiers gain experience, the number of weapons or rounds fired in order to obtain a 'kill' declines significantly. However, there are only a limited number of Ukrainian training establishments, so experienced front-line units are often tasked with providing 'on the job' training for inexperienced arrivals.

Some observers have likened the current conflict between Russia and Ukraine to the trench warfare of 1914–18, with the large-scale use of drones representing the present-day equivalent to the massed machine-gun fire which caused so many casualties on both sides more than a century ago. Yet just as workable tactical solutions had to be developed to cope with the machine gun, the same will probably apply to drones. What that solution will be has yet to be found. To adapt the words of a reportedly traditional Chinese curse, we live in interesting times.

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Hypersonic weapon interceptor developments

Sidney E. Dean

The growing threat posed by hypersonic weapons triggers multiple nations to pursue development of hypersonic missile interceptors.

China and Russia have fielded hypersonic cruise missiles (HCMs) as well as hypersonic glide vehicles (HGVs); most recently, North Korea announced the development of an HGV. HCMs have air-breathing propulsion and generally operate akin to conventional cruise missiles, albeit at hypersonic speeds (>Mach 5) thanks to the employment of scramjet propulsion systems.

HGVs are launched atop rocket boosters which propel them to hypersonic speeds before the stage housing the glide vehicle performs a dive manoeuvre, at which point the glide vehicle separates from the stage, often at high endoatmospheric altitudes or (depending on range) at very low exoatmospheric altitudes and continues the dive. Once at the appropriate altitude, the HGV then performs a pull-up manoeuvre to orient themselves and begin their endoatmospheric glide phase, using atmospheric lift to sustain their glide and to manoeuvre. Their combination of speed and manoeuvrability makes hypersonic weapons difficult to intercept, and Western nations have recently intensified their efforts to develop countermeasures to this threat.

United States

Despite the reported success of PATRIOT PAC-3 MSE against the likes of Russia's Zircon HCM on 25 March 2024, military planners agree that the increasing sophistication of hypersonic weapons requires intercept systems specifically optimised to combat this threat. The United States armed forces are pursuing several programmes.

THAAD 6.0

The Theater High Altitude Air Defense (THAAD) system is currently designed for exo- and endoatmospheric intercept of short- and medium-range ballistic missiles (SRBMs and MRBMs), along with a limited capability against intermediate-range ballistic missiles (IRBMs). THAAD's MIM-401 Talon interceptor missile is capable of engaging targets at ranges of around 200 km distance from the THAAD launcher and at altitudes between 40 km and 150 km. In its current configuration, THAAD is ill-suited for HCM/HGV interceptions. While the interceptor achieves Mach 8 flight speed, it operates at too great an altitude to effectively combat HCMs and HGVs; in the former case, because HCMs typically fly at altitudes well below 40 km, while in the latter case, if THAAD is located relatively near the HGV's target, the HGV would be expected to be flying at below 40 km by the time it is in range of THAAD.

▲ A THAAD interceptor is launched from the Reagan Test Site, Kwajalein Atoll in the Republic of the Marshall Islands, during Flight Test THAAD-23, on 30 August 2019. [MDA]

The Pentagon's Missile Defense Agency (MDA) has been incrementally upgrading THAAD's capabilities. The THAAD 4.0 software upgrade currently being fielded permits networking the THAAD and PAC-3 MSE systems. This enables sharing sensor data from the THAAD's AN/TPY-2 X-band radar, which could enhance PATRIOT's targeting of hypersonic weapons. The THAAD Build 5.0 mid-term upgrade is scheduled to be operational in July 2026, and encompasses both software and hardware elements. Details largely remain classified, but the upgrade is expected to involve improved guidance algorithms, processing speed, and seeker software. This may incrementally improve odds of intercepting some types of target, but THAAD 5.0 will still deploy the legacy Talon missile with its previously described limitations.

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In this context, the MDA is upgrading the AN/TPY-2 radar employed with the THAAD system. In May 2025, Raytheon delivered the first AN/TPY-2 outfitted with a Gallium Nitride (GaN) antenna array and advanced CX6 high-performance computing software. This is the first unit of the AN/TPY-2 expressly capable of acquiring and tracking hypersonic vehicles. According to RTX, the improved radar acquires targets at twice the range of the previous generation, and with improved target discrimination, enabling tracking of smaller and faster targets. Specifically, Raytheon reports that it can detect and track objects such as a separated HGV at long ranges and immediately after booster separation. Through future network integration of THAAD with PATRIOT and other intercept systems, the AN/TPY-2 GaN array promises incremental enhancement of US counter-hypersonic capabilities.

MDA is also thinking further ahead. In February 2025, the agency awarded Lockheed Martin a contract to develop the next-generation THAAD 6.0. Although concrete details are scarce, the MDA's 'Fiscal Year (FY) 2025 Budget Estimates' document said the THAAD 6.0 upgrade aimed to update "THAAD with Increased Threat Space including THAAD Interceptor capability upgrades to improve performance against existing and emerging threats". Furthermore, according to MDA Director Lieutenant General Heath A. Collins, speaking before the Senate Armed Services Committee Strategic Forces Subcommittee on 8 May 2024, *"THAAD System Build 6.0 operational availability has been expedited to 2027 from 2032 and will provide initial capability against maneuvering threats and increase the threat engagement space. TH 6.0 includes capability enhancements to the THAAD interceptor, increased integration with Patriot MSE, and improvements to the cybersecurity risk posture and program protection."*

The following year, on 13 May 2025, speaking before the Senate Armed Services Committee Strategic Forces Subcommittee, Collins added that THAAD 6.0 "provides initial capability against non-ballistic threats". Taken together, the aforementioned official statements strongly suggest that THAAD 6.0 will be aimed at providing some level of capability against threats such as HGVs – especially taken in conjunction with the When taken in conjunction with the aforementioned upgrade to the AN/TPY radar. The technical approach taken by THAAD 6.0 has not been officially revealed, but the upgrade is expected to include modifications to the interceptor's propulsion system and the kill vehicle (KV).

The US MDA plans to conduct Flight Test Aegis Weapon System-43 (FTM-43) with the goal of using an upgraded Standard Missile-6 (SM-6) to physically intercept an HTV-1 hypersonic target. [MDA]

Sea-Based Terminal (SBT)

The Sea-Based Terminal (SBT) system is an incremental, near-term capability currently fielded on selected Aegis-equipped ships as well as with Aegis Ashore. It utilises the Aegis Baseline 9 fire control system (in the Baseline 9.C2.0+ upgrade) and the SM-6 missile to defeat terminal-phase threats, understood based on tests to some level of capability against manoeuvring hypersonic targets such as HGVs. SBT expands the previous Aegis capabilities by adding SM-6 salvo engagement against threats entering their terminal phase.

To date, MDA and Lockheed Martin have successfully developed the first two increments of SBT, which utilised SM-6 Dual

I (Block I) and Dual II (Block IA) configuration missiles and are gauged toward endoatmospheric interception of ballistic missiles. SBT Increment 3 utilises the SM-6 Block IA upgrade or IAU (integrated avionics upgrade) missile equipped with improved guidance section electronics, which are expected to enhance the missile's capability against manoeuvring hypersonic threats in the terminal phase.

On 24 March 2025, the MDA and US Navy conducted Flight Test Other 40 (FTX-40) which involved an interception of a simulated hypersonic threat – in this case using an MRBM mounting an HTV-1 (hypersonic test vehicle), understood to be a form of HGV. The test involved the Arleigh Burke class destroyer USS Pinckney (DDG 91) which used the SBT Increment 3 capability to acquire and track the target and simulate firing the SM-6 IAU onto an intercept course.

FTX-40 prepares the stage for the next, more ambitious test of the SBT's hypersonic intercept capability. That planned test will be designated Flight Test Aegis Weapon System-43 (FTM-43), and will constitute a live intercept of the MRBM HTV-1 target using the SM-6 IAU. FTM-43 will determine whether the seeker upgrades and new flight-control algorithms enable the interceptor to outmanoeuvre the HTV-1. Overall, "the Aegis Weapon System will play a vital role in the next-generation integrated air and missile defense system (...) as we continue to partner with the Navy in advancing our Nation's counter-hypersonic capabilities," according to MDA Director Collins following FTX-40.

Glide Phase Interceptor

The prominent role of Aegis (both at sea and ashore) for the hypersonic defence mission is not limited to the SBT. The Glide Phase Interceptor (GPI) is a separate development effort to field a new, higher-energy interceptor capable of engaging HGVs earlier, while they're still in the very high atmosphere. In principle, it is intended to bridge the gap between the exoatmospheric SM-3 and the endoatmospheric SM-6.

It will launch from Mk-41 VLS cells on Aegis ships and Aegis Ashore facilities, but will carry a purpose-built KV and seeker optimised for the long, flat glide trajectories of HGVs. The US and Japan signed a co-development agreement for GPI in May 2024, and selected Northrop Grumman's design proposal in September 2024. This design will include a sophisticated seeker design, with the manufacturer's phrasing suggesting a probable dual-mode (infrared and radar) seeker, along with a re-ignitable upper stage engine for threat containment and dual engagement modes to handle threats across a wide range of altitudes.

The current programme timeline calls for achieving IOC by the end of FY 2029, with a minimum of 12 interceptors delivered by that date. Full operational capability (FOC) is required by the end of 2032, including integration with space-based or terrestrial sensors for collaborative engagements. Inventory must consist of at least 24 interceptors by 2040.

Overall, the Aegis system promises to provide a comprehensive and layered engagement capability against HGVs, with the GPI making the first attempt at exoatmospheric levels, while the SBT provides a backup endoatmospheric capability.

Glide Breaker (DARPA)

The Defense Advanced Research Projects Agency (DARPA) initiated the Glide Breaker programme in 2018 to develop and demonstrate "a propulsion technology to support a lightweight vehicle designed for hit-to-kill engagement of hypersonic threats at very long range". Development of a next-generation divert and attitude control system (DACS) capable of executing very tight turns to outperform the manoeuvres of the target will be a central aspect of this programme.

Phase 1 of the Glide Breaker programme focused on development of a control system to enable interception of hypersonic targets. Phase 2 will "develop the technical understanding of

Concept image of hypersonic missiles being deployed to intercept hypersonic glide vehicles. DARPA presented the image as an illustration on its Glide Breaker programme page. [DARPA]

Concept of a European hypersonic interceptor which could emerge from the TWISTER programme. [PESCO/Mourad Cherfi]

jet interactions necessary to enable the design of propulsion control systems for a future operational glide-phase interceptor kill vehicle," said DARPA programme manager Major Nathan Greiner in 2023.

In September 2023, the agency selected Boeing for the Phase 2 contract, which will be fulfilled through early 2027. Boeing will conduct wind tunnel and flight tests to evaluate real-world jet-interaction dynamics and refine DACS-aerodynamics integration. "If successful, the results of Phase 2 will provide the foundation for a future programme of record interceptor," the DARPA solicitation for Phase 2 said. Results are expected to flow into the GPI development programme.

Europe

Several multinational European initiatives to develop hypersonic interceptor technology in support of a layered, interoperable European missile defence architecture are also underway.

TWISTER

In November 2019, the EU's Permanent Structured Cooperation (PESCO) defence initiative launched the Timely Warning and Interception with Space-based Theater surveillance (TWISTER) programme.
The official purpose of TWISTER is to "[strengthen] the ability of Europeans to better detect, track and counter hypervelocity threats, in close cooperation with NATO, through a combination of enhanced capabilities for space-based early warning and endoatmospheric interceptors".
A comparatively broad-based endeavour, the programme addresses a variety of threats including ballistic missiles up to 3,500 km range (including manoeuvring targets such as quasi-ballistic missiles and re-entry vehicles), HGVs, high-altitude supersonic cruise missiles, HCMs, and other manoeuvring air breathing targets (ABT). The three 'legs' of the programme are expansion of space surveillance capabilities to detect HGVs and HCMs in early flight, data fusion across domains to ensure coordinated tracking and engagement among allies, and development of a multi-role interceptor compatible with both ballistic and hypersonic threats.

Two parallel and competing multinational programmes are currently underway to develop the interceptor portion of a future European counter-hypersonic architecture to be fielded circa 2035. Both are coordinated by the Organisation Conjointe de Coopération en matière d'Armement (OCCAR), a multinational organisation that facilitates collaborative defence procurement and development programmes among European nations.

HYDEF

The European Defence Fund (EDF) 2021 call for proposals included a tender for "protection against high-velocity aerial threats". Two proposals were presented: the Hypersonic Defence (HYDEF) concept by a Spanish-German-led consortium (Sener Aeroespacial and Diehl Defence), and the Hypersonic Defence Interceptor Study (HYDIS) consortium led by MBDA France. In July 2022, the European Commission awarded the project to the HYDEF consortium. OCCAR signed the HYDEF contract with Sistemas de Misiles de Es-

The Aquila interceptor missile concept designed by MBDA is a contender for the HYDIS interceptor system. [MBDA]

paña as overall project coordinator on 31 October 2023. Additional industry partners from seven nations are participating, including Diehl Defence as technical coordinator.

The project has a run-time of 36 months and constitutes the concept phase for the endoatmospheric interceptor. As defined by OCCAR, "the project will result in the concept, risk mitigation and demonstration of a cost-effective endo-atmospheric interceptor able to operate in different air levels encompassing new aerodynamic and actuator system for high manoeuvrability, highly agile guidance concepts, and advanced sensor/seeker systems."

The programme met its third technical milestone at the Early Maturation Kick-Off (EM KO) meeting in October 2024. The meeting involved assessing the current technological readiness level (TRL) of these technologies and identifying the resources required to advance their TRLs. All planned activities for the early design and technology maturation phase were reviewed and declared ready to begin. The expected development challenges, as outlined in the Technology Plan, were also addressed. Following the EM KO event the programme formally entered the technology maturation phase, with a focus on defining the system concept. The Concept Selection Milestone (CSM) is planned for August 2025, followed by the Early Maturation Mid-Term Review Milestone (EM MTR) in October 2025.

HYDIS

For its part, MBDA France revised its proposal and resubmitted it in response to the EDF March 2023 call for tenders for a concept architecture and technology maturation study of an endoatmospheric interceptor against new high end emerging threats. In July 2023, the European Commission accepted the tender for what was now designated the HYDIS2 project. OCCAR describes it as "the wider European collaborative response to the pressing need for a new interception solution able to effectively protect European territory, population, high-value assets and deployed forces in the years ahead".

The HYDIS2 consortium consists of four core members – France, Germany, Italy and The Netherlands – and an additional ten participating or supporting nations. With MBDA as the lead contractor among 19 participating firms, the programme is currently in its three-year Concept Phase, which began in May 2024. Interim achievements as of June 2025 include down-selecting from an initial 11 interceptor concepts to six promising designs, and completing a Concept Robustness Review. The Initial Concept Review is scheduled for October 2025. It will downselect the top two designs for further development. The HYDIS programme's goal is to mature critical technologies and finalise a design by 2030, with an in-service target date of 2035.

Israel

In 2023, Rafael Advanced Defense Systems announced it was developing the SkySonic interceptor, with special attention to the European market. According to the firm's website, Rafael's SkySonic interceptor is designed to match the manoeuvrability and speed of hypersonic weapons flying at Mach 5 to Mach 10. The weapon utilises a two-stage design, comprising a solid-fuel booster and the rocket-powered kill vehicle.

SkySonic is intended to confront the complete spectrum of hypersonic threats, neutralising ballistic missiles, HCMs and HGVs. The interceptor system works with current tactical radars for initial target acquisition. Subsequently, the on-board synchronised sensor system identifies incoming threats, permitting the guidance system to predict the threat's trajectory and calculate an intercept course even against projectiles following unpredictable flight paths. The interceptor assumes a non-ballistic flight path, relying on manoeuvrability to quickly adjust to changes in the target's trajectory. Target destruction can be achieved either through direct impact or by proximity detonation of the interceptor's warhead.

The system appears to still be in development. To date, Rafael has not revealed many technical details or precise performance data such as operating altitude and range, nor have they announced any information regarding flight or intercept testing. The firm has published an animated video showing the missile being launched in the field from a transporter-erector launcher, which appeared to be based on a MAN HX81 10×10 vehicle. The vehicle carries a single launch tube, which is nearly as long as the vehicle, implying a missile approaching 10 m in length.

The SkySonic kill vehicle separates from the rocket booster. [Rafael]

Japan

Japan is taking an alternative approach to hypersonic defence. The Japanese MoD's Acquisition, Technology and Logistics Agency (ALTA) is developing and testing an electromagnetic railgun (EMRG) to be used aboard Japanese Maritime Self Defense Force (JMSDF) destroyers for air and missile defence, includ-

▲ **The Japanese railgun demonstrator aboard JS *Asuka*, photographed in April 2025 in Yokosuka. [JMSDF]**

ing intercept of hypersonic weapons. HCMs are considered the primary target set. The current programme was initiated in 2016. In 2023, a prototype was installed aboard the JMSDF's test vessel JS Asuka for evaluation at sea. In October 2023, the ship fired the worldwide first EMRG shots at sea. Testing continues, with ALTA publishing photos of an upgraded ship-mounted prototype in April 2025.

The current demonstrator weighs approximately 8 tonnes and has a 6 m barrel. It fires 40 mm steel projectiles weighing 320 g and consumes circa 5 MJ of energy per shot, achieving muzzle velocities circa Mach 6.5 in testing. Press reports indicate that the prototype has so far achieved sustained firing of 120 rounds without barrel degradation. Scaling the weapon up to 20 MJ, as planned by ALTA, would permit operationally significant range, projectile size and muzzle velocity suitable to the counter-hypersonic mission. Graphics published by the MoD indicate that the operational weapon might deploy various projectile types including a fragmenting or exploding round which would produce a shotgun-like projectile cloud better suited to destruction of high-speed manoeuvring targets.

Remaining challenges include development of materials capable of withstanding the heat and friction of high-intensity rates of fire, as well as improving firing cadence and projectile stability in flight. The demonstrator is powered by three 5 MJ capacitor banks housed in standard ISO containers. According to presentations by Vice Admiral Imayoshi Shinichi, ATLA's Director General of Naval Systems, at the Combined Naval Event 2024 in Farnborough, the JMSDF plans to deploy the ERGM on the future 13DDX destroyer class. These ships are being designed with sufficient power production to support ERGMs as well as directed energy weapons (DEWs). Some Japanese press reports also discuss plans to deploy the railguns on trucks to defend infrastructure and facilities on Japan's islands.

Trends

Research and development activities, as well as discussion of operational concepts, reflect the need for defensive technology to match or outperform the current and the anticipated future threat systems. Several focal points for future enhancement of interceptor systems are likely. These include performance enhancement for interceptor missiles and KVs through higher-performance propulsion and improved manoeuvrability through thrust vectoring and control surfaces optimised for thin-atmosphere flight; AI-driven targeting systems capable of distinguishing targets from decoys and predicting trajectories of manoeuvring targets; multi-domain sensor fusion (space, air, ground, sea) to create a unified threat picture and cooperative intercept procedures; and modular and scalable design to create 'families' of interceptors which can be reconfigured to optimally match threat profiles. Given the fluid and ongoing nature of threat development, hypersonic interceptor systems will be forced to also consistently adapt and improve.

Dual-use offensive/defensive interceptors: Panacea or chimera?

Dr Sidharth Kaushal

Western militaries face an acute shortage of complex weapons while confronting numerically superior adversaries. Multifunctional interceptors offer an appealing solution – yet the reality of engineering missiles to excel in multiple roles proves more challenging than theory suggests.

The question of whether complex weapons should become more multifunctional is a subject of considerable discussion. In the US, the SM-6 missile, which can act as both a surface-to-air missile (SAM) as well as a land-attack and anti-ship capability, represents an exemplar of this design philosophy in action. In Ukraine, the Russia's ability to use SAM systems as a crude form of rocket artillery has also been demonstrated. A focus on multifunctionality has also characterised the design of the Anglo-French Future Cruise/Anti-Ship Weapon (FC/ASW) which will apparently be capable of engaging naval vessels, land targets and high-value aerial targets.

An SM-6 missile is launched from the USS *John Paul Jones* (DDG 53) during Flight Test Standard Missile-27 Event 2 (FTM-27 E2) on 29 August 2017. [MDA/Latonja Martin]

At one level, this is understandable. Complex weapons pipelines are highly strained throughout the West, and the ability to get more functionality out of any given system represents a partial solution to this challenge. It is also the case that the capacity to integrate offence and defence represents a means of mitigating the challenge of adversary mass, which is an acute problem for Western forces and their Allied across multiple theatres. A number of sensors already support offence-defence integration, with examples including the AN/MPQ-64 radar which forms part of a Patriot battery. The radar is capable of calculating the launch position of a target such as a tactical ballistic missile based on its trajectory. It would stand to reason, then, that multifunctional interceptors should complement the inherent versatility of many sensors.

While there is much to be said for this argument, there are significant design trade-offs which multifunctionality imposes on the design of a missile. These trade-offs do not mean that versatility loses all value, but they provide reasons for planners to think carefully about when and where they seek to integrate functions on a single missile and what the price they pay for doing so is.

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Multifunctionality in the maritime domain

The maritime domain represents an area where there has been considerable progress in the fielding of dual-use inter-

ceptors, with the US Navy's SM-6 representing a leader in the class. The SM-6 Block 1B can be employed against air breathing targets, ballistic missiles, surface vessels and ground targets. During the Valiant Shield Exercise in June 2022, the SM-6 was employed in a ship sinking exercise (SINKEX) involving a decommissioned frigate.

While this multifunctionality is impressive, it comes at a price. In a rather literal sense, the SM-6 is one of the most expensive SAMs on the planet with an estimated unit cost of USD 10 million based on the prices for missiles delivered in FY24. In addition, there are fundamental design differences between SAMs and anti-ship missiles. The propulsion system for a SAM is typically a solid rocket motor, which enables the missile to close the distance with fast-moving targets rapidly. By contrast, cruise missiles are typically jet powered which provides them with greater manoeuvrability (albeit typically at lower speeds) and the ability to fly low to evade shipboard air defences. If employed in an anti-ship role, a missile like the SM-6 would likely have to fly on a high-altitude trajectory which would make it independently vulnerable to on board air defences on a well-defended vessel.

There is something to be said, however, for the potential use of a missile such as an SM-6 as part of a larger salvo involving anti-ship cruise missiles. A number of operational analyses conducted by China's People's Liberation Army (PLA) examining the conditions for the defeat of an Aegis-equipped destroyer such as the *Arleigh Burke* class suggest that the convergent use of a ballistic missile and a number of anti-ship cruise missiles might be sufficient to saturate the vessel's onboard radar. In principle, an SM-6 acting as a ballistic target could play a similar role. However, it is unclear whether or not a similar role could also be played by a purpose-designed ballistic missile such as China's ship-launched YJ-21, arguably at a lower cost with greater effectiveness. True, a ballistic missile requires certain enabling features on a vessel such as the capacity to cold-launch missiles, as well as large diameter vertical launch system (VLS). However, the dimensions of an SM-6 do not vary drastically from those of many short-range ballistic missiles (SRBMs) such as PRSM; indeed SM-6's booster diameter is wider than PRsM's diameter.

Second, the warheads on SAM systems are typically poorly-optimised for the defeat of larger vessels and this is true of the SM-6 which appears to employ a blast fragmentation warhead across different categories. Moreover, the warhead is necessarily light to provide the missile with the kinematics needed to engage airborne targets. As such, the functionality of SM-6 against larger vessels remains an open question, with some analyses suggesting it has limited utility against larger vessels (something which would seem to be validated by the fact that it was one of a number of missiles used against a single frigate type target in the Valiant Shield SINKEX).

It should be noted, however, that warhead size is not the best predictor of a missile's lethality against a surface vessel, with kinetic energy on impact typically correlating more closely with the number of missiles on target needed to mission kill or sink a vessel. Even so, however, a blast fragmentation warhead represents a poor tool with which to inflict structural damage on a vessel.

Arguably, multifunctionality might be achieved with a different warhead type such as a hit-to-kill warhead which could be employed against both air-breathing and ballistic targets, as well as high-value surface vessels. A missile with sufficient kinetic energy could in theory achieve lethal effects against a large vessel with even a relatively small warhead. This having been said, much is likely to depend on factors such as whether a missile penetrated a vital part of a vessel. More importantly, however, a SAM used on a ballistic trajectory will provide considerably less range than a comparably-sized cruise missile.

This raises the question of how missiles such as the supersonic, ramjet-powered RJ10 being developed for FC/ASW would be intended to operate, since as a cruise missile, it uses air-breathing propulsion, and thus does not follow the same design principles as the SM-6. If the RJ10 model is used against high-value targets such as bombers, the missile may have to keep pace with potentially supersonic, albeit relatively large, targets. Its ramjet engine should in principle enable supersonic flight at relatively high altitudes – for example Russia's P-800 Oniks anti-ship cruise missile (ASCM) has a flight ceiling of 14 km (roughly the service ceiling of a Tu-22M bomber).

However, complexity arises when designing a payload for two very different tasks. If one equips a missile like RJ10 with a large unitary warhead, such as the 300 kg warhead of a P-800 Oniks, or the 453 kg warhead of LRASM, then it is less useful as SAM given the negative impact of a large warhead on manoeuvrability. A smaller blast fragmentation warhead like the roughly 64 kg of the SM-6 warhead would allow for better

Artist's impression of the two effectors being developed under FC/ASW. These comprise the ramjet-powered supersonic cruise missile known as RJ10 (top), and the low-observable turbojet-powered subsonic cruise missile TP15 (bottom). [MBDA]

USS *Savannah* (LCS 28) launches an SM-6 missile during a demonstration of a containerised launch system, in the Eastern Pacific Ocean, on 24 October 2023. This was understood to be a developmental version of what would later become the US Army's Typhon ground-based launch system for SM-6 and Tomahawk missiles. [US Navy]

functionality as a SAM, but at a cost in terms of anti-surface warfare utility. It could be argued that since kinetic energy is the best predictor of anti-ship lethality, this is an acceptable trade-off. This is particularly true given that in the European theatre most Russian targets are likely to be small surface vessels (with size being the other predictor of how many missiles are needed to sink a ship). However, while justifiable, this choice would necessarily entail trade-offs.

Finally, in addition to the complex dynamics associated with missile design, the matter of command and control (C2) bears considering. If air warfare officers and surface warfare officers are employing the same capabilities, there will be a pull on shared resources. Principle warfare officers can mediate these trade-offs, but multifunctionality makes it more difficult for each group of officers to anticipate precisely which resources will be at their disposal.

The land operating environment

Arguably in the land environment there are stronger incentives to employ dual-use missiles. This stems from the fact that many plausible targets for dual-capable missiles, such as tactical ballistic missile launchers and multiple launch rocket systems (MLRSs) are not large robust targets such as ships and can be destroyed with relatively small payloads. Indeed, evidence from Israel suggests that kinetic hit-to-kill warheads can inflict considerable damage on many types of launchers. While it might be argued that there are a number of launch systems in the land environment which can engage high-value targets, including assets supporting from the air, it must be noted that doctrinally defined tasks such as suppression of enemy air defences (SEAD) will absorb the majority of the strike capacity in both the land and air domains in a number of theatres, including Europe. The suppression of the enemy air and missile threat might, then, benefit from the presence of dual-capable missiles, which can be employed by air defenders without a requirement for support from other arms and echelons.

The use of dual-capable interceptors in the land operating environment is not without its own imposed costs. For example, active radar seekers are unlikely to be of utility against ground targets unless they employ especially small wavelengths. Even then, it is likely that a second mode of inference such as infrared (IR) seekers would be required to cross-reference target types – adding cost and weight to a missile. Alternatively, cueing could be provided from offboard by air assets redirecting missiles towards targets. This would require a network architecture comparable to the US Navy's Naval Integrated Fire Control-Counter Air (NIFC-CA), as well as a mechanism for moving data using low-latency bearers. Equally, however, counterbattery attacks do not need to be perfect to deter the use of a tactical ballistic missile (TBM), for example, as they need to be prompt and have a sufficient chance of damaging impact – something which dual-capable missiles could achieve. Moreover, the development of low-payload effectors which can strike soft skinned targets (as well as supporting air defence) could also enable other parts of a strike campaign.

Closing thoughts

While there are arguably advantages to the use of dual-capable effectors, their development and fielding is by no means simple. Particularly in the maritime domain, even limited multifunctionality arguably imposes cost in excess of the value generated. In the land environment, there is somewhat more purchase for dual-capable effectors, albeit with some latent system engineering problems remaining to be resolved.

Ground-based DEWs: From science fiction to operational deployment

Sidney E. Dean

On 13 November 1973, an MQM-33B aerial target drone 3.6 m long was shot down by a 100 kW class Carbon dioxide laser over Kirtland Air Force Base, New Mexico. A half century later, laser weapons finally had their combat debut.

In late May 2025, reports surfaced on pro-Russian *Telegram* channels stating that the Russian military was deploying a Chinese-built laser weapon against Ukrainian drones. To date, these claims have not been confirmed by either Moscow or Beijing. In contrast, there is more certainty regarding the 28 May 2025 Israeli government announcement that laser weapon systems developed by Rafael Advanced Defence Systems successfully downed "dozens" of aerial drones launched by Hezbollah from Lebanese territory at the beginning of October 2024. Rafael's chairman, Yuval Steinitz, stated that Israel had become the "first country in the world to transform high-power laser technology into a fully operational system and to execute actual combat interceptions".

Rafael's Lite Beam system is a 10 kW class HEL designed to be compatible with even relatively small land platforms, such as the Joint Light Tactical Vehicle (JLTV). [Rafael]

This begs the question: why did 51 years pass between the 1973 Kirtland AFB demonstration and the first operational deployment of an offensive or interceptor laser? The short answer is that the technology of the 1970s – and 1980s and 1990s – was insufficient to realise the ambitions of either the United States or any other military. It was not until the early 2000s that the Zeus-HLONS (Zeus-HMMWV, Laser Ordnance Neutralization System) was deployed to Afghanistan and Iraq. Despite still being developmental, and having no more than 2 kW output, the vehicle-mounted system succeeded in destroying hundreds of mines and roadside bombs. However, the static targets provided comparatively little challenge. Fielding directed energy weapons (DEWs) which were both battlefield practical and possessed sufficient precision and power to engage and neutralise moving targets would take another two decades.

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Major challenges

While various different technologies fall under the category of DEW, the two types of weapons currently being pursued are high-energy laser (HEL) and high-power microwave (HPM) weapons. Near-term ambitions centre around counter-unmanned aerial vehicles (C-UAV), as well as counter rocket, artillery and mortar (C-RAM) applications. With further development, armed forces hope to eventually expand DEW capabilities to include downing cruise missiles, ballistic missiles and manned aircraft. While research and development is ongoing for ground-based, ship-based, and even airborne DEW systems, this article will focus on fixed and mobile ground-based technology.

Fielding effective directed energy weapons faces several challenges. HELs in particular rely on generating and maintaining a sufficiently powerful and coherent beam, and keeping that beam on a moving target for sufficient time to either disable sensors (if pursuing the less-lethal option), or burn through the target's skin to destroy vital components. Improvements in optics, computing power and artificial intelligence are making significant progress with regard to beam coherence and targeting capabilities.

However, power and cooling demands remain significant challenges for both HELs and HPMs, especially for mobile weapon systems. While industry and the military frequently cite DEWs as possessing 'infinite magazine depth' as a major advantage over conventional projectile weapons, in practice tactical DEWs still have a limited combat endurance. Most vehicle engines and diesel-powered field generators do not produce sufficient continuous power to directly feed energy weapons (especially at higher power levels). More commonly, they charge batteries which in turn power the weapons, either directly or via Supercapacitors. When the batteries are drained, they must be recharged before the weapons can resume firing. DEWs deployed to protect fixed or relocatable sites can alternately be powered directly from the electric grid, promising greater endurance.

Independent of energy supply, DEWs' operational endurance is limited by their thermal management capacity. Both HELs and HPMs both quickly generate massive amounts of heat which, if not managed correctly, degrades performance and can damage vital working components. Both weapon types typically require substantial cooling-off intervals after relatively brief (compared to projectile weapons) sustained firing. Here again, DEWs operating from fixed locations (and indeed on naval vessels) can be provided with larger and more powerful cooling systems than those operating from tactical vehicles. Indeed; for land vehicles, these cooling systems will represent a further burden on available power, as well as available volume and weight.

Further complicating matters is the issue of increasing effective range – simply put, to make HELs and HPMs able to engage targets beyond very short ranges, significantly more power is needed. This in turn makes it more of a challenge to meet system power supply and cooling requirements, and so requires more onboard volume and weight dedicated to the DEW. Additionally, in the case of HPMs, the powerful signals they emit make them highly vulnerable to discovery by hostile electronic intelligence (ELINT) systems.

The challenges have not deterred the armed forces of many nations from systematically pursuing the technology. This persistence is beginning to pay off, with development projects in the United States, Europe and Israel showing significant progress recently.

United States

The United States Army and US Air Force (USAF) are pursuing multiple DEW programmes, several of which are considered high priority. These include:

DE-M-SHORAD

The Stryker-mounted Directed Energy Maneuver Short-Range Air Defense (DE-M-SHORAD) system is intended to augment the in-service gun- and missile-armed Sgt Stout M-SHORAD vehicles escorting manoeuvre forces.

The Army intends to deploy DE-M-SHORAD against Group 1-3 UAVs and in the C-RAM role; Department of Defense (DoD) documents also mention a potential capability to combat helicopters and low-flying fixed-wing aircraft, although this would be considerably more challenging given the typically greater ranges which would be required for engaging these latter target types.

In 2023, four prototypes (developed by Kord Industries as lead integrator) were assigned to an Army Air Defence Artillery platoon for evaluation. The prototypes' primary weapon is a scalable RTX-designed 50 kW class laser powered by Lithium-Nickel-Cobalt-Aluminium oxide (Li-NCA) batteries charged by diesel generators aboard the vehicle. The platoon deployed to Iraq in 2024 for operational evaluation, but the results were below expectations. The Army's Rapid Capabilities and Critical Technologies Office (RCCTO) postponed DE-M-SHORAD's transition to a programme of record, and issued new prototype contracts.

▲ The DE M-SHORAD prototype in February 2024 in Huntsville, Alabama. [US Army]

In June 2025, the Army conducted an exercise at Fort Sill, pitting prototype DE weapons, including a DE M-SHORAD system, against a swarm of Group 1-3 UAS. The Army's 27 June 2025 press release stated that data from these tests will shape future HEL development and procurement. The statement also stressed that short-range directed energy systems are intended to augment, not replace, kinetic weapon systems.

IFPC-HEL/IFPC-HPM

The indirect fire protection capability (IFPC) is a vehicle-mounted system designed to protect high-value fixed and relocatable sites against UAVs, RAM threats and cruise missiles. In addition to kinetic weapon systems, an IFPC-HEL variant and an IFPC-HPM variant were planned. In 2023, the RCCTO awarded Lockheed Martin a contract to deliver vehicle-mounted 300 kW class laser weapon systems prototypes by October 2025. However, the Congressional Research Service notes that future funding for IFPC-HEL is eliminated from the Army's budget plans starting in

FY2026, effectively freezing the programme; the impact of this on the IFPC-HPM remains to be seen, as the two types were to be used in tandem.

Meanwhile, Epirus provided the RCCTO with four transportable IFPC-HPM prototypes in FY 2024. According to Epirus, New Equipment Training (NET) and Engineering Developmental Testing (EDT) by the Army validated the HPM system's effectiveness against drones and drone swarms in a series of increasingly complex flight patterns. Epirus has stated that their HPM system functions differently to many others, using long pulses (circa 1 ms) to cause more sustained interference within circuitry, as opposed to the more typical approach employing very short pulses (circa 10 ns) at very high peak power.

Furthermore, on 17 July 2025, the RCCTO placed an order worth USD 43.5 million for two Integrated Fires Protection Capability High-Power Microwave (IFPC-HPM) Generation II (GEN II) systems. According to Epirus, these models are more capable than the GEN I models initially procured; in a press release the company stated: "*The IFPC-HPM GEN II systems are expected to more than double the maximum effective range of GEN I systems, increase power by a projected 30 percent and feature the inclusion of high-density batteries for prolonged operating times and decreased external power requirements, extra-long pulse widths for maximizing energy output for target defeat, high-duty burst mode for faster multitarget engagement, advanced waveform and polarization techniques for increased lethality against a broader set of targets of interest and Soldier usability enhancements.*"

Open architecture HEL

The IFPC-HEL funding change notwithstanding, the Army underscores its enduring commitment to fielding HELs. In March 2025, Huntington Ingalls Industries (HII) announced an RCCTO award to develop and test an open architecture HEL weapon system prototype to acquire, track and destroy Group 1-3 UAVs. It will be suitable for both fixed-site defence and integration onto vehicles. The open architecture will permit exchange of subsystems and software as the weapon evolves. According to HII, the RCCTO award is expected to ultimately culminate in a transition to the US Army's Program Executive Office for Missiles and Space. "As part of this process, HII's prototype HEL will undergo field testing to evaluate its safety and operational suitability. Upon successful demonstration, the system is expected to transition into low-rate initial production," according to the company's press release.

High-power microwave weapons

The USAF is focusing more closely on developing HPMs suitable for defence of fixed or semi-fixed installations such as air bases. In December 2022, the Air Force Research Laboratory (AFRL) opened the 1,100 m2 High-Power Electromagnetic Effects and Modeling Facility at Kirtland AFB. According to the AFRL press release, the facility will be used for planning, developing, prototyping, testing and deploying high-powered radio/microwave frequency weapons systems.

THOR/Mjölnir

Even prior to opening the centralised lab, the USAF has experimented with several HPM designs and prototypes. These include the Tactical High-Power Operational Responder (THOR) technology demonstrator developed by the AFRL in conjunction with Leidos and BAE Systems. The entire weapon system fits inside a 6-m ISO container, topped by the emitter antenna mounted on a fast-moving gimbal. THOR is powered directly from the electric grid, operating (as expressed by the AFRL) "from a wall plug. (...) A target is identified, the silent weapon discharges in a nanosecond and the impact is instantaneous." Evaluation began in 2018, and following a successful 12-month overseas field operation assessment, testing culminated in April 2023 with the defeat of a mock swarm attack at Kirtland AFB.

A follow-up system designated Mjölnir (named for the mythological Thor's hammer) is being developed by Leidos under a 2022 contract. Building on THOR's capabilities, the new prototype is expected to achieve greater capability, reliability, and manufacturing readiness. "Mjölnir will focus on creating a detailed blueprint for all future [C-UAV] HPM systems with enhanced range and technology for detecting and tracking UAVs," said Adrian Lucero, THOR programme manager at AFRL's Directed Energy Directorate, in February 2022. Like THOR, it is conceived for comparatively close-range defence against Class 1 and 2 UAVs.

CHIMERA

In contrast, the Counter-Electronic High-Power Microwave Extended-Range Air Base Defense (CHIMERA) is designed to engage medium- to long-range targets.

Air Force Research Laboratory researchers making final touches on the CHIMERA equipment prior to conducting system tests. Beam width on HPMs can generally be scaled to match the threat scenario. [AFRL]

AFRL awarded the development contract to Raytheon Missiles and Defense in October 2020. In January 2024, a successful three-week field test was conducted during which CHIMERA applied directed energy to multiple static target variations, and acquired and tracked aerial targets through their entire flight path. According to Raytheon, the system wields more power than other HPMs designed to defeat airborne threats (as indeed it would need to, in order to engage such targets at longer ranges). Unclassified public information regarding CHIMERA remains limited.

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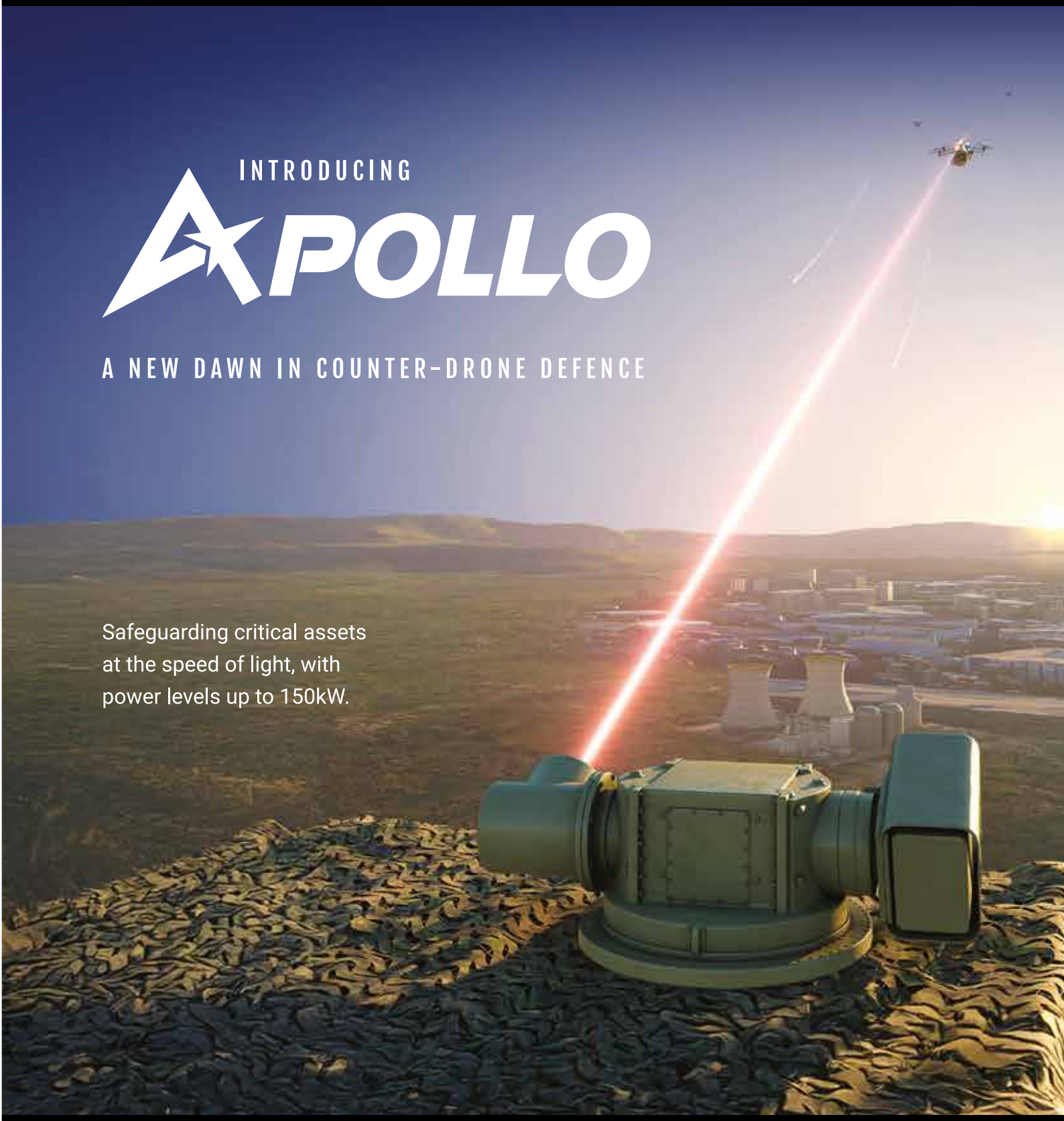

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Europe

Numerous multinational (European Union) and national-level DEW research, development and testing programmes are underway in Europe.

TALOS-TVVO
The Tactical Advanced Laser Optical Systems: Technologies for High Power Laser, Vulnerability study, Vignette development and Operational Study (TALOS-TVVO) is funded by the European Defence Fund. Launched in December 2024 and running for 36 months, some 21 firms and institutes from eight EU nations are involved, including CILAS (as project coordinator), Leonardo and Rheinmetall. The goal is to enable development of fully European and sovereign 100 kW class laser weapons by 2030. To this end, the project will work to mature critical technologies and subsystems, ensure an adequate European industrial base and supply chain for HEL production, and build demonstrators. The programme intends to coordinate with national MoDs to permit TALOS-TVVO technologies to flow into national HEL programmes; technologies are to be flexible enough to satisfy different end-user requirements.

PESCO DES
The EU's Directed Energy Systems (DES) project was officially approved on 27 May 2025 under the EU's Permanent Structured Cooperation (PESCO) initiative framework and is set to run from 2025 to 2029. The project aims to develop modular and scalable DEWs that can be mounted on any mobile platform. The primary focus is on Short- and Very-Short-Range Air Defense (SHORAD/VSHORAD) capabilities for the CUAV and CRAM mission as well as defence against loitering munitions and cruise missiles. The DES initiative will integrate scalable high-energy laser technology (10–100 kW power) into military vehicles and will feature an advanced command and control (C2) system, incorporating threat evaluation, sensing, and weapon assignment tools. Precision, engagement speed, adequate 'magazine depth' and low-collateral potential are key requirements. The project is led by Italy, with Spain as a key partner; major industry partners include Leonardo and MBDA.

DragonFire
At the national level, Britain has been making notable advances toward fielding a HEL weapon. Overall the MoD plans to invest GBP 1 billion for DEW programmes over the next five years as part of a spending package announced in June 2025, building on years of previous research and development.

The MoD's Defence Science and Technology Laboratory (Dstl) awarded the DragonFire HEL technology demonstrator contract in 2017. The system was designed by MBDA as lead contractor, with Leonardo providing the beam director and QinetiQ the laser source. A series of incremental tests led to the UK's first high-powered long range laser trial in 2022, during which DragonFire was successfully tested against static targets (including mortar bombs) at up to 3.4 km range. In late 2023, the HEL defeated the first aerial targets. According to a June 2025 statement by Dstl, recent successful testing includes over 300 firings of the DragonFire demonstrator and 30 drone defeats. Precise performance parameters remain classified, but the MoD states that DragonFire can engage with any visible target with "pinpoint accuracy, [...] leading to structural failure or more impactful results if the warhead is targeted". On 2 June 2025 the MoD announced plans to arm the Royal Navy's Type 45 destroyer with DragonFire. By contrast, the current Army-tested demonstrators will not enter service, but provide crucial insights for future DEW development.

Land LDEW Demonstrator
Another ongoing UK MoD programme is the 'Land LDEW' (Laser Directed Energy Weapon) Demonstrator programme, an advanced capability demonstrator initiative designed to explore and accelerate the integration of DEWs onto land platforms.

During this programme, British Army air defence personnel evaluated the Raytheon High-Energy Laser Weapon System, mounting it on a Wolfhound armoured vehicle. In early November 2024, the

▲ The British military's advanced capability laser demonstrator mounted on a Wolfhound tactical vehicle. [UK MoD]

system engaged and destroyed multiple UAVs in midair at varying altitudes, distances and speeds. This constituted the first such test of a HEL from a British armoured vehicle (the DragonFire tests were conducted from fixed test platforms). As noted by the MoD, "putting the demonstrator in the hands of the Army early will help inform future requirements and reduces the risks associated with future DEW acquisition. The intent is not to simply introduce these systems into service, but to use the demonstrators as building blocks for laser weapon capability in the UK."

On 13 June 2025, the UK MoD put out a preliminary market engagement notice soliciting industry proposals for a HEL system capable of destroying small UAVs at ranges of over 1 km, with a declared budget of GBP 20 million for purchasing "multiple systems", and with envisioned contract period of 1 August 2025 to 31 March 2026.

RapidDestroyer
The UK's Dstl is also testing an HPM for the C-UAV mission. The system has previously been referred to as 'RFDEW' (Radio Frequency Directed Energy Weapon) under Dstl's Project Ealing, but has since been designated 'RapidDestroyer' by Thales UK, the lead developer under Team Hersa (which also includes QinetiQ, Teledyne e2v and Horiba Mirais).

Like other HPM weapons, RapidDestroyer promises to be especially valuable against drone swarms by virtue of being able to generate a wide beam to engage multiple targets simultaneously, though it can also generate a narrow beam to engage individual targets. Both the UK MoD and Thales announced on 17 April 2025 that the system had successfully concluded the largest counter-drone swarm exercise the British Army had conducted to date. During the experiment, the Army brought down two swarms of drones in a single engagement; across the complete testing cycle more than 100 drones were tracked, engaged and defeated by RapidDestroyer. "With improvements on range and power, which could come with further development, this would be a great asset to Layered Air Defence," said Royal Artillery Sgt Mayers after participating in the experiment.

▲ The 'RapidDestroyer' HPM system on an RMMV HX60 4×4 truck platform during British Army trials. [UK MoD]

The electromagnetic pulses emitted by RapidDestroyer disrupt or damage critical electronic components inside drones, causing them to crash or malfunction. According to the UK MoD, the system currently has a range of up to 1 km against small UAV-type targets.

Israel

According to the Israeli MoD, the laser DEW systems deployed at the country's northern border in 2024 were related, but not identical to, the Magen Or ('Shield of Light'; better known internationally as 'Iron Beam') system, which the Israel Defense Forces plan to introduce operationally by the end of 2025. The 100 kW class Iron Beam system is designed to intercept UAVs, RAM threats, and cruise missiles at ranges of up to 10 km (roughly the same as early versions of Iron Dome). The semi-mobile containerised weapon system can be deployed to defend military installations, high-value infrastructure or civilian population centres. The system operator controls the weapon remotely via datalink. As described by Rafael, high-performance beam directors and adaptive optics permit persistent focus of the beam on one coin-sized spot on the target, resulting in target neutralisation within seconds. Rapid retargeting capability neutralises swarm attacks.

Rafael is also developing a mobile variant 'Iron Beam-M', a truck or armoured-vehicle mounted system utilising a 50 kW laser, with a range of "several kilometres". Suitable as a stand-alone weapon or integration into a layered air defence network, the Iron Beam-M can accompany manoeuvre forces or be deployed to protect fixed sites against UAVs and loitering munitions. Power for beam generation and for cooling is provided by a battery storage bank that is charged periodically by an onboard generator.

Rounding out the Rafael L-DEW family is the Lite-Beam, a 10 kW class system which can engage low-flying aerial targets as well as ground targets. It is designed to neutralise swarms of

▼ Iron Beam HEL shown during testing. [Israeli MoD]

up to ten targets at ranges up to 3 km. The lightweight weapon can be integrated aboard a wide range of tactical vehicles including 4×4, 6×6, 8×8 and tracked armoured fighting vehicles. This versatility makes it highly suitable for rapid relocation as needed.

Finding their niche

While not a panacea, DEWs – whether HELs or HPMs – have great promise as one component of layered air and missile defence networks defending both fixed installations and manoeuvre forces. The growing diversity of aerial threats requires an equally diverse set of scalable countermeasures. Both lasers and microwaves travel at the speed of light, hypothetically making them more responsive than kinetic munitions (depending on the 'dwell time' on target). DEWs are particularly suited to defeating small to medium UAVs and swarm attacks which could either overwhelm, or would be uneconomical to engage with traditional cannon-or missile-based air-defence systems. Engineers and military planners presume that upscaled DEWs, such as lasers in the 500 kW to MW range, could defeat cruise or even ballistic missiles. Integration into air defence command and control systems, refining targeting systems, and overcoming thermal management and power supply challenges will determine if and when DEWs can unleash their full potential on the future battlefield.

Catch the wave

Dr Thomas Withington

European military networking has taken an important step forward with the realisation of the ESSOR suite of waveforms, some, or all, of which look likely to be adopted throughout NATO in the coming years.

Land forces fighting together in a coalition have, in recent times, often struggled to talk to their counterparts. For example, a Canadian Army brigade might struggle to communicate with elements from the *Heer* (German Army). Should land formations need to communicate directly, voice and data traffic has often flowed upwards to reach the joint command, flowing back downwards to its intended recipients. The reason for this is comparatively simple: Land forces have lacked common, interoperable, tactical communications waveforms they can use for interforce connectivity.

Intra-force communications, where individual armies network between formations, echelons and combat arms, have been comparatively easy. Several NATO member countries employ tailored tactical waveforms to meet their specific operational needs. For instance, the French Army *(Armée de Terre)* uses the Geomux high-data-rate waveform with Thales' PR4G family of radios. The US Army and US Marine Corps, meanwhile, operate a wide range of tactical communication waveforms suited to their respective missions. The Army's TSM waveform carries secure high-data-rate voice and data traffic for instance.

A common inter-force waveform was developed in the 1980s to equip the Single Channel Ground and Airborne Radio System (SINCGARS), a revolutionary family of tactical radios and waveforms intended to provide secure and robust inter-force communications. It was adopted by the US Army and other NATO land forces. Nonetheless, some exceptions to this dearth of inter-force connectivity do exist: NATO's HAVEQUICK-I/II waveform is intended for Alliance-wide air-to-surface/surface-to-air and air-to-air communications. HAVEQUICK-I/II is a frequency-hopping waveform using a very/ultra-high frequency (UHF) waveband of 225 MHz to 400 MHz. The waveform is installed on US-supplied radios as it is covered by the US's International Traffic in Arms Regulations (ITAR). The majority of NATO's land forces have tactical radios provided by US suppliers such as L3Harris. These ITAR-controlled radios contain the HAVEQUICK-I/II waveform. The intrinsic interoperability of HAVEQUICK-I/II makes sense. A Hellenic Army Joint Terminal Air Controller (JTAC) might be coordinating a close air support (CAS) mission with a *Luftforsvaret* (Royal Norwegian Air Force) F-16 series combat aircraft. It is imperative that both the JTAC, and the Norwegian pilot, can use a common, robust and secure waveform to manage a task as complex as CAS.

AUTHOR

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

The advent of the SINCGARS radio in the 1990s was a major step forward in fostering intra-force connectivity in the US Army, and elsewhere in NATO. However, inter-force networking for land formations has, until now, remained elusive. [US Army]

European nations have fought in coalitions in scores of operations since the end of the Cold War. NATO efforts in the Balkans and Libya were primarily focused on air campaigns, though this was not the case in Afghanistan. There, Alliance and Allied nations deployed significant land power. Two realities highlight the imperative that European nations need robust and effective interforce communications: The first is the continent's strategic situation. Russia's initial invasion of Ukraine in 2014, and full-scale invasion eight years later, has shown that Moscow's territorial ambitions remain the greatest threat to Europe since the Cold War. Short of a complete Russian defeat in Ukraine, and her full expulsion from the territory of Ukraine, the threat posed by the muscular strategic posture of President Putin's government is unlikely to diminish. Any invasion of NATO will see European Alliance members fighting to push the aggressor back behind its borders. It is noteworthy that several European nations already comprise eight NATO battlegroups deployed in Bulgaria, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia.

Multi-domain operations

Alongside Europe's strategic reality, NATO's membership writ large is embracing the multi-domain operations (MDO) mindset. The Alliance defines MDO as "the push for NATO to orchestrate military activities across all operating domains and environments. These actions are synchronised with non-military activities and enable the Alliance to create desired outcomes at the right time and place."

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When communications go dark, so does command

New tools for assured coordination when digital infrastructure collapses

Tim Williams

In modern military operations, digital silence is not an edge case – it's a likely condition. Denied environments, electronic warfare, emissions control protocols and infrastructure attacks routinely disrupt the systems that forces rely on for coordination. Traditional communications become unreliable, untrusted or vanish altogether. When connectivity fails, units risk becoming operationally isolated, unable to verify instructions, share intent or maintain tempo. This "cliff edge" in command-and-control infrastructure is one of the most immediate and under-addressed threats facing deployed forces today.

Although long-cycle modernisation programmes continue to reshape communications architectures, they cannot eliminate the reality of collapse. The assumption that assured command is always available – via hardened networks, roaming agreements or access to secure cloud environments – no longer holds. And this is not solely a concern for expeditionary forces. In European, Indo-Pacific and grey zone contexts, degraded digital conditions are increasingly the norm. Forces must plan not just for contested networks but for their total absence.

Bracer is not simply a tactical radio or niche app, it is a coordination tool built for the hard edge of modern operations where systems fragment; emissions must be tightly governed; and no commercial trust layer can be assumed. It preserves command logic when primary networks fail.

Coordination under pressure

Dispersed units that cannot coordinate, cannot contribute meaningfully to a manoeuvre force. In degraded conditions, even essential mission data – location, intent, timing or task updates – becomes vulnerable to delay, duplication or doubt. Mission command is often employed to address communication losses. However, today's battlefield is a complex, multi-layered domain where continuation of broader coordination is essential across all elements, not just single entities.

AUTHOR

Tim Williams is a former military tactical communications specialist who joined QinetiQ after a distinguished career. He led the concept, design, and introduction of Bracer to meet the operational need for resilient PACE communications.

[QinetiQ]

Conventional platforms often rely on persistent signal, SIM-bound identity or centralised infrastructure. When these fail, commanders face more than a loss of connectivity – they risk the erosion of trust in the operational picture: who sent what, when, why and under whose authority?

Coalition operations amplify these problems. In joint or combined deployments, forces often rely on improvised tools: commercial messaging apps, hybrid networks or fragmented systems with limited interoperability. These may suffice during training but often collapse in the operational environment – or introduce unacceptable risks. In some scenarios, commercial identity services or cloud-hosted apps can even compromise emissions discipline, inadvertently revealing force posture or movement.

In response, a new class of coordination tools is emerging – lightweight and built to function when conventional infrastructure fails. Among these is Bracer, a UK-developed coordination tool, designed and delivered by QinetiQ, for assured mission continuity off-grid, under pressure, and in digitally contested environments.

Engineered for the break

Bracer does not assume connectivity. Its architecture is multi-peer, with no reliance on central servers, cloud infrastructure or commercial identity services. Instead, it uses cryptographically assured

identity and message validation, bound directly to the device rather than a SIM or user account. This ensures that even in the absence of signal, users can trust not only the message content but also its origin, timestamp and delivery integrity.

Bracer prioritises mission assurance over user convenience. It does not automate delivery acknowledgements; instead it supports voice-based verification, auditability and policy-driven usage – not chat threads or video feeds. Bracer supports BLOS (Beyond Line of Sight) communication via the Iridium satellite constellation.

The interface is stripped back for field use: one device, one identity, fully controlled by the owning organisation. There is no app store, no vendor back-end and no marketing data trail. Bracer operates as a standalone secure node or integrates into wider mission systems via specific audio leads. Position reports are received by the Bracer handset and can be converted into mapping formats (Cursor on Target or KML) using software on a connected laptop to ingest the data onto mapping software.

From concept to combat

Bracer's design is grounded in operational need, not theoretical risk modelling.

On an operational deployment, teams operating in a non-permissive, infrastructure-poor environment were unable to use their standard communications suite due to concerns over attribution and emissions. With no access to classified networks and no safe reliance on commercial infrastructure, Bracer enabled secure peer-to-peer coordination between teams – preserving tempo and situational awareness without compromise.

In another case, a deployed reconnaissance unit experienced partial jamming and GPS denial in a hostile EW environment. Conventional systems degraded unpredictably and coordination was lost briefly. Bracer, running independently using its mitigation techniques, enabled team leads to verify instructions and keep the mission running while primary links remained unreliable.

Joint operations illustrate Bracer's utility. In a coalition exercise involving mixed national infrastructure, the platform was used to establish a shared coordination layer – enabling units to exchange verified instructions without dependence on a single common network or commercially hosted platform. Each nation retained control over its own secure node but Bracer enabled trusted interoperation without requiring shared infrastructure or disclosure of sensitive configuration.

These examples are not anomalies. As more forces conduct contingency planning for grey zone, sub-threshold and EW-contested environments, the requirement for infrastructure-independent, survivable and interoperable coordination tools is growing. Bracer is not a replacement for enterprise command systems – it is a fallback system designed to persist when they fail.

Designed for command, owned by the operator

Bracer is designed for deployment under full organisational control. It runs on standard or ruggedised hardware, can be body-worn or embedded on platforms, and requires minimal vendor-managed infrastructure. All coordination logic is bound to the organisation's defined trust model. Administrators – not developers – define the platform's operational policies, with the flexibility to adjust behaviour in line with emissions protocols, security posture and mission context. Bracer behavior is governed by cryptographically-asssured policies, defined and updated by the owning organisation.

Bracer is not subject to ITAR export controls. For coalition and Special Operations users, this offers critical operational freedom where other systems may be constrained by licensing, national caveats or vendor dependencies. It is well-suited to partnering with forces in developing countries where interoperability is essential. Sovereign encryption will not be compromised, while still ensuring security, coordination and position reporting.

Bridging the gap

Bracer plays a strategic role, filling a vital capability gap between current limitations and future infrastructure. Major modernisation efforts are underway but many hardened networks and battle management systems remain years from full operational deployment, and even when fielded are often operationally irrelevant. Yet the need for assured coordination exists now – at the edge, under pressure and often with no reliable backup.

By offering a resilient tool that operates without dependence on traditional infrastructure or fragile trust models, Bracer is already enabling frontline users to preserve mission continuity in the most demanding conditions. Iridium provides a robust, global option when other links are unavailable.

Bracer is already in operational use. It is enabling assured coordination, verified command and mission continuity when digital infrastructure is degraded or absent.

[QinetiQ (4)]

Download the technical white paper at www.qinetiq.com/en/capabilities/ai-analytics-and-advanced-computing/bracer-white-paper

MDO can also be defined as the full inter- and intra-force connectivity of all military assets within and beyond one or several theatres of operations to enable synchronous operations at all levels of war across all domains. The goal of MDO is to facilitate faster, and better quality, decision-making than one's adversary. The logic underpinning this decision-making improvement is to ensure that blue forces remain continuously proactive. Conversely, red forces will be compelled to be continually reactive. MDO theory holds that this proactive/reactive paradigm should be a precondition for blue force victory.

Enter ESSOR

This apparent lack of a common, secure inter-force networking waveform has concentrated minds within the European defence community and prompted the development of such a capability. Work began in 2009 on an initiative known as the European Secure Software Defined Radio (ESSOR) waveform. Prophetically, ESSOR began before the full breakdown in relations between Russia and NATO, but the effort has proven prescient. The goal foreseen for ESSOR was to develop a secure networking waveform that can be installed in a host of different tactical radios used by different nations. The ESSOR programme is managed by OCCAR (*Organisation Conjointe de Coopération en Matière d'Armement*/Joint Organisation for Armaments Cooperation), a European supranational institution which manages collaborative defence programmes across the continent. The waveform is being developed by six companies in a consortium called A4ESSOR namely Bittium, Indra, Leonardo, Radmor, Rohde & Schwarz, and Thales. The armed forces of France, Finland, Germany, Italy, Poland and Spain are slated to receive ESSOR waveforms. Funding for ESSOR is secured from member nations and OCCAR itself.

Alongside OCCAR, the ESSOR initiative is supported via a European Defence Agency (EDA) Permanent Structured Cooperation (PESCO) project. PESCO was established in December 2017 under Article 42(6) of the Lisbon Treaty—introduced in the 2007 Treaty of Lisbon—to deepen defence cooperation among EU member states. The Lisbon Treaty essentially forms the EU's constitutional basis, and lets the Union sign treaties and join international organisations as an entity. As such, PESCO projects are intended to help EU member states develop common defence capabilities collaboratively by pooling financial and intellectual capital. The ESSOR PESCO was one of the original tranches of 17 projects adopted by the European Council in March 2018.

The ESSOR effort is developing four specific waveforms that can be installed across a wide array of tactical radios, airborne transceivers and satellite communications (SATCOM) terminals. Land forces are set to use the high-data-rate waveform (HDRWF) and narrowband waveform (NBWF). Both the HDRWF and NBWF will primarily be employed for surface-to-surface communications carrying voice and data traffic. The three-dimensional waveform (3DWF) is designed for air-to-air and air-to-surface/surface-to-air traffic. Finally, the SATCOM waveform supports over-the-horizon space-based communications. Both the Finnish and French militaries are using the HDRWF operationally, ESSOR programme sources have disclosed. Moreover, both the Croatian and Irish militaries will receive the waveform by virtue of recent tactical radio acquisitions they made from Bittium and Thales respectively.

The HDRWF uses frequencies of 225 MHz to 400 MHz handling up to 1 Mbps of data with up to 200 individual radios being hosted on each HDRWF network. The NBWF uses similar V/UHF frequencies to the HDRWF, with the addition of a 30 MHz to 88 MHz VHF waveband. This waveform handles data at kilobits-per-second rates and each NBWF network hosts up to 60 users. Data rates for the 3DWF are dynamic, adjusting to prevailing electromagnetic conditions, with each network capable of hosting up to 32 users. Like all ESSOR waveforms, it incorporates robust communication and transmission security protocols.

ESSOR for NATO

To date, the ESSOR programme has primarily been a European effort, rather than a NATO-wide initiative, led by OCCAR. Nonetheless, the situation is changing. In 2023, the HDRWF's specifications were formally enshrined in NATO's STANAG-5651. By enshrining the waveform's design criteria in this STANAG, tactical radio developers have a blueprint on the software characteristics. This is essential if their wares will need to accommodate this waveform. The HDRWF's incorporation into STANAG 5651 goes a long way to answer a longstanding NATO requirement for a wideband coalition waveform. NATO launched the Coalition Wideband Networking Waveform (COALWNW) initiative in 2009, coincidentally the same year that ESSOR got underway. COALWNW had many similar aspirations to ESSOR: It was to provide a wideband waveform that could expand and deepen multinational networking for land forces. However, COALWNW's development proceeded at a glacial pace for

Finland's land forces, alongside those of France, are now thought to be using the ESSOR high data rate waveform operationally. Other armies are expected to implement ESSOR in their tactical communications in the coming years. [Bittium]

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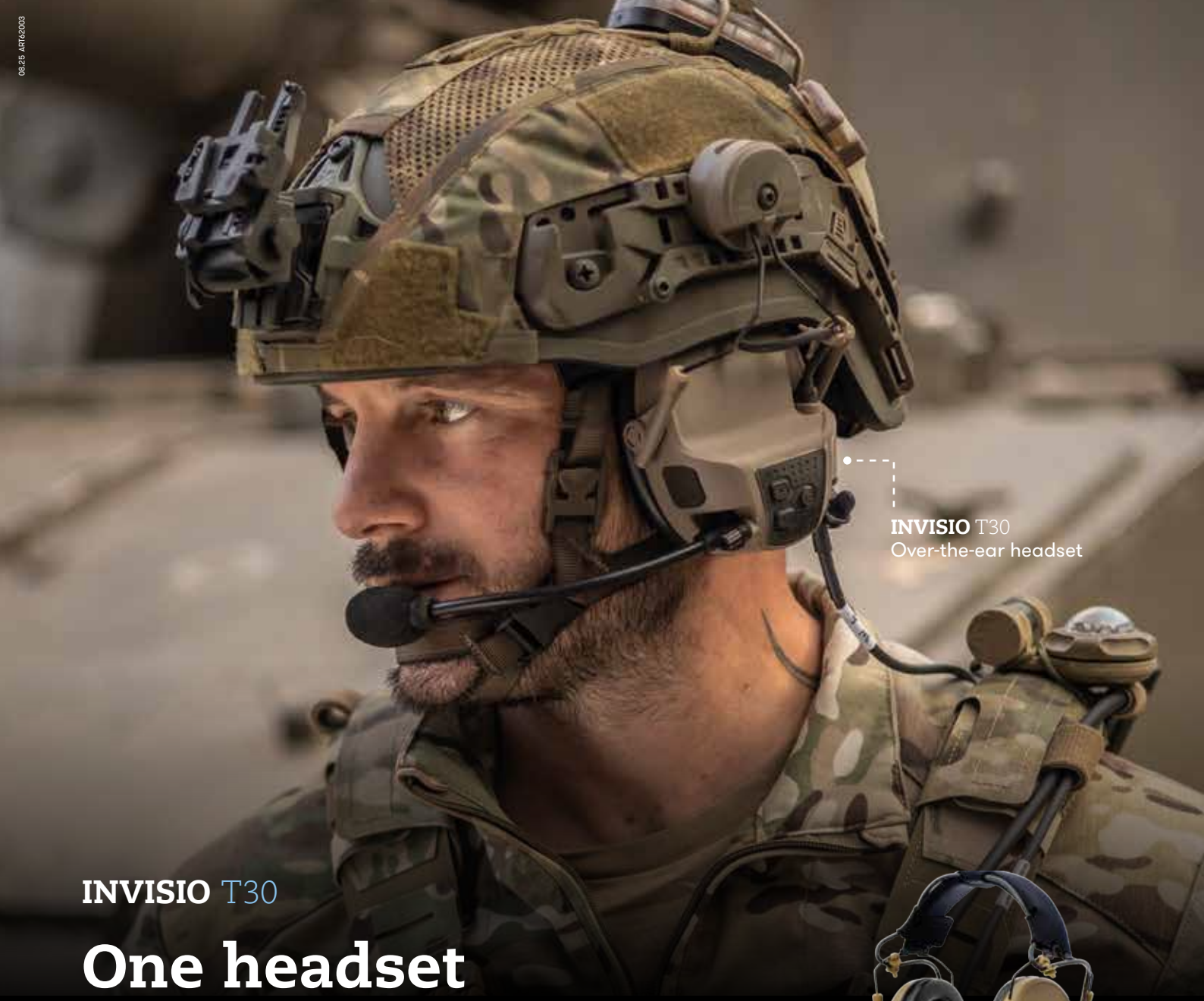

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New tactical radios being supplied by Thales to equip Ireland's military will comprise the ESSOR HDRWF which will significantly improve intra- as well as inter-force networking. [Thales]

many years, and the initiative is now considered all but ended, according to NATO sources. ESSOR's adoption into STANAG-5651 effectively sees this waveform satisfy the COALWNW requirement.

In fact, the adoption of ESSOR by countries such as Ireland show that the waveform will help inter-force networking both within and beyond NATO's militaries. Although not an EU member state, the United Kingdom is a member of OCCAR. Like other NATO members, the UK's Ministry of Defence (MOD) sees the importance of the realisation of a wideband, coalition networking waveform. Although the MOD is yet to formally join ESSOR, there is substantial interest in the project. There may also be added urgency for the UK to participate in the initiative given that COALWNW is now all but dead. The UK has two choices in that she could join the programme as an industrial partner. This was the route Germany took in February 2020 which also saw Rohde & Schwarz join A4ESSOR as an industrial participant. Alternatively, the MOD could remain outside the programme but add the waveforms to UK military radios as and when they become available. This could be done via the NATO STANAGs discussed in this article. Likewise, the UK could simply have the waveforms preloaded into the future tactical radios the MOD acquires. This has been the approach that nations like Ireland and Croatia have taken.

Interestingly, other ESSOR waveforms in development maybe adopted in other NATO communications STANAGs potentially increasing the adoption of the overarching programme's output in other areas. NATO has, for all intents and purposes, satisfied its COALWNW requirement with HDRWF. Nevertheless, the Alliance is looking for a narrowband waveform to foster inter-force networking across land forces. Unsurprisingly, the NBWF appears to be in the offing to meet this demand. ESSOR officials are hopeful that the NBWF's specifications will be enshrined in the second edition of NATO's STANAG 5630, which covers narrowband waveforms for V/UHF radios. Likewise, 3DWF specifications could be enshrined in the fourth edition of NATO's STANAG-4372, which covers NATO's Second-Generation Anti-Jam Tactical UHF Radio for NATO (SATURN) waveform specifications. It is possible that the 3DWF's architecture could form the basis to support SATURN's surface-to-air/air-to-surface networking requirements. Finally, SATWF's specifications may yet be incorporated into STANAG-4681 which concerns the realisation of an integrated waveform to foster digital interoperability between UHF SATCOM terminals. Sources close to the ESSOR initiative have shared with the author that the first edition of STANAG-5630, which covers fixed frequency waveforms, has now been ratified by NATO. The second edition covering frequency-hopping waveforms is expected to be finalised in early 2026. Once the STANAG is finalised, it will then commence the process of NATO ratification. When ratified, NATO members will be able to use STANAG-5630's specifications to guide their realisation of NBWF-compatible waveforms. The sources continued that, for now, the emphasis is on completing the full ratification of STANAG-5630 and 5651.

Although a comparatively late entrant to the ESSOR programme, Germany is an active participant and the waveforms emanating from the initiative will be ported into that nation's current and future tactical communications. [Rohde & Schwarz]

Outlook

It is entirely possible that the suite of four ESSOR waveforms are precisely the right thing at the right time. The onward march of MDO has underscored the need to significantly deepen intra- and inter-force connectivity. At the same time, the tense strategic situation in Europe today highlights the necessity for the continent's Allied forces to have unprecedented levels of deep, survivable networking. The work of ESSOR helps to answer those requirements. Meanwhile, initiatives like the HDRWF may answer existing desires within NATO for wideband coalition networking waveforms. Thus, the ratification of STANAG-5651 enshrining the HDRWF specifications will provide benefits beyond the ESSOR partner nations. This process of ratification also allows the adoption of these waveform standards by non-European NATO members. Therefore, it would not be unsurprising if Canada and the United States adopt ESSOR waveforms in the future as these nations, like other NATO members, are pledged to embrace the Alliance's MDO posture.

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A SATCOM lingua franca

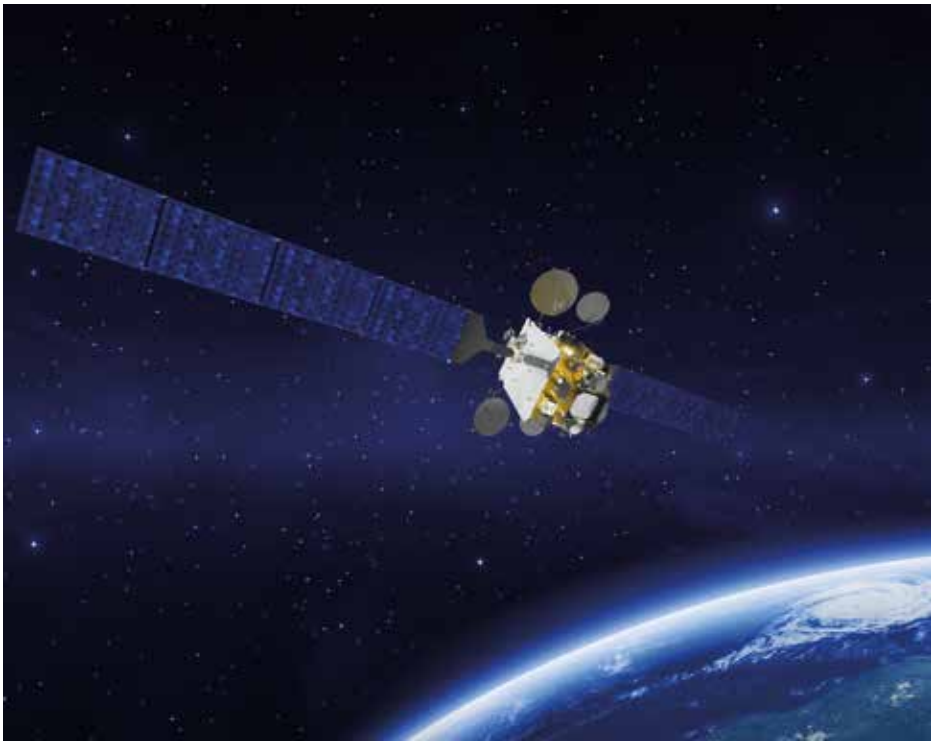
Dr Thomas Withington

Europe is chalking up another military connectivity success story thanks to ongoing work of the European Protected Waveform satellite communications initiative.

"I saw two shooting stars last night, I wished on them, but they were only satellites. Is it wrong to wish on space hardware? I wish, I wish, I wish you'd care." sang singer-songwriter Billy Bragg in his 1983 hit 'A New England'. Wishing on satellites, and their communications capabilities, is central to the European Protected Waveform (EPW) initiative. Satellite communications (SATCOM) have long been integral for military communications at the tactical, operational and strategic level. The first military communications satellite, Project SCORE (Signal Communications by Orbital Relay Equipment), was launched by the United States Air Force (USAF) on 18 December 1958. Since then, the global dependence of the world's militaries on SATCOM has steadily increased.

One consequence of this exponential growth is that demand has largely out-stripped provision. Nations typically own just a handful of these expensive assets. For example, France possesses two Thales Alenia Space/Airbus Defence and Space Syracuse (Système de Radio Communication Utilisant un Satellite; ENG: Radio Communications System by Satellite) spacecraft. Syracuse-4A and Syracuse-4B provide X-band (7.9–8.4 GHz uplink/7.25–7.75 GHz downlink) and Ka-band (26.5-40 GHz uplink/18-20 GHz downlink) coverage across much of the globe. The outlier in terms of military SATCOM fleet size is the United States. As of 2023, the US Department of Defense (DoD) reportedly has 53 dedicated military communication satellites, according to the Union of Concerned Scientists (USC), a scientific advocacy organisation based in Cambridge, Massachusetts.

The relative paucity of dedicated military communications satellites has resulted in governments and militaries looking towards the private sector to lease bandwidth from commercial operators. An understandable prerequisite of such services is that they provide secure communications. However, while better than nothing, the use of commercial provision for military SATCOM is not always ideal. First, these services can be expensive to lease. Second, the user must trust that the security of the communications they are leasing is up to scratch. Third, the user might have to obtain dedicated SATCOM terminals to access these services. Sometimes, the terminals will be included in the leasing agreement. On other occasions, the user might need to configure their existing terminals to use these services. Dedicated software which can handle the communications waveforms used by a particular satellite or constellations might be necessary. Moreover, one set of waveforms and terminals may not always work with those of another commercial operator. The leaser may then need to procure additional terminals and/or waveforms to use additional commercially-provided secure SATCOM services.



▲ Syracuse-4A, an artist's impression of which is shown here, forms one half of the Syracuse-4A/B military communications satellite constellation. The constellation is accessible via sovereign, secure military SATCOM waveforms. [Safran]

The European approach

Europe gets some flak, some deserved, some not, for the continent's effectiveness at working collaboratively on joint defence programmes. Nevertheless, a quiet revolution is occurring in the continent's military communications sector. The European Secure Software Defined Radio (ESSOR) waveform is a successful example of several nations working together to answer a common need. In this case, the project is delivering a suite of tactical communications waveforms, primarily for land forces. These waveforms are designed to be 'radio agnostic'.

AUTHOR

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Navigating the GNSS Threat Landscape: How VIAVI Solutions Is Redefining Resilient PNT

In today's contested electronic warfare environment, GPS and GNSS jamming and spoofing have become routine tactics. These disruptions, once considered niche threats, now pose serious risks not only to military operations but also to aviation, shipping, communications, and emergency services. As the global reliance on satellite-based navigation intensifies, so does the urgency for resilient, multi-layered Positioning, Navigation, and Timing (PNT) systems.

VIAVI Solutions Inc., bolstered by its acquisitions of Jackson Labs and Inertial Labs, is rapidly emerging as a force in assured PNT—delivering technologies that are not only innovative but essential for mission continuity in GPS-denied environments.

A Strategic Alliance for Assured PNT

VIAVI's SecurePNT platform can derive timing from an unmatched range of sources—including Geostationary Orbit (GEO), Medium Earth Orbit (MEO), and Low Earth Orbit (LEO) satellite constellations, atomic clocks, and terrestrial signals. Through intelligent sensor fusion and transcoding, SecurePNT ensures the most reliable reference is always available, even when GNSS is compromised.

Complementing this, the recent acquisition of Inertial Labs contributes to the widest portfolio of positioning sensors in the industry. From accelerometers and gyroscopes to inertial measurement units (IMUs) and inertial navigation systems (INS), Inertial Labs enable autonomous navigation in tunnels, urban canyons, and other GPS-denied environments. Their sensor fusion algorithms ensure accurate navigation where satellite signals simply can't reach.

Together, these companies form a triad of innovation—delivering resilient, redundant, and ready solutions for defense, aerospace, and critical infrastructure.

STL-1000: Compact Powerhouse for Secure Timing

VIAVI's latest breakthrough, the STL-1000, exemplifies this commitment to innovation. A low-power Iridium PNT receiver in an M.2 form factor, the STL-1000 is designed for seamless integration into handheld and reconfigurable devices. It receives both Iridium STL signals and GNSS L1 for timing and location, offering a GNSS-independent capability to generate UTC nanosecond timing and meters-accurate stationary positioning anywhere in the world.

Operating similarly to traditional GPS but without relying on it, the STL-1000 combines a custom-designed Iridium LEO receiver with a disciplined, high-stability reference oscillator. When paired with VIAVI's Iridium-based SecureTime LEO Services, it delivers an accurate, resilient PNT solution ideal for mobile military platforms.

Showcasing Innovation at DSEI

At DSEI, VIAVI and Inertial Labs will present a comprehensive suite of defense-ready technologies:

- **RSR GNSS Transcoder (Gen 2)** VIAVI's second-generation RSR Transcoder retrofits legacy systems with assured PNT. It simulates full GPS constellations and instantly converts inputs like M-Code, SAASM, and INS into universal GPS signals using patented algorithms. Built for GPS-denied environments, it features an ICD-GPS-153 interface.
- **Electromagnetic Warfare Solutions:** Designed to monitor, record, and synthesize complex EMS environments, these systems support electronic attack (EA), obfuscation, and training through dynamic signal creation and automation.
- **Tactical Radio Test Solutions:** Capable of testing everything from handheld radios to aircraft-mounted systems and broadband networks, these tools ensure secure and reliable communication across battlespace.
- **Visually Enhanced Inertial Navigation System (Next Gen – VINS)** VINS leverages a combination of visual-based positioning software and inertial sensor data to provide positioning, navigation, and timing information without relying on GNSS signals.

From the lab to the battlefield, VIAVI Solutions combat-proven technology ensures your military equipment is mission-ready whenever you are.

Future-Proofing Navigation

The future of navigation lies in hybrid, multi-layered systems. VIAVI is leading the charge by integrating LEO satellites, terrestrial backups, inertial navigation, and AI-enhanced sensor fusion. Regulatory bodies like the Federal Aviation Administration (FAA), Federal Communications Commission (FCC) and European Union Aviation Safety Agency (EASA) are pushing for resilient PNT adoption, and VIAVI is ready to meet the demand.

Whether safeguarding telecom networks, enabling autonomous systems, or ensuring mission-critical reliability in defense operations, VIAVI Solutions—with Jackson Labs and Inertial Labs—is building the future of navigation.

Visit us at DSEI 2025 from 9-12 September
VIAVI Solutions – Booth S4-351
Inertial Labs (A VIAVI Solutions company) – Booth S4-142

Users can load them into their existing and future transceivers and benefit from secure, wideband intra- and inter-force communications. The logic of ESSOR is to ease the ability of forces to not only communicate within themselves, but also between nations. Providing these connections is a sine qua non for coalition operations. The chance that European nations will fight alone on the continent, or elsewhere for that matter, are practically zero. ESSOR greatly improves the ability of militaries to move voice and data traffic securely across the battlespace within and between forces. Alongside the wideband high-data rate waveform the A4ESSOR industrial consortium is developing, narrowband, air-to-surface/surface-to-air and SATCOM waveforms are in the offing. Currently, the ESSOR initiative involves Finland, France, Germany, Italy, Poland and Spain. The A4ESSOR consortium comprises Bittium, Indra, Leonardo, Radmor, Rohde and Schwarz, and Thales.

Impressive as ESSOR is, it is not the only collaborative military communications programme on the continent. In 2021, the European Commission commenced the European Protected Waveform (EPW) initiative. It is the Commission's role to draft and present proposed policy to the Council of the European Union, which is then voted on by the European Parliament as potential legislation. The EPW is financed by the European Defence Fund (EDF), which is part of the EU's Common Security and Defence Policy (CFSP). Established in 2017, the EDF is mandated to manage, promote and coordinate collaborative European defence projects. According to the Commission, the EDF also aims to improve European military interoperability. The EPW is emblematic of these intentions and aspirations.

EPW Phase 2's logo shows the participating member states. [ST Engineering iDirect]

According to the Commission, realisation of the EPW is expected to cost circa EUR 65 million over the two phases funded thus far, with Belgium, Croatia, Denmark, France, Germany, Italy, Luxembourg, The Netherlands, Poland, Romania and Spain all involved in the initiative. The industrial effort is pursued by 19 companies and organisations. Belgium leads the initiative, which is coordinated by STE Engineering iDirect Europe. The EPW industrial base is confined to EU member states, and their companies, as the finance is secured via the EDF.

In the Commission's own words, the EPW project will *"study and design a multi-layered security and resiliency solution built around the cornerstones of efficient, secure, affordable and interoperable (satellite communications) to embrace today's and future challenges related to increased throughput demand over satellite, dispersed operations, mobility and new security threats."*

Within the waveforms

Koen Willems, EPW project coordinator at STE Engineering iDirect Europe, shared that the EPW programme has three phases. According to an iDirect press release, Phase 1 commenced in January 2023 and is scheduled to run until the first quarter of 2026. Phase 1 is worth EUR 29.9 million, with the Commission contributing EUR 25 million and EU member state co-financing providing the remaining EUR 4.9 million; 12 nations and 19 companies were involved in this phase and the work forces on the study and design of the EPW. The second phase was awarded by the EDF in 2024. The Commission is contributing a further EUR 25 million, with EU members contributing EUR 10 million; 22 companies and 12 nations are involved in this phase which will perform EPW prototyping and testing work. According to an iDirect press release, Phase two began in January 2025, and is expected to conclude in 2028. According to Willems, Phase 3 should be awarded circa 2028.

The main EPW deliverable is a secure and resilient military-grade SATCOM waveform supporting voice, video and data traffic that can be ported with ease into third-party SATCOM terminals. Willems notes that nations with their own dedicated military communications satellites already have sovereign waveforms they use with these constellations. These waveforms are typically not shared with other nations and may have some disadvantages. For example, they may only work with geostationary satellites. These spacecraft remain in a fixed orbital position above a specific place on Earth providing coverage over a finite area. This area may be huge, encompassing millions of square kilometres of the planet's surface. Nonetheless, there may be some areas where these geostationary satellites are unable to provide coverage. The US DOD has been investing in communication satellites in recent years to provide coverage in Arctic regions since the high North has suffered shortfalls in military SATCOM availability. Some of these sovereign waveforms may now have comparatively old design features and are likely to be highly constellation- and spacecraft-specific. This greatly restricts, if not altogether prevents, sovereign waveforms' ability to work across other constellations in different satellite orbits.

At the industrial level, sovereign waveforms limit the user to procuring these from a single supplier which has been tasked with developing and implementing the waveform. EPW takes a different approach as several companies are involved. Each participating nation can procure the interoperable EPW waveform from the

The US DoD's MUOS UHF satellite constellation is only accessible using the WCDMA dedicated waveform. The EPW initiative is working towards terminal- and constellation-agnostic SATCOM connectivity. [General Dynamics]

The advent of space-based 5G provision could revolutionise satellite communications by providing users with similar benefits in terms of data rates, latency reduction and subscriber hosting that they will enjoy from terrestrial 5G cellular networks. The EPW initiative aims to harness these benefits for military SATCOM users. [Luxembourg Space Agency]

participating national supplier. Koen Willems said that spreading the development effort, and hence the expense, of realising the waveforms will help reduce the cost of their procurement. Taking a similar approach to ESSOR, EPW essentially drafts a series of standards for specific waveforms. Customers then use these standards to draft the software for their SATCOM terminals allowing the latter to send and receive the desired waveforms.

The lack of flexibility of some existing sovereign military SATCOM waveforms means that they also cannot take advantage of several important and imminent satellite communications technological advancements. An instructive example in this regard is the onward march of 5G/6G cellular communications. While 5G is arguably most clearly associated with terrestrial cellular networks, the technology has applicability to SATCOM. It would be possible to write a whole article on 5G and its benefits vis-à-vis existing 4G cellular standards. Broadly speaking, 5G will allow significantly more subscribers to be hosted by each individual node, such as a cell tower, on a specific network. Larger throughputs of data are promised by 5G protocols when compared to 4G. Latency rates, the time it takes for traffic to move from a transmitting device to a receiver and vice versa, are set to reduce with 5G.

Plans are afoot to provide 5G provision from space. The International Telecommunications Union (ITU), the designated UN organisation governing the global use of the radio spectrum, has earmarked several wavebands for non-terrestrial 5G communications. The ITU states that these bandwidths are between 410 MHz and 7 GHz, and between 17.3–30 GHz. An article published by the Institute of Electrical and Electronic Engineers (IEEE) entitled '5G Satellite Spectrum' provides more specifics regarding 5G for SATCOM: Low-Earth orbit (LEO) satellites are the favoured means of providing 5G coverage. Orbiting at a maximum altitude of 2000 km (1,080 NM), these spacecraft are not geostationary. Instead, they zip across the sky, visible for a comparatively short time. No sooner has one LEO satellite disappeared over the horizon, than another has arrived. In fact, the IEEE says that around 5,000 LEO

The EU's IRIS2 project is an ambitious effort to provide broadband connectivity to civilian, commercial and government users across the EU's membership. The EPW effort is developing a secure 5G-compatible military SATCOM waveform that can use this constellation. [ESA]

satellites may be in orbit, and more are on the way. This means that 5G users on Earth will always have several satellites in their field-of-view with which to communicate. Willems says that the EPW waveforms will be compatible with these LEO satellites providing 5G coverage. He adds that, while "5G is a key standard" it is "not fully developed and not fully secure". With this in mind, the EPW adds an additional software layer to make the 5G protocol secure for military use.
Another interesting EPW design feature is that the waveforms will not depend on position, navigation and timing (PNT) signals from global navigation satellite system (GNSS) constellations. SATCOM terminals can depend on GNSS PNT signals for an accurate time source to synchronise with the constellation, but without going into specifics, Willems says the EPW is developing non-GNSS PNT alternatives, to eliminate this dependence. As the GNSS jamming by both sides in the ongoing war in Ukraine illustrates, this is an important consideration.

Terminal and constellation agnosticism is a key EPW consideration. The resulting SATCOM waveforms will work with the EU's Infrastructure for Resilience, Interconnectivity and Security by Satellite (IRIS2) constellation. The Commission says that IRIS2 is a planned constellation of 290 multi-orbit LEO and medium-Earth orbit (MEO) communications satellites, which orbit at altitudes of between 2000 km (1,080 NM) and 36,000 km (19,438 NM). IRIS2 will provide broadband connectivity to individual, commercial and governmental users across the EU. The project commenced this year and its associated satellites should begin launching from 2029, the author understands. IRIS2 sources say the satellites will carry secure Ku-band (14 GHz uplink/10.9 GHz to 12.75 GHz downlink) and military Ka-band traffic. Koen Willems says that EPW will also yield military-grade 5G waveforms which can be used with the IRIS2 constellation.

EPW Phase-1 "is running fine and will be delivered on time", according to Willems. This phase primarily concentrates on study and design work, which will draft the so-called 'blue book', intended to define the waveform standards. Phase-2 will see the continued update of the blue book to account for changes to the 5G protocol, and evolving security threats, both of which are evolving over time, Willems stressed. This phase will also see the waveforms initially being brought to market. Work scheduled for Phase-3 includes making the 5G SATCOM protocol fully secure and "working on the compatibility with IRIS2".

Initially, the waveforms that will be developed via the EPW2 initiative will only be for use by EU member states; however, the waveforms can be made available for acquisition beyond those nations that are the original partners in the project. Koen Willems does see the possibility that the waveforms could be made available to partner nations outside the EU over the long term and notes that Belgium is both an EU and NATO member. EPW waveforms could be provided to NATO nations in the future provided this is permitted by the European Commission. Expanding the user community beyond the EU would have the benefit of making the waveform available to non-EU members such as Canada, Norway and the United Kingdom.

Alongside ESSOR, the EPW programme showcases the continent's collaborative acumen in the all-important field of military communications. The developmental trajectory of the project also shows that EPW is preparing for the future with the advent of space-based 5G. To paraphrase singer-songwriter Billy Bragg, the EU may well be wishing on space hardware, but it looks likely to have those wishes granted.

How Next-Gen Tactical Communications Empower Autonomous Systems

Modern warfare requires real-time situational awareness, which demands broadband capabilities from communication systems. However, the requirements for communication systems are often contradictory: long range requires narrowband transmission and low frequencies, but at the same time, real-time video transmission is necessary. The rise of autonomous systems makes it even more complex, while opening the door to new tactical communications capabilities.

The war in Ukraine has shown that inexpensive, even off-the-shelf drones can destroy enemy equipment and troops. These operations require real-time, uninterrupted wireless communications, but commercial technology has its limitations: because its functionality is well understood, it is relatively easy to jam. Jamming narrows the operational area of unmanned vehicles, forcing operators dangerously close to enemy lines.

▲ Unmanned systems must be integrated into the tactical communications and C5 systems. [Bittium]

Manual remote control with visual line of sight or video feed is only a step toward autonomy. In the future, higher levels of autonomy could enable drone swarms to operate independently after receiving a mission. They could then rely on short-range, high-bandwidth communication within the swarm, and possibly on slow, periodic data links between the swarm and the C5 system to relay, for example, location and status information.

Enhanced Performance Through System Integration

To transmit data like drone video to command units, unmanned systems must be integrated into the tactical communications and C5 systems. If a vehicle can carry enough payload, it can host sensors to generate and relay data through the tactical network. Communication devices may also act as relays within the network. The challenge is that small drones, especially those carrying weapons, have limited payload capacity.

This is where technology convergence becomes essential – integrating electronic warfare capabilities into communication devices. For example, a software-defined radio (SDR) could also detect jamming, determine their location, and share that data in near-real time. Fully integrated systems also allow unmanned platforms to use advanced LPD/LPI/AJ features – including frequency hopping, cognitive spectrum management, and interference mitigation.

When linked into a mobile ad hoc network (MANET), unmanned vehicles can extend both range and data transfer speed by relaying traffic between nodes. Airborne nodes are well suited for this purpose, though they are also more susceptible to jamming. On the other hand, line of sight between friendly nodes allows the use of higher frequencies and directional antennas, which improve resistance to jamming and reduce emissions toward the enemy.

From Theory to Practice

In the European Integrated Modular Unmanned Ground System (iMUGS) project, Bittium contributed a hybrid networking concept, combining C5 tactical communications with commercial mobile networks, allowing, for example, smartphone access to services.

Bittium also introduced TAC WIN Smart Link 360 functionality to its broadband TAC WIN Waveform. With the Smart Link 360, network nodes using electronically controlled SBA antennas autonomously locate their counterparts and can track their movements. Additionally, the steering of antenna beams is synchronized with the transmission, enabling full MANET networking while still providing the benefits of directional antennas traditionally used in fixed links. This solution – providing enhanced performance, automation, and jamming resistance – works also for unmanned vehicles.

Shaping the Battlespace of Tomorrow

Integration, autonomy, and adaptability are not just buzzwords, they are the blueprint for next-generation defense. With SDR-based solutions, Bittium is building communications systems that empower autonomous systems and secures the tactical edge.

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Contact: defense@bittium.com

Bittium

Pilots for soldiers

Dr Thomas Withington

The US Army's Radio Frequency Data Pilot initiative is developing capabilities to handle data and develop effects in support of electromagnetic manoeuvre warfare.

A US Soldier assigned to 2nd Brigade Combat Team, 101st Airborne Division operates the Kraken during exercise Spectrum Blitz 25 at the Hohenfels Training Area, Germany, on 11 April 2025. [US Army/Sgt Collin Mackall]

It is probably fair to argue that the radio spectrum in the Ukraine theatre of operations is the most congested and contested the world has ever seen. Russia and Ukraine depend on this spectrum for command and control (C2) and intelligence, surveillance and reconnaissance (ISR) with conventional and satellite radio communications links providing the all-important connectivity for the flow of C2 voice and data traffic. Signals from space convey positioning, navigation and timing (PNT) data from global navigation satellite system (GNSS) constellations. These PNT signals guide everything from troops to missiles, while also providing the timing information that automated systems and networks rely on to synchronise and govern their processes. Radars, be they positioned on the ground, in the air, on weapons or naval vessels, use radio signals to find, identify and track targets; these same radars may also help direct weapons to their targets. Radio and radar signals will collectively be known as radio frequency (RF) signals in this article.

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Alongside the Russian and Ukrainian militaries, civilians also depend on the radio spectrum for cellular, satellite and conventional telecommunications. Broadcasting, emergency services and the private sector also rely on the spectrum for communications and PNT provision. To compound this congestion, military RF signals do their level best to be as difficult as possible to detect. Find the signal, and you find the asset, says the electronic warfare adage. RF emissions can potentially be used to pinpoint the location of the asset transmitting them. That asset could be an armoured vehicle, a soldier, warship, aircraft, sensor, weapon or headquarters. Once an asset is found, it can be struck with kinetic fires. Likewise, the asset's RF signals can be attacked electronically using jamming. Networked military assets across sea, land, air, space, and cyberspace domains can be attacked with RF signals modulated with malicious code, directed at the networks they rely on. Once inside the networks, the cyberattack goes to work; individual assets may be infected with the malicious code, as might digitally-dependent battle management and C2 systems. Electronic warfare (EW) delivered cyberattacks not only have the propensity to cause chaos; they can also be useful vectors for stealing valuable data.

Such is the military value of the radio spectrum, as ongoing conflicts in Ukraine and the Middle East are proving, that navies, armies, air, space and cyber forces are looking to secure 'spectrum dominance'. What this means in practice is hard to define, and the term has become something of a cliché. Nonetheless, the term can be translated as the capture and sustainment of electromagnetic superiority and supremacy (E2S). E2S is achieved through electromagnetic manoeuvre, which emphasises the continuous movement of friendly electromagnetic capabilities to gain an advantage over hostile forces within the spectrum. Manoeuvre in the spectrum can be performed at the tactical, operational and strategic levels of war across the spectrum of conflict. This approach to electromagnetic spectrum operations is as relevant to counterinsurgency warfare as it is to high-intensity combined arms battle.

Borrowing from airpower theory, electromagnetic superiority is the condition in which red force electromagnetic capabilities can only sporadically challenge blue force spectrum ownership. Electromagnetic supremacy is won when red forces are incapable of any meaningful interference of blue force spectrum use. E2S can be both spatially and/or temporally limited, depending on the demands and exigencies of electromagnetic combat and the overriding mission.

In a nutshell, the electromagnetic spectrum is a manoeuvre environment much like the domains mentioned above. A key difference, however, is that the electromagnetic spectrum spans all these domains, and operations across them all depend on spectrum access and ownership. As such, it is probably more appropriate to refer to the electromagnetic spectrum as an environment as opposed to a domain.

It could also be argued that the radio spectrum is becoming so complex that it soon risks eclipsing the limits of human cognition to find, fix and engage a signal of interest (SOI). According to the research company Datareportal, as of 2024, Ukraine had 55.6 million cell phone network subscribers and add hundreds of thousands more military assets using the radio spectrum in some shape or form. Military spectrum users will employ radio signals using communications/transmission security (COMSEC/TRANSEC) protocols such as frequency hopping to hide in this electromagnetic morass. These same signals often employ low probability of interception/detection means to make them difficult to detect.

Concept of operations

The US Army Cyber Command's (ARCYBER) Radio Frequency Data Pilot (RFDP) initiative is helping make sense of the spectrum, and to enhance the force's ability to manoeuvre within it. In essence, the RFDP is a software experiment aimed at making the spectrum easier to comprehend, and thus exploit. The army became interested in its ability to exploit relevant RF battle management data in 2021. The result of successive army studies between 2021 and 2024 was that the force needed to *"(o)perate in the electromagnetic spectrum with agility to manoeuvre and deliver effects at the operational pace", according to a US Army presentation. The presentation continued that the RFDP will perform experiments to identify requirements for "RF data triage, transport and follow-on data analysis and countermeasure/RF effects capability development".*

In essence, the RFDP experiment will ascertain methods to prioritise RF-relevant data. What this may mean in practice is that the importance of that RF data might be weighted. Consider this scenario: Blue force communications intelligence (COMINT) gathering reveals the positions of stationary red force troops. The troops' RF emitters, notably their radios, are stationary, which may indicate that the platoon is resting or awaiting orders. Should that COMINT now show that those radios are moving at speeds of circa 35 km/h (22 mph), this may indicate that the platoon is mounted in its vehicles; any upsurge in radio traffic may indicate an attack is imminent. An EW practitioner does not need to break into the red force traffic to discern these potential events, as even a sudden loss of all red force radio signals may indicate the platoon is observing emission control conditions which may also be a possible prelude for an attack. This example illustrates how different data can be weighted according to what the data are representing. The value of this information, and the need to share it with the blue force unit facing the red force's possible axis of advance, changes.

Before sharing, the data highlighted above may need additional analysis. What types of radios might the red force unit be using, based on the parameters of the signal detected by the blue force EW cadres? Let us suppose they are detecting VHF transmissions from P-187 Azart radios equipping a Russian Army motorised rifle platoon. The radio traffic from the handheld P-187P1 radio is using a 1 MHz waveband stretching from 42 MHz to 43 MHz. These signals use a frequency-hopping rate of 50 hops-per-second across this waveband. The signal has an effective radiated power of 31 dB, reducing to circa -86 dB at a range of 12 km. P-187 series radios are being introduced into Russian land forces although anecdotal evidence suggests that, as Russia's most advanced tactical radios, these are initially equipping elite units. Observing the signal parameters detailed above allows EW cadres to determine with high probability that the signals they detected are from P-187 radios. The fact that this radio model that has been discerned may indicate that local blue forces might be about to face attack by an elite Russian unit.

As noted in the US Army presentation, the RFDP is seeking to advance "countermeasures/RF effects capabilities development". What this could mean in practice, returning to our above example, is that appropriate countermeasures could be rapidly devised and disseminated to the blue forces facing the expected Russian attack. By comprehending the signal parameters of P-187 radios it becomes possible to draft a jamming waveform which might prevent these radios communicating with one another. Perhaps the jamming waveforms are already available and ready for use? Alternatively, could artificial intelligence algorithms rapidly configure jamming waveforms that show promise of being effective? Maybe the blue force EW cadres at the tactical edge already have electronic attack tactics they can bring to bear? Either way, the goal of the RFDP undertaking is to accelerate the pace at which electronic attack effectors can be placed in the hands of those who need them.

The US Army's RF Data Pilot initiative commenced in October 2024 and is expected to continue until the end of the 2025 financial year. The project will make an important contribution to the force's efforts to refine and improve how it fights in the electromagnetic spectrum. [US Army]

Stakeholders

The RFDP comprises scores of stakeholders beyond US Army Cyber Command: The Army Cyber Centre of Excellence is involved along with the force's Programme Executive Office for Intelligence, Electronic Warfare and Sensors. Other participants include the Army Command, Control, Communications, Computers, Cyber, Intelligence,

Surveillance and Reconnaissance Centre, the Army Intelligence Centre of Excellence and Army Futures Command. Alongside the objectives discussed above, the results of the RFDP will influence how the army will fight in the future within the electromagnetic spectrum.

To this end, relevant RFDP capabilities have been put through their paces during recent exercises, including Vanguard 24 at Fort Huachuca, Arizona in September 2024. According to a US Army report on the event, Vanguard 24 "delved into high-altitude sensors, terrestrial systems, and microsensors and explored electronic warfare capabilities that can traverse vast distances". The event was co-sponsored by the US Army Intelligence Centre of Excellence and the force's Intelligence-Capability Development Integration Directorate. The article continued that the exercise offered a glimpse of emerging technologies and programmes of record that could influence warfare in the 2030 to 2040 timeframe. Technologies participating in the exercise included aerostats, crewed and uncrewed aircraft, along with space-based sensors. A key aim of the exercise relevant to the RFDP was the ability to gather, process and share data with participants.

The US Army conducted the Vanguard 24 exercise at Fort Huachuca, Arizona, in September 2024 during which technologies relevant to the RFDP were evaluated. [US Army]

ARCYBER told the author that the RFDP is essentially an operational experiment which "informs programmes of records, government and commercial-off the shelf solutions, and strategic force modernisation". The outcomes of the RFDP will "impact army doctrine, organisation, training, materiel; leadership and education; personnel and facilities policy adjustments", ARCYBER's statement continued. While some of the experiment's outcomes may result in the exploitation and realisation of tangible technologies "others will refine policies and operational frameworks", while ultimately, all efforts are "aimed at enhancing lethality in the electromagnetic spectrum".

Army deliverables

More tangibly, the US Army is in the midst of a major overhaul of its manoeuvre force EW assets. This effort includes the procurement of the Terrestrial Layer System (TLS) family of capabilities. TLS will deliver a tactical manoeuvre force electronic warfare system in the guise of the TLS BCT (TLS Brigade Combat Team). Mastodon Design is delivering the backpack, dismounted element of the overall TLS BCT requirement, while Lockheed Martin is delivering the vehicle-mounted TLS BCT component. Operational-level manoeuvre force EW will be provided by the TLS EAB (Echelon Above Brigade) architecture and Lockheed Martin is also involved in the TLS EAB provision. The battle management and C2 element for army manoeuvre force EW is being provided by Raytheon's Electronic Warfare Planning Management Tool (EWPMT). The ARCYBER statement added that results of the RFDP could be implemented into capabilities such as TLS and EWPMT where relevant.

Likewise, the RFDP could help inform the future trajectory and specifications of other ongoing US Army electronic warfare programmes such as the Terrestrial Layer System–Echelon Above Brigade capability, an artist's rendering of which is shown here. [Lockheed Martin]

The US Army's Electronic Warfare Planning and Management Tool is the force's EW command and control and battle management system. EW tactics and techniques realised via the RFDP could be introduced into the EWPMT in the future. [US Army]

Technologies developed via the RFDP are being developed to Technology Readiness Level Six (TRL-6). According to US Department of Defense definitions, TRL-6 means that a system or subsystem has been demonstrated in a relevant environment. Clearly, efforts like Vanguard 24 play an important role in this regard. The ARCYBER statement says these TRL-6 outcomes will establish a "foundation for effects generation and delivery". In essence, an architecture will be developed that can generate required electromagnetic effects, such as electronic attack waveforms, and deliver these effects accordingly. Another key outcome is that these effects should be deliverable using multiple and disparate systems. Taken further, this means that effects will not necessarily be deliverable solely via the TLS variants, but via other RF emitters where possible: If it is more appropriate to deliver desired electromagnetic effects through a jamming payload equipping an unmanned aerial vehicle (UAV), then so be it. From the data standpoint, RFDP will inform the architecture design to ensure that electromagnetic data is delivered to commanders at a pace relevant to the mission.

The initiative formally commenced in October 2024 with current planning calling for the RFDP to run until the end of the 2025 US fiscal year, according to ARCYBER. Following the RFDP's conclusion, there is the possibility of the programme continuing, or implementing the experiment's outcomes into US Army EW capabilities. The programme's deliverables will be realised via a series of milestones. RFDP milestone-1 will develop the architectures for rapid effects generation and delivery. Milestone-2 will continue with rapid effects generation and programming while milestone-3 will look at techniques for sharing electromagnetic data with allies and partners. Integral to all these milestones, ARCYBER said, is developing a series of standards to ease the interforce and intra-force handling of data.

It would be easy to characterise the RFDP as primarily fixated on technology, but ARCYBER insists that the initiative's goals are deeper: "The RF Data Pilot is about more than just new technology," says Steven D. Rehn, deputy to the ARCYBER's commanding general for support: "It's about empowering commanders at all levels to 'own' the electromagnetic spectrum and enable our troops on the ground to be more efficient." Through initiatives such as RFDP, Army Cyber Command is "giving (the manoeuvre force) the tools to make faster, more informed decisions and generate RF effects supporting their operations in an increasingly complex battlespace". Moreover, it is easy to perceive the RFDP as purely relevant to electromagnetic manoeuvre, but this is disingenuous. Electromagnetic manoeuvre is not an end in itself. The capture and sustainment of E2S is relevant across all domains, at all levels of war across the spectrum of conflict. For the US Army, the RFDP's deliverables "protects our boots on the ground and gives them the battlefield advantage against our enemies".

The continuing evolution of tube artillery

Alex Tarasov

The experience of modern warfare has underlined the importance of tube artillery. While debates about its employment and future continue, a clear consensus has emerged: tube artillery remains relevant on the modern battlefield – and it continues to evolve.

Modern warfare is being fundamentally reshaped by the experience of the Russo-Ukrainian War, widely regarded as the largest artillery war since World War II. This conflict has reintroduced large-scale, high-intensity combat to the forefront of military thinking and has underscored the enduring importance of conventional capabilities – especially classic tube artillery, including towed and self-propelled systems, as well as mortars. Before beginning any discussion about the capabilities of tube artillery on today's battlefield, several important considerations must be highlighted.

The 8×8 variant of the CAESAR SPH on display at the Eurosatory 2024 exhibition. [Tank Encyclopedia, courtesy photo]

- First, the experience of the ongoing conflict in Ukraine should not be regarded as universally applicable. While it offers many valuable insights, the conflict has been shaped by a range of political, geographical, and military factors that make its overall environment unique. The specific conditions of the Russo-Ukrainian war may not be replicated in future conflicts.
- Second, tube artillery has one of the longest life cycles of any land-based weapon system, with service lives of over 40–50 years being common. While both sides have deployed some newer systems, the majority of artillery systems used in Ukraine date back to the Cold War era or even earlier.
- Third, multiple factors influence the performance of artillery, including technological, tactical, organisational, and industrial aspects, to name a few. These factors, individually or in combination, can significantly enhance the effectiveness of both modern and legacy systems.

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What are the most important changes that have been implemented by 2025, and what developments are likely to be introduced in the near future?

Automating the artillery: UAVs and C2 systems

The mass adoption of tactical reconnaissance unmanned aerial vehicles (UAVs) and their integration into artillery units at all levels can be considered one of the most influential changes of the past decade. While less-capable UAVs have been available since the Cold War and even earlier, what we can think of as truly modern UAVs began to trickle into service in the 1990s and 2000s in limited numbers. This increased somewhat throughout the 2010s, however large-scale adoption has only occurred since the beginning of the 2020s.

The Russian Army provides a clear example of the significant progress made in this field. In 2018, it operated more than 1,800 UAVs of various types, mostly fixed-wing UAVs such as the Orlan-10, Tachyon, Eleron-3, and similar models. Contrast this to 2023, when the Russian Army had received over 140,000 UAVs of all types that year alone, with further plans to increase production output tenfold in 2024, according to a speech by President Vladimir Putin at the Military-Industrial Committee in September 2024.

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Importantly, the quantitative growth has been accompanied by the wider integration of intelligence, surveillance, and reconnaissance (ISR) UAVs into the organisational structure of the army, including artillery units and formations. For example, in 2024–2025, reconnaissance-strike UAV battalions were integrated into the organisational structure of artillery brigades within the Russian Ground Forces.

Another crucial enhancement is the development and introduction of automated fire control systems (FCSs) into artillery units. Combined with organic strike and ISR UAV capabilities, this has allowed for a significant increase in effectiveness at the brigade level, as well as at lower echelons, down to the battery or platoon level.

The synergistic effect of these innovations can be demonstrated by the following case. In May 2023, the Russian Army deployed artillery units equipped with integrated strike and ISR UAVs, as well as the cross-service information exchange system (abbreviated as 'МСИО' in Russian; ENG: MSIO). Analysis of their actions showed that the average duration of the 'detect–decide–engage' cycle was reduced down to around 4-6 minutes, with an ammunition expenditure of 2-5 rounds per target. By comparison, in 2017, the average counterfire time (from target acquisition to shot) 'across a wide variety of US and multinational allied units' hovered around 12 minutes, according to a 2018 article in the US Army's *Fires* magazine. Similar processes could be observed in other militaries, including those of Ukraine and China, with other nations closely following in their footsteps through their own programmes and experimentation.

Mobility

Brigadier General Rory Crooks, director of the Army Futures Command Long-Range Precision Fires Cross-Functional Team, has identified three fundamental problems facing US artillery: range, capacity, and survivability based on mobility.

Indeed, the latest transformations in warfare have once again highlighted the importance of survivability for tube artillery – and mobility is one potential solution. While wheeled self-propelled howitzers (SPHs) have certain disadvantages compared to tracked platforms, such as poorer off-road performance, they offer significant advantages, including lower production and maintenance costs, greater operational mobility and being typically easier to deploy by air, as well as a reduced logistical footprint.

The last five years have seen a surge in interest in wheeled SPHs systems, with many systems at various stages of development or already adopted into service. Numerous examples exist today. The British Army has transitioned from the tracked AS90 platform to the wheeled Archer SPH, with the prospect of procuring the Boxer platform-based RCH 155 SPH. Russia has completed development and entered serial production of at least two variants of the Malva wheeled SPH: one equipped with the 2A64, a 152 mm L47 howitzer, and the other armed with the longer-range 2A37, a 152 mm L54 howitzer. Meanwhile, Ukraine has accepted into service and significantly expanded production of the wheeled 2S22 Bohdana SPH. Based on battlefield experience, this system has undergone incremental upgrades since 2018, when the experimental prototype was introduced. Notably, prior to the war in Ukraine, neither country had wheeled SPHs in service, and the need for this class of artillery remained in question.

Today, the market for wheeled SPHs offers a wide range of options on different platforms, ranging from 4×4 (mostly used for mortars) to 6×6, 8×8, and even 10×10 configurations, examples of the latter including the Piranha HMC AGM and the Israeli SIGMA 155. Further development of wheeled systems is likely in the near future, with the next logical step in their evolution being modularity, allowing a system to be mounted on any wheeled platform on the market, depending on the operator's needs and requirements. While mobility increases survivability on its own, tube artillery requires greater protection against emerging threats.

Survivability

The modern battlefield is characterised by several factors, including the expansion of combat zones, increased counter-battery response speed, and the proliferation of reconnaissance assets and new threats such as loitering munitions and one-way attack (OWA) drones.

These factors have translated into a number of tactical and technical requirements aimed at increasing the survivability of self-propelled and towed artillery. In short, this can be summarised as: unprotected vehicles should receive protection, while protected vehicles should be upgraded with additional countermeasures against a range of threats.

A 2S43 Malva SPH at the Armiya 2024 exhibition. This variant is armed with the 2A64, a 152 mm L47 gun previously used on the 2S19 Msta-S SPH. [Alexey Tarasov]

The new variant of Malva shown during the Victory Day Parade rehearsal in Moscow, in May 2025. This variant of the Malva SPH is armed with the 2A37, a 152 mm L54 gun previously used on the 2S5 Giatsint-S SPH. [Alexey Tarasov]

Examples include Russian and Ukrainian SPHs equipped with standard protection kits, including slat or net armour screens covering vulnerable areas, electronic warfare (EW) systems, and camouflage systems designed to reduce visual, thermal, and electromagnetic signatures. Protected cabs have become a standard feature on wheeled SPHs and multiple launch rocket systems (MLRS), while add-on armour kits have been introduced for previously unprotected vehicles.

Another example is a standard additional armour kit for the Msta-S series tracked howitzers, developed and fielded in 2024. Notably, recently released US Department of Defense documents on the Fiscal Year 2026 Budget Estimates mention a vehicle protection suite (VPS) programme that will "evaluate, mature, and integrate onto multiple combat and tactical vehicles combinations of active, reactive, and passive protection capabilities." Among other measures, the document refers to signature management and passive add-on armour for top-attack protection (presumably against bomblets). While the description does not specify which vehicles will be involved or what the final variants of protection systems will look like, it is possible that the US Army's M109A6 SPGs may also receive additional protection.

Further improvements in this area would likely include advanced camouflage technologies allowing for better concealment and signature management, explosive reactive armour (ERA) or non-explosive reactive armour (NERA) kits for SPHs, and soft-kill active protection systems. Another possible enhancement could be the integration of remote weapon stations (RWSs) with a counter-UAV capability.

Range, precision and firepower

The requirement for longer range is now considered essential. It has emerged in response to the expansion of the battle zone to beyond 30 km, where an artillery system faces increased risk of detection and may encounter multiple threats – ranging from counterbattery fire to loitering munitions and tactical UAVs.

On the other hand, it is understood that long-range missiles or precision-guided rounds may not always be available, nor effective due to electronic warfare (EW) countermeasures and air defence systems deployed by the adversary. At the same time, the need to strike high-value targets (HVTs) in the enemy's depth remains, while the number and dispersion of these targets has increased.

KNDS expects that within ten years, most ammunition stockpiles will consist of rounds compatible with 155 mm L52 guns; these are able to be fired at charge 6, while rounds developed for L39 guns are limited to charge 5 within L52 guns. Accordingly, tube artillery fleets are likely to include more SPHs with L52, or possibly even longer-range, guns.

These developments come at a price. Long-range tube artillery requires more powerful charges, and their frequent use accelerates barrel wear. Transitioning artillery fleets to L52 guns will require stable mass production of barrels, large stockpiles of replacements, and deployed repair and maintenance units. In 2024, the US Army cancelled the L58 Extended Range Cannon Artillery (ERCA) programme; one of the reasons for this decision

A screengrab from Russian MoD footage showing a Msta-S SPH equipped with part of an additional protection kit, which includes an anti-drone cage around the turret, supplemented with camouflage netting. [Russian MoD]

was the excessive barrel wear observed during testing. An even more long-range and ambitious programme – the US Army's Strategic Long Range Cannon (SLRC) – was halted in 2022.

Another aspect of the issue is munitions. Until recent years, it was widely accepted that precision-guided artillery rounds were a cost-effective solution compared to traditional unguided rounds. However, many of these conclusions were based on experiences of the low-intensity conflicts against sub-peer adversaries, where artillery was typically employed in relatively small numbers from static firebases – often to deliver precision-guided munitions.

The experience of the war in Ukraine against a peer adversary has demonstrated that precision-guided rounds can be spoofed by Russian EW, while stockpiles of such munitions were clearly inadequate for a large-scale conflict. In other words, a combination of mass (unguided) munitions and precision guided weapons is needed for modern peer conflict, while domestic industry must be prepared to deliver both guided and unguided munitions in sufficient quantities at affordable prices.

A range of artillery ammunition and modular charges from Nexter (now KNDS France) on display at EDEX 2021. The KATANA round is visible in the top left. [Alexey Tarasov]

Future developments in the area of munitions will likely involve greater efforts toward guided rounds that are less susceptible to EW jamming – such as KNDS France's KATANA round, which is equipped with a GNSS/INS guidance system.

Another possible direction for increasing the performance of tube artillery is the development of artillery-launched drones.

A Chinese tube-launched system named Tianyan (ENG: 'Sky Eye') was recently tested, successfully completing five live-fire trials. While this design is still in the development stage, the capabilities it may eventually offer could further expand the capabilities of tube artillery in future operations.

The combination of requirements for greater mobility and enhanced firepower may also lead to the broader implementation of innovative fire modes, such as multiple round simultaneous impact (MRSI) and fire-on-the-move capability – aligning with the evolving threat landscape and the operational demands of the modern battlefield.

Final thoughts: Finding the balance

Over the last few decades, the evolution of artillery has been heavily influenced by major shifts in doctrinal thinking, driven by global changes in the military, political, and economic environment. Following the end of the Cold War and the dissolution of the USSR, future warfare – particularly as envisioned by NATO countries – was seen as a series of high-speed encounters conducted by small professional armies using long-range precision weapons, while large-scale conventional conflict was considered unlikely. Within this paradigm, tube artillery was regarded as a secondary and often unnecessary tool, compared to the air force or long-range rocket artillery.

Today, large-scale conventional conflict with a peer or near-peer adversary is once again a reality. The relevance of tube artillery on the modern battlefield has been reaffirmed by the experience of combat in the Russo-Ukrainian War. This renewed focus has prompted significant research and development in the field, with numerous innovations introduced to align tube artillery with the requirements of modern warfare.

At the same time, many longstanding debates have been settled. Discussions such as 'tracked versus wheeled platforms' or 'precision fires versus massed fires' have largely concluded with a common understanding: a modern army needs a substantial amount of artillery, and it must also have all the necessary tools in its toolbox. The question is how to find the right mix of systems, effectors, and capabilities that will enable forces to operate effectively on the battlefields of today and tomorrow.

Marketing Report: WEIBEL

Napoleon said: "God is on the side with the best artillery". Applying a filter with the experiences from the last two year's war in Ukraine, it could be rephrased to "God is on the side with the most effective artillery" – and why is that?

Mass still matters, but when artillery units are running short on ammunition, more effective use of available ammunition is paramount.

What has become clear is that the ability to focus precise and accurate fires from indirectly firing weapons on the prioritized targets will make a difference. Coupled with the ability to shoot-and-scoot, precision and accuracy will dominate the battlefield – ensuring survivability from counter battery fires, loitering ammunition and drones – while suppressing or even destroying enemy forces.

In the past, there has been a move from lighter artillery to heavier, complex self-propelled howitzers. However, over the last years the trend has changed. The heaviness of an indirect firing platform is not the only parameter making indirect firing weapons the "King of the Battlefield". An emergence of lighter and more mobile howitzers of all calibers and autonomous heavy mortars has seen the light of day. "Below" the 52 cal. (+) howitzers is a layer of lighter indirect firing weapons based on 105mm guns and heavy 120mm mortars for the clos-in battlefield.

Traditionally the light guns would have longer range than heavy mortars, but mortar systems in general are better suited for fighting in built up areas due to their high trajectory. With new propellants and longer and heavier tubes, the gap between the two is closing.

Enabling those systems with the full technical enhancement package of heavier artillery will make them "just as lethal" as the heavier systems, and in some instances, the lightness will make them faster i.e. less vulnerable and help reduce the strain on the logistic trains.

A key component of enabling rapid and precise fires whether on various types of howitzers or heavy mortars is 1; digitization of fire control, 2; utilizing meteorology data and finally 3; updating base line firing tables with accurate and current muzzle velocity data. These three parameters were already found in a US DARPA study on improving accuracy of mortars from 2005. And to be correct, the third factor was recommended to be solved through "lot firing tables", to be more specific than "type firing tables". However building a firing table

[DALO]

[KNDS]

needs the use of 800-1000 rounds, which may not be the best use of the ammunition during "ammunition famine". The question then is; how to obtain more effective fires without unnecessarily depleting scarce ammunition resources?

For the third element (muzzle velocity data), Weibel's muzzle velocity radars of the 700-series provides new and legacy weapons with an easily integrated muzzle velocity radar system, from which data can be used by the fire control system to correct the platform's fires. From first round fired, the muzzle velocity data will make reducing unwanted dispersion possible, thus the desired effect is achieved faster and with fewer rounds fired.

On modern lightweight and mobile artillery systems, the MVR is e.g. integrated on the AMG Hawkeye lightweight howitzer. Based on the Hummer CT-2 platform, this systems plays on its high mobility and fast deployment, and through that, it's a system designed specifically for "shoot-and-scoot" mission, making use of fire optimization tools extremely important.

The radar does not only see usage on artillery howitzers, the Danish Army are the first in the world to permanently mount muzzle velocity radars onto their Cardom 10 120 mm mortars, installed onto the Piranha V platform. As mentioned; with modern propellants, longer tubes and thus increased range, modern autonomous mortars close in on the performance of light artillery. Hence the need for better control over ballistics, which propels the requirement for digitization and the use of MVRs, which not so many years ago was considered irrelevant. In short: The more knowledge about your muzzle velocity an indirect firing platform can get, the more effective it will be in consuming the available ammunition resources.

No matter the indirect fires platform, artillery or mortars, the use of digitization, meteorology and muzzle velocity data in an integrated system will improve and expedite the delivery of effects. Which close the circle: The favor is the side with the most effectively used artillery – and mortars.

Weibel's muzzle velocity radar systems are used on more than 4000 howitzers worldwide in some 30 countries.

1 Some may argue that mortars are not artillery, but they do deliver indirect fire and are subject to the same impact dispersion issues as artillery, hence they are included here.

Europe's dash to procure rocket artillery

Tim Guest

Rocket artillery systems have been employed extensively by both sides during the ongoing Russian war against Ukraine. As a result, Kyiv's European/NATO Allies are now investing heavily and apace in their own long-neglected, rocket-artillery inventories.

Pictured: Dutch Army PULS validation test firings, July 2025. Several European NATO armies are racing to build their rocket-artillery inventories after years of complacency and in the face of old dangers having returned to the continent. Achieving this quickly means systems from various suppliers are being procured across the Alliance. [Dutch MoD]

In part, the latest wave of procurement is due to various users having supplied launchers and ammunition to Ukraine over the past few years, leaving various stocks depleted and in need of replenishment. In addition, Europe has begun to realise that it needs to depend less on the US for its future security and more on its own resources, equipment, and supply chains. As far as rocket artillery is concerned, the war in Ukraine has also underlined the urgent need for European nations, several of which are immediate Russian neighbours, to increase their longer-range, surface-to-surface, precision-strike, indirect-fire capabilities; traditional tube artillery, no matter how sophisticated and large-calibre the gun, while still of crucial importance, simply does not meet the longer-range requirements of the modern battlefield.

Emerging from this overview, are developments towards indigenous European rocket artillery solutions and industrial capabilities, as well as overseas procurements of new systems from the likes of Israel and South Korea by several European nations, and the continued adoption of latest rocket artillery from the US.

This article takes a look at just some of the recent and ongoing procurements and developments set to bolster rocket-artillery inventories and capabilities across European NATO Alliance member states. A look at the part the war in Ukraine has played as a catalyst to such procurements sets the scene.

Ukraine war has upped the ante

From the US-made M142 High Mobility Artillery Rocket System (HIMARS) and M270 multiple launch rocket system (MLRS), to Czech-made RM-70 MLRS, and more, Ukraine's Armed Forces, in their defence against their Russian invaders, have been using a variety of rocket artillery platforms in longer-range engagements, out to around 80 km, since the early months after the initial invasion. They knew they needed such systems and made numerous requests for them from allied nations. And while not acquired, for the most part, through typical commercial channels, it's worth knowing which systems have been provided, in what numbers, and by whom, because many of those donor nations are now procuring new weapon platforms to replace and bolster their own stocks.

One source of such details, the Kiel Institute for the World Economy, has kept a track of government-to-government materiel transfers/donations from 41 countries, which have donated weapons and assistance to Ukraine since the start of the war, or immediately before. In the case of rocket artillery, according to the institute's Ukraine Support Tracker's data, systems supplied between late January 2022 and 30 March 2025, is summarised in the table below.

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TABLE 1

Rocket artillery supplied to Ukraine (January 2022 – March 2025)

Country	Equipment	Quantity
Czech Republic	RM-70	12
France	M270 MLRS	4
Germany	MARS II/MLRS Evolution	5
Germany	M142 HIMARS	3
Italy	M270 MLRS	2
Norway	M270 MLRS	11
Poland	BM-21 Grad	>30
UK	M270 MLRS	6
USA	M142 HIMARS	41

Note:
a) Data sourced from Kiel IFW's Ukraine support tracker, aside from Poland.
b) Poland figures sourced from the Office of the President of Poland.

The HIMARS platforms supplied by the US, for example, were requested in early discussions between Ukraine with the Biden Administration, and have been highly effective in engaging and hitting targets at ranges out to 84 km using guided rockets, as have the M270 MLRS; both platforms have been able to use a unitary-warhead variant of the 227 mm guided multiple launch rocket system (GMLRS) M31A1 (unitary warhead) and M30A1 (alternative warhead) rockets. These use a combination of global navigation satellite system (GNSS) and inertial navigation system (INS) guidance for accuracy to engage targets anywhere between 15 km and 84 km distant; they're designed for precision strikes on point targets using a high-explosive fragmentation (HE-FRAG) warhead, and can be set for either impact or air-burst fuzing modes.

Ukraine was also on the lookout, early on, for M270 MLRS. Indeed, the UK's announcement to gift six M270 MLRSs was made back at the start of June 2022, and was a decision, as confirmed by the UK MoD, co-ordinated closely with the US' decision to gift the single-pod, wheeled HIMARS. The UK said at the time that M31A1 munitions would also be supplied at scale together with the six weapon platforms. It also confirmed that the decision to supply these M270 MLRS had been taken by the then UK Minister of Defence, Ben Wallace, following specific requests for the system from Ukrainian Forces, who'd said they needed the longer-range precision weapons to defend against Russia's heavy rocket artillery, which they'd previously experienced during the devastating counter-battery artillery engagements in the eastern Donbas during 2014. Before the six MLRS launchers were sent, Ukrainian troops were trained in their operation at the UK at the Royal School of Artillery on Salisbury Plain.

Among the growing number of urgent new orders for rocket artillery across NATO's European members, tried and tested US stalwart HIMARS, continues to be in huge demand. However, that demand has squeezed supply timelines, resulting in several nations looking elsewhere, to ensure they have a suitable rocket artillery system of some kind, in place, as fast as possible. So, even as Lockheed Martin is addressing increased demand for HIMARS by upping annual launcher production rates in 2025, according to the International Institute for Strategic Studies (IISS), from 60 to 96 units, (though Lockheed Martin recently said it had "doubled" its production, without specifying the final number), together with the company's target to "increase GMLRS production capacity to 14,000 per year in 2025" (from its rate of 10,000 in 2024, and 6,000 in 2023), other makers beginning to take up the slack to meet Europe's needs in the coming years. These include Israel with Elbit's PULS MRL, and South Korea with Hanwha Aerospace's K239 Chunmoo MRL.

The Baltics, Scandinavia, and Italy opt for US systems

All three Baltic states, Estonia, Latvia, and Lithuania, have elected to adopt HIMARS, together with GMLRS rockets to enhance their deep-strike capabilities as part of a joint force development project. This joint force collaboration was formalised in Riga, Latvia, in January 2024, when the three nations' ministers of defence signed an agreement of mutual intent to develop their new HIMARS capabilities, collectively.

As for procurements, at the end of April 2025, the Estonian Defence Forces took delivery of six new HIMARS MLRS, which arrived at the Ämari Air Base, following three-and-a-half years to procure the systems and train the soldiers to operate them. It's one of Estonia's largest weapons' acquisitions and the director general of the Estonian Centre for Defence Investments (ECDI), Magnus-Valdemar Saar, said, "HIMARS is a joint force development project among the three Baltic states... the same systems will soon be delivered to our neighbours, Latvia and Lithuania, representing a major leap in the region's defence capabilities, enabling rapid strike effects deep into enemy territory." He added that while defence procurement cooperation among the Baltic States was close, joint programmes of this scale, which has involved the US and Lockheed Martin, were rare. The ECDI's Strategic Category Manager (armaments), Ramil Lipp, added that

▼ An M270 MLRS conducting a launch at the Grafenwöhr training area in Germany. [PEO Missiles & Space]

▲ An Estonian Defense Forces M142 HIMARS launches a training rocket during a live-fire exercise in Undva, Estonia, on 11 July 2025. [US Army/SSgt Rose Di Trolio]

the original December 2022 contract, signed with the US Defence Security Cooperation Agency (DSCA), includes rockets of various range capabilities, as well as communications, training, logistics, and full lifecycle support.

With the arrival of the new systems, Hanno Pevkur, Estonian Minister of Defence, said that the US had financed the procurement and the US Army's Victory training unit, already stationed in-country, had already trained Estonian troops to use HIMARS prior to the new systems arriving. The first live-firing and division-level exercises have already been taking place this summer, 2025. The US funding for Estonia's HIMARS is understood to be part of a broader security assistance package intended to strengthen the defensive capabilities of NATO's eastern flank.

Neighbouring Latvia, meanwhile, signed its agreement with the US at the end of December 2023 to similarly purchase six HIMARS launchers, together with ammunition of various kinds and ancillary equipment. Its decision to procure the system was a direct result of the system's use in Ukraine, according to the Latvian MoD. In the deal worth USD 179.8 million, Army Tactical Missile Systems (ATACMS) tactical ballistic missiles (TBMs) are also part of the package. This munition which will enhance Latvia's deep-fire capabilities out to some 300 km. Latvian Defence Minister, Andris Sprūds, said the acquisition underpinned the country's strategic partnership with the US, as well as helping to bolster NATO's collective defence. US Ambassador to Latvia, Christopher Robinson, added that the new systems would be crucial in 'deterring aggression' and sending a clear signal that, "the US and Latvia will stand by [their] joint commitment to defend every square inch of NATO's territory". Delivery of the six systems and ammunition is slated to begin in 2027, although Latvia's Armed Forces will be trained in their use prior to delivery. It is also worth noting that in Latvia's approved 2025 defence budget, EUR 52.84 million have been allocated to indirect fire support capabilities, including for long-range rocket systems.

It was, however, Lithuania, which was the first Baltic states to sign up for HIMARS, back in December 2022. This followed the November 2022 green-lighting of the potential acquisition by the US Department of State, as a potential FMS. As well as eight launchers with live and dummy ammunition, together with different ammunition pods, including pods for ATACMS, full training, maintenance equipment and support services, and more, were all itemised at that November 2022 stage. However, the Lithuanian MoD also said that the USD 495 million deal also included systems integration and connection with NATO's integrated air and missile defence system (NATINAMDS). Lithuania's Minister of National Defence, Arvydas Anušauskas, said at the time, that with its Latvian and Estonian allies also looking to acquire HIMARS, this would "unquestionably lead to the capability becoming a substantial boost to the defence of not just Lithuania, but the entire region". Just one month later, in mid-December 2022, Mr Anušauskas and then-US Secretary of Defence, Lloyd Austin, signed Lithuania's M142 HIMARS contract for the eight launchers and ancillaries, with first deliveries slated for 2025.

▼ A USMC M142 HIMARS loads onto a USMC C-130 Hercules cargo aircraft to conduct a High Mobility Artillery Rocket System Rapid Infiltration (HIRAIN) during Exercise Baltic Operations 25 (BALTOPS 25), at Klaipeda, Lithuania, on 18 June 2025. [USMC/LCpl Van Hoang]

Norway is one Scandinavian HIMARS adopter, which received initial approval from the US State Department in August 2024 to acquire 16 M142 HIMARS launchers together with associated ancillary equipment. This included a range of pods for various rocket munitions, including for ATACMS TBMs; the acquisition, will be conducted as a foreign military sale (FMS), and is valued at around USD 580 million.

Finland, on the other hand, is undertaking an extensive upgrade and refurbishment programme of its M270 MLRS platforms instead of new procurement, as announced in December 2023. Conducted by maker Lockheed Martin, the programme will ensure the resulting M270A2s are almost brand-new systems, so they remain effective and in operation through 2050. They'll have a new common fire control system, shared with HIMARS, thereby enabling interoperability in several areas, including the ability to use a wider range of latest munitions, such as Lockheed Martin's new Precision Strike Missile (PrSM) and extended-range (ER) GMLRS. The upgraded platform will also have a new 600 hp engine and new transmission, together with a new armoured cab offering additional crew protection against mines and IEDs.

For its part at NATO's southern extremities, Italy began the year by announcing the acquisition of 14 M142 HIMARS launchers in January 2025, completing the Directorate of Land Armaments' (Terrarm) overall procurement of 21 HIMARS for the Italian Army under the terms of an FMS with the US, valued at around USD 400 million. As with other such deals, training and specialist technical support to guide the systems into service are included, as well as additional equipment, including an M31A2 GMLRS unitary pod with an insensitive munitions compliant propulsion system. Discussions on the acquisition began with the US in late 2023/early-2024, and bringing it into Italian service complies with the Italian Army's Operational Concept 2020-2035 plan, as well as with enabling capabilities for the army outlined in its 'Army 4.0' paper. These capabilities include such things as mobility and extended range, as well as accuracy to enable deep, precision fires, all contributing to greater operational flexibility. The new systems will eventually operate alongside 21 upgraded Italian M270A1 MLRS, which can also use/share GMLRS rocket supplies.

Poland's powerful preparations

Not one to shirk its own and Alliance collective responsibilities, in August 2023 Poland took delivery of the first three of 290 South Korean K239 Chunmoo MRLs currently on order. Poland's initial end-2022 contract with Hanwha Aerospace was for 218 systems, and a follow-on USD 1.6 billion contract in April 2024 was for 72 Chunmoo systems, together with an unspecified 'thousands' number of guided tactical missiles. According to Poland's IAR news agency, 12 of the 72 launchers in the 2024 contract will be made in South Korea, with the remaining 60 to be built in Poland, with deliveries slated for a 2026-2029 timeframe.

Designated Homar-K in Poland, the K239 systems are being integrated with Jelcz 8×8 trucks and will incorporate Polish Topaz combat management systems. The Homar-K platforms

Pictured: Poland's Homar-K conducting its first live firing. Poland will eventually have an inventory of 290 K239 Chunmoo MRLs. [Polish Armed Forces]

will operate alongside the Army's existing HIMARS platforms, and will be able to launch a variety of munitions, including CGR-080 239 mm guided rockets with a range of 80 km, and 600 mm CTM-290 tactical ballistic missiles (TBMs) with a range of 290 km.

However, taking this major procurement to the next level and aiming to create a domestic rocket-artillery capability, Poland's largest private defence company, WB Group, signed an agreement with Hanwha in April 2025 to create a guided missile joint venture (JV) in the country. The new JV – formed to produce guided munitions for the Homar-K MRL – will be majority-owned by Hanwha Aerospace (51%), with the remaining 49% held by the WB Group subsidiary, WB Electronics. The facility will eventually produce the 80 km range, GNSS/INS guided CGR-080 rockets for the Homar-K. The JV will also jointly market its product portfolio to other European nations. Indeed, as part of a bigger picture, not only does this JV agreement bolster the Korean company's long-term commitment to playing a key part in the modernisation of Poland's defence industry, but also gives it strategic-partnering potential with other European NATO members.

Europe's increasing PULS rate

Spreading the load to meet demand and adding to the mix of rocket artillery among European NATO states is Elbit Systems' Precise and Universal Launch System (PULS). The Israeli system has so far been adopted by several European nations, including Denmark, Germany, The Netherlands, and Spain. And while these nations are not on NATO's immediate eastern flank, they are moving ahead with rocket artillery procurements as fast as possible, having seen the critical role such systems are playing in Ukraine, and to bolster their own precision deep-fire capabilities, urgently. Let's now take a look at aspects of some of these procurements.

According to the IISS, the Royal Netherlands Army (RNA), had been on track to acquire HIMARS as its latest rocket artillery asset, but due to demand for that system outstripping timely supply, as well as other differentiators such as PULS' greater ammunition capacity (depending on munition) compared to HIMARS, the Israeli system was chosen by the Dutch. Accordingly, mid-May 2023, a USD 305 million contract was awarded to Elbit Systems to supply 20 PULS artillery rocket systems to the RNA over a five-year period, from first deliveries in 2025, to 2030. The RNS's new launchers, which have already begun arriving, are mounted on the COMMIT 8×8 truck platform. The contract also includes rockets and missiles of various calibres and range capabilities, as well as maintenance support services and full end-user training. According to Elbit, the system has an open architecture to support growth, legacy C4i systems integration, as well as being able to accommodate bespoke customer needs. The munitions being supplied to the RNA include Accular guided rockets (122 mm variant has a range of 35 km, while 160 mm variant has a 40 km range), EXTRA 306 mm guided rockets with a range of 150 km, and Predator Hawk TBMs with a range of 300 km; all use GNSS/INS guidance.

Having recently taken delivery of its first PULS launchers mid-2025, the RNA conducted successful live-fire, precision-strike validation tests over 8-9 July 2025, at the Afsluitdijk coastal training ground, during which 16 rockets were fired at specific coordinates out to sea. The results proved the system's accuracy, with all projectiles landing within their designated target areas, as well as confirming operator certification requirements.

The RNA has recently, mid-2025, taken delivery of the first of its 20 PULS launchers. Pictured: Rear view of PULS pods during Dutch Army test firings, July 2025. [Dutch MoD]

As for Germany's USD 57 million PULS deal, or, rather, 'Euro-PULS', this was announced in February 2025 as having been "carried out through agreements between the Dutch, Israeli and German Governments". KNDS and Elbit Systems actually signed a teaming agreement in September 2023 to formalise and implement their strategic cooperation to further all aspects of the EuroPULS, next-generation, rocket artillery system concept.

To deliver the new contract, Elbit is working with KNDS Deutschland on various system adaptations for the German end-user, including the integration of domestic C4i equipment, as well as command and weapons control systems, and full in-service support. The launchers will eventually undergo test and evaluation with German procurement agency, BAAINBw, as well as associated technical test centres, in order to attain approval for in-service use with the German Armed Forces. CEO of KNDS Deutschland, Ralf Ketzel, said, "The cooperation between Elbit Systems and KNDS Deutschland marks a milestone in the development of a European indirect fire system for rockets. As the OEM for European land systems, such as the Leopard 2 and PzH 2000, KNDS will ensure that the PULS systems become the EuroPULS."

Yehuda Vered, General Manager of Elbit Systems Land, concluded that the German acquisition and arrangement "paves the way for future orders of the EuroPULS configuration". It is worth noting that, as well as its open architecture, the Euro-PULS MRL can operate using third-party rockets from other manufacturers, such as Lockheed Martin.

As for Spain's USD 700 million PULS deal – PULS is designated SILAM with the Spanish Forces – the collaboration involves technology transfer to enable participating Spanish companies, Escribano Mechanical & Engineering and Rheinmetall Expal Munitions, to manufacture the launchers and munitions, respectively, in Spain.

Finally, on 1 April 2025, Elbit announced having been awarded a USD 130 million contract by an unnamed "European customer" for artillery rockets, and slated to be delivered over an unspecified three-year period. The contract included a variety of munitions, from training rockets to the Accular 122 mm variant rocket, the EXTRA rocket, as well as the Predator Hawk TBM. The wording of the Elbit press release seemed to suggest that these would be going to an existing European PULS operator.

Preparing for the future

The above is just a snapshot of some of the latest procurements of rocket artillery by several European NATO member states, who've been watching events in Ukraine closely. Over the past three years, they seem to have woken up to the importance of rocket artillery on today's battlefields, the need for longer-range precision fires, and the urgency of restocking depleted inventories. At the same time, they are acquiring new systems with improved capabilities, accuracy and lethality, while also working to collaborate more efficiently and effectively with Allies – driven by a shared sense of urgency in preparing for an uncertain and potentially perilous future.

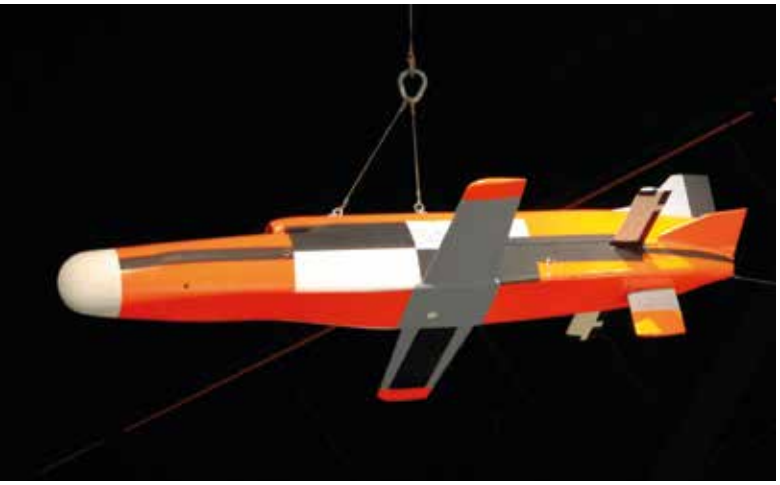
Loitering munitions: Production scaling kicks into higher gear

Sidney E. Dean

Demand for loitering munitions is growing exponentially. Industry is challenged to scale up production capacity to adjust to the changing operational realities.

Loitering munitions (LMs) combine the capabilities of a small drone and a guided missile. They are designed to remain over a target area for short-to-extended periods, identify and verify targets using onboard sensors, then transition to attack mode, executing precision strikes by impacting the target.

The concept can be traced to the 1980s, originally in the form of loitering missiles. Early models include the air-launched AGM-136 Tacit Rainbow loitering anti-radiation missile, developed by Northrop (now Northrop Grumman) along with Texas Instruments and Boeing, but cancelled by the US Department of Defense (DoD) in 1991 before it could enter production. The IAI Harpy, developed by Israel Aerospace Industries (IAI) and thought to have been first deployed in 1991, is generally considered the first operational drone-based LM. These early LMs were configured for the Suppression of Enemy Air Defences (SEAD) role. Since then, the mission profile has broadened significantly, and now prominently includes (among others) anti-personnel, anti-vehicle and anti-armour attacks.



▲ Northrop AGM-136A Tacit Rainbow on display in the Cold War Gallery at the National Museum of the US Air Force in Dayton, Ohio. [USAF]

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LMs fill a capabilities niche between artillery and missiles, providing additional options and, depending on operational scenarios, potential advantages over other munitions. The most obvious advantage is the extended dwell time over the target zone, increasing the search window for hidden targets, permitting attacks against targets of opportunity, and the ability to analyse and prioritise targets before attacking. Unlike tube or traditional rocket artillery, LMs' sensors allow them to discriminate between and verify individual targets, increasing precision and reducing the risk of collateral damage. Furthermore, given the two-way data link between UAV and operator, these sensors also provide the LM a secondary or alternate capability as reconnaissance and surveillance aircraft, and can provide immediate feedback about mission success. Also unlike shells and rockets, LM operators can divert the munition to different targets or fully abort the mission. Unlike either artillery or missiles, many LM classes can be recalled, recovered and reused if no target is found. Finally, LMs can be deployed by tactical vehicles and dismounted infantry, providing small units with beyond-line-of-sight (BLOS) precision-attack capability without the need to call in and wait for artillery strikes. Aside from these tactical considerations, LMs are often lower cost than missiles; as one example, the US Congressional Research Service in 2023 cited a unit cost of USD 6,000 for the Switchblade 300 tube-launched LM.

Proving grounds

LMs have been used increasingly in recent conflicts, including the 2020 Second Nagorno-Karabakh War (during which Azerbaijan launched numerous IAI Harpy and other LMs to significantly degrade Armenian air defences and armour) and the Syrian Civil War of 2016–2021 (during which the US supplied the Syrian Democratic Forces with circa 150 Switchblade series LMs).

The battlefield role of LMs jumped exponentially after the Russia's full-scale invasion of Ukraine in 2022. Precise numbers of LMs deployed in the Ukraine war are difficult to verify, but there are estimates by reliable sources. Russian materiel loss tracking website *lostarmour.info* stated a figure of over 3,500 confirmed Lancet strikes as of early August 2025. Ukraine also quickly adopted LMs, using both western-supplied and domestically developed systems. Here, too, precise figures are largely classified. In October 2023, the vice president of US-based AeroVironment Inc. confirmed that his company had delivered "a very large number" of Switchblade 300 LMs to Ukraine, and was transitioning deliveries to the more powerful Switchblade 600. In 2024, AeroVironment went a step further, partnering with a Ukrainian firm for local manufacture of the Switchblade 600. In December 2024, Forbes magazine revealed that Florida-based Aevex Aerospace had delivered 5,000 Phoenix

Ghost LMs to Ukraine up to that point, at a production tempo that peaked at roughly 230 units per month. The firm itself describes the Phoenix Ghost family as the "Nr. 1 US Government provided loitering munition to support the conflict in Ukraine." Poland's WB Group, which had a pre-war contract to sell 1,000 Warmate LMs to Ukraine, supported Kyiv's war effort with an undisclosed number of systems. Ukraine's domestic efforts included developing their own LMs. In summer 2024, Ukraine's Digital Transformation Ministry confirmed that multiple companies were mass-producing such 'Lancet analogues'.

Beyond traditional LMs, both sides in the Russo-Ukrainian War have been heavy adopters of first-person view (FPV) drones, an improvised form of LM. Thanks to their relatively simple construction, both sides have been able to produce these in large volume, with production now in the low millions of units per year for both Russia and Ukraine.

Surging demand in NATO

Even before the Russian invasion of Ukraine, Western nations recognized LMs' potential. Government documents confirm that US Special Operations Command (SOCOM) acquired 1,000 Switchblade 300 units between 2012 and 2020, conducting up to 400 launches in Afghanistan during that timeframe; thousands of additional Switchblades were deployed by conventional forces.

Current US Marine Corps acquisition efforts include the Organic Precision Fires – Mounted (OPF-M) programme to equip light armoured reconnaissance and amphibious units with Hero-120 LMs, and the Organic Precision Fires-Light (OPF-L) programme to provide man-portable LMs to every infantry squad, with fielding to begin in 2027. In August 2024, the US Army awarded AeroVironment a five-year indefinite-delivery, indefinite-quantity (IDIQ) USD 990 million contract for Switchblade 300 and 600 LMs. A portion of this procurement will serve the goal, confirmed by Army Vice Chief of Staff Gen. James Mingus in June 2024, of acquiring more than 1,000 Switchblades to support the Replicator Initiative. Another portion will support the Army's Low Altitude Stalking and Strike Ordnance (LASSO) project to provide Infantry Brigade Combat Teams (IBCTs) an organic BLOS precision-strike capability. The Switchblade 600 was selected as the Phase 1 effector. Procurement began in Fiscal Year 2025 with 434 All-Up Rounds (AURs), followed by a request for 294 AURs in the FY 2026 budget request. The immediate goal is to equip five IBCTs. The Army is pursuing additional capabilities to form a multi-tiered LM family-of-systems including medium- and long-range helicopter-launched effectors.

US Soldiers assigned to 3rd Brigade, 10th Mountain Division fire a Switchblade 600 LASSO weapons system at the 7th Army Training Command's Grafenwoehr Training Area, Germany, on 25 February 2025. [US Army/K.S. Payne]

European nations are also intensifying efforts at the national and multinational level, most notably France and Germany. France is pursuing multiple initiatives to acquire domestically produced LMs. In March 2024, Defence Minister Sébastien Lecornu announced that France planned to purchase 2,000 LMs of various classes. Among such efforts was France's Colibri programme for a UAV with a minimum 5 km range and 30 minute endurance, which culminated with the selection of the Delair/KNDS team's MV-25 OSKAR, a fixed-wing LM with a 25 km range and 45 minute endurance. Thus far the DGA is known to have contracted a batch of 100 MV-25 OSKAR LMs for Ukraine.

France's efforts on rotary-wing LM procurement have moved forward somewhat further. In July 2024, the DGA awarded Delair/KNDS team the development contract for the Munition Téléopérée – Courte Portée (ENG: Loitering Munition – Short Range), selecting the firm's MX-10 Damocles quadcopter LM design. The team managed to develop, produce and qualify the LM within a single year. The DGA's procurement contract calls for 460 units to be delivered in 2025, of which the first batch of 30 were slated to have been delivered in July 2025.

In April 2025, the German armed forces (Bundeswehr) announced procurement of "a large number" of LMs to be directly assigned to frontline units for in-depth operational evaluation. Contracts were awarded to the German start-ups Helsing SE (HX-2 'Karma') and Stark Defence GmbH (OWE-V 'Virtus'). Following evaluation in operational units, leadership will decide to either procure larger orders of the same LMs or consider acquiring alternative systems in support of the Force 2030 modernisation programme. The German MoD has not released a precise stockpile target, however, Simon Brünjes, Helsing's vice-president of sales estimated a requirement for 120,000 to ensure sufficiency for 60 days of fighting while production ramped up, or increasing to 200,000 to ensure that 120,000 could be available in case of ammunition depots being targeted.

Industry's response

Given their extant physical infrastructure, financing and staffing, established defence companies can be expected to have an innate advantage regarding the emerging market, especially since some have already established a track record for developing and fielding LMs. The challenge will be upgrading the ability to produce en masse and for short-term, crisis-driven demand cycles.

A prime example of proven manufacturers would be Virginia-based AeroVironment (AV). Founded in 1971, AV became an early pioneer of military unmanned aircraft development;

operational introduction of the rucksack-compatible Switchblade 300 in 2012 helped make the firm a major player in the LM sector. The Switchblade 300 and 600 munitions can be launched by infantry or integrated on vehicles and special operations watercraft; they have also been test-launched from helicopters. Switchblade systems are still mostly operated by US and Ukrainian forces, but international interest is growing. To meet future demand, AV is making significant investments to expand production capacity, with perhaps the most notable example being the firm's new 19,000 m2 FreedomWerx facility in Salt Lake City, Utah, expected to begin operations in the second half of 2025.

▲ A UVision Hero-120 launching from a Boxer armoured fighting vehicle. [Rheinmetall]

In October 2021, Rheinmetall and Israeli firm UVision Air Ltd. announced a strategic partnership to meet sharply increased demand for remotely controlled precision munitions. Under this framework, Rheinmetall has agreed to manufacture and supply UVision's Hero LM family for the European market; the German firm is also responsible for certification of the Hero series to NATO standards. Production is being undertaken by Rheinmetall's Italian subsidiary RWM Italia. In the course of this partnership Rheinmetall has also integrated the LM with various manned and unmanned vehicles. In September 2022, the Rheinmetall/UVision partnership secured its first sale of the Hero-30 to the Italian special forces, followed in July 2023 by a 'low three-digit million-Euro range' sale to Hungary and, in September 2023, the first sale of the Hero-120 in Europe (to an undisclosed customer).

Poland's largest private defence manufacturer, WB Group, produces the Warmate family of LMs which can be equipped with various warheads depending on the mission. The flexible, swarm-capable system can be deployed by infantry or vehicles. On 15 May 2025, Poland's armament agency signed a framework agreement with the WB Group for delivery of 10,000 Warmate LMs. This is the third, and by far the largest, order placed by the Polish MoD for this weapon system since 2017. In the accompanying press release, the firm described this as the largest single signed order for LMs in the world. The contract is slated for completion in 2035. The firm is also actively marketing the Warmate for export, most recently participating in the DSEI Japan in May 2025. Foreign customers include NATO members as well as Middle Eastern and Asian nations, with South Korea placing an order for "several hundred" Warmate munitions in October 2024, according to WB Group.

While established firms enjoy innate advantages, comparatively new technologies such as LMs also provide opportunities to dynamic young firms; not 'burdened' by established procedures

▲ On 15 May 2025, WB Group, represented by CEO Piotr Wojciechowski (left), and the Armament Agency of the Polish MoD, represented by Deputy Agency Head, Col Piotr Paluch (right, signed an agreement for the delivery of 10,000 Warmate LMs. [WB Group]

and infrastructure, start-ups can immediately forge ahead with new production concepts that, if successful, could hypothetically transform the industry. If, that is, they can overcome such challenges as economies of scale, quickly establish an adequate physical manufacturing base, and secure reliable supply chains.

The German start-up Helsing, founded in March 2021, has lost no time establishing a market niche characterised by fast-paced weapon system development and maximum use of software-guided production processes. The firm's public statements present a vision of scalable mass production at speeds much faster than currently demonstrated by major firms. Following multiple large orders from the German government, along with 4,000 HF-1s and 6,000 HX-2 LMs for Ukraine, Helsing now describes itself as "one of the largest manufacturers of strike drones globally".

To finance its ambitious expansion plans, Helsing has raised USD 1.37 billion in investment capital in four major funding rounds between 2021 and 2025. The firm plans to estab-

RF-1, Helsing's first resilience factory, has a monthly production capacity of "more than 1,000 HX-2s". [Helsing]

lish several 'resilience factories' (RF) at different locations throughout Europe. This concept calls for decentralised mass production to ensure continuity if facilities in one allied nation are destroyed. Each RF will maintain its own localised supply chain. Helsing's production concept emphasises an artificial intelligence (AI)-supported, software-centric approach that automates and accelerates complex processes. Efficiency is enhanced by contracting with other manufacturers to produce subassemblies and components according to Helsing's specifications. The first resilience factory, RF-1, was completed in December 2024 at an undisclosed location in southern Germany. Helsing cites RF-1 as having an "initial monthly production capacity of more than 1000 HX-2s". RF-2 is currently at the planning stage, and will have a higher production capacity. The firm expects its various RFs to jointly produce tens of thousands of units monthly during a crisis. However, to date Helsing has not published a timeline regarding construction of additional RFs.

Surge capability required

Just as governments and industry have recognised the need to significantly boost artillery production, they are also systematically pursuing expansion of LM manufacturing capacity. While adequate standing arsenals must be maintained to permit rapid response to crises, a major requirement will be the ability to rapidly scale up production on demand. General Pierre Schill, Chief of Staff of the French Army, summarised the problem during an October 2024 hearing before the French National Assembly. *"The challenge for me is to have industries capable of producing the most up-to-date [LMs] possible, to have a production flow that allows training and a minimum stock, but above all to produce much more when I need it. The risk of building up stockpiles of such ammunition would be like having obsolete ammunition, so rapid is the evolution in this field."* Established firms and start-ups alike are racing to develop this capability.

Challenger 3: Rising to the Challenge

Jim Backhouse

After decades of false starts, the UK Ministry of Defence (MoD) has begun to upgrade 148 of its Challenger 2 main battle tanks to the Challenger 3 standard. With the programme understood to be progressing according to schedule, this article examines the history of the Challenger 3, its technical characteristics, and what this programme says about the wider state of the British Army and the UK's defence industry.

▲ Only 148 of the British Army's Challenger 2 MBTs will be upgraded to the Challenger 3 standard. [Crown Copyright 2025]

Arriving more than three years after Russia's full-scale invasion of Ukraine and amidst intensifying pressure from the Trump administration for Europe to spend more on its defence, the UK Labour Government's Strategic Defence Review was finally published in June 2025. Advocating for a 'NATO first' defence policy, it calls for the British Army to be able to contribute two divisions to NATO, one of which will have three brigades equipped with armoured and mechanised capabilities, as well as their supporting enablers. Yet the British Army's Challenger 2 main battle tank (MBT) – one of the critical capabilities for these brigades – is an outlier in NATO. Not only is the British Army the sole European user of this vehicle, but it is also the only NATO MBT armed with a 120 mm rifled gun, meaning that it can only be used with proprietary, non-standard two-piece ammunition. Moreover, the Challenger 2 lags behind its NATO contemporaries in other key respects, being underpowered for its weight and deficient in situational awareness. Scheduled to enter service in 2027 and to serve until at least 2040, the Challenger 3 upgrade is a belated attempt to remedy many of these deficiencies and lift the platform to the level of its NATO contemporaries.

A long time in the making

Should the Challenger 3 enter service on time, it will come into the hands of British Army soldiers more than 30 years after the first Challenger 2s entered service in 1994. Whereas its (admittedly older) NATO counterparts such as the Leopard 2 and M1 Abrams have received extensive upgrades across this period, the Challenger 2 has been less fortunate. Although some vehicles were modified during 2003 to improve their suitability for operations in Iraq and a programme was initiated to replace their outdated thermal imagers in 2019, the British Army prevaricated over making a decision on a comprehensive mid-life upgrade for the Challenger 2 until 2021, leaving it more and more outdated by contemporary NATO MBT standards.

This was certainly not a result of a shortage of options – many of the Challenger 3's upgrades have their roots in earlier programmes that were ultimately cancelled. One of the first serious efforts to upgrade the Challenger 2 was the Challenger Lethality Improvement Programme (CLIP), which started around 2004. With the need to maintain commonality with older Chieftain and Challenger 1 MBTs no longer a factor in the post-Cold War downsizing of the British Army, this project proposed reworking the turret and replacing the rifled gun with a NATO-standard 120 mm L/55 smoothbore gun from Rheinmetall. Deemed prohibitively expensive, this specific programme was cancelled around 2006 and rolled into the more extensive Challenger Capability Sustainment Programme (CSP). Maintaining the switch to the new Rheinmetall smoothbore gun, this also included the installation of the 1,500 hp MTU EuroPowerPack, rectifying another major issue with the Challenger 2: its relatively low power-to-weight ratio.

As austerity took its toll on the MoD's finances and counter-insurgency remained top of the British Army's agenda, the CCSP found itself cancelled in 2012 in favour of the much less ambitious Challenger Life Extension Programme (LEP). Focused on obsolescence management, the LEP abandoned earlier efforts to replace the gun and powerpack and instead aimed to digitise the vehicle's archi-

RBSL published photographs of P1, the first prototype of the Challenger 3, in January 2023 during the International Armoured Vehicles Conference. [RBSL]

tecture and substitute ageing subsystems such as the sights and fire control system (FCS) for modern alternatives. Two contractors were down-selected in December 2016 to meet this brief: Germany's Rheinmetall pitted against the Team Challenger 2 alliance formed of BAE Systems Land and General Dynamics Land Systems (GDLS), with the latter's UK subsidiary having already been chosen to build the new Ajax family of tracked armoured fighting vehicles. In a sign of things to come, both contractors tried to tempt the British Army by fitting their demonstrators with extra capabilities.

First to be unveiled in October 2018 was Team Challenger 2's 'Black Night' prototype, which integrated proven components used on other British Army platforms to reduce development risk and costs. These encompassed new sights for the crew, a new FCS, new gun control equipment (GCE), and an architecture that was compliant with Generic Vehicle Architecture (GVA) standards. However, it was also showcased with an Elbit Systems Iron Fist hard-kill active protection system (APS), showing how the new architecture could accommodate capabilities beyond the LEP's narrow remit. Rheinmetall's demonstrator shown in January 2019 pushed the envelope even further by once again proposing to fit its NATO-standard 120 mm L55 smoothbore gun mounted in a newly designed turret.

Despite the new gun not being a requirement for the LEP, Rheinmetall's efforts to tempt the British Army to reconsider the scope of the LEP appear to have worked, as the programme evolved into the more extensive LEP+, which combined the obsolescence

management of the original LEP with the addition of a new gun as championed by Rheinmetall. This also coincided with a major industrial development that saw Rheinmetall buy a controlling stake in its competitor BAE Systems Land, resulting in the formation of the Rheinmetall BAE Systems Land (RBSL) joint venture company in July 2019 and the upending of the LEP competition. With the British Army's requirements now aligned with industry's vision, the Defence Command Paper published in March 2021 announced that an upgrade of 148 of the British Army's 213 Challenger 2s then in service would be funded by a GBP 1.3 billion investment. Shortly afterwards, RBSL was awarded a GBP 800 million to carry out the upgrade of 148 Challenger 2s, including eight prototypes.

Construction on the initial prototypes had started by January 2022 and the first photographs of the initial prototype were shown at the International Armoured Vehicles (IAV) Conference one year later in January 2023. Remarkably for such a complex and long-coming programme, the MoD announced that the Challenger 3 had passed its Critical Design Review (CDR) in February 2023, one month ahead of schedule. If this momentum continues, the qualification review of the demonstration and trials phase will be passed before the end of 2025, after which manufacturing of series-production vehicles will commence.

Strong but slow

As the final product of this extended development process, the Challenger 3 ties together the developmental strands that had been abandoned in earlier programmes such as the CLIP, though some shortcomings remain.

The most noticeable change over the Challenger 2 is the new turret and the new gun. The Challenger 3 will be armed with the Rheinmetall 120 mm L55A1 smoothbore gun, which also arms the Leopard 2A7 and A8 variants. Compared to the standard L55 proposed under the CLIP and CCSP programmes, the L55A1 has a higher chamber pressure, which in turn enables it to fire higher velocity armour-piercing fin-stabilised discarding sabot (APFSDS) projectiles capable of perforating armour with a thicker rolled homogenous armour equivalent (RHAe). This will include the KE-2020Neo enhanced Kinetic Energy (eKE) round that Rheinmetall has developed under a government-to-government agreement between the UK and Germany. Rheinmetall received a contract from Germany and the UK to qualify this round in October 2024. KE2020Neo is expected to receive the designation 'DM83'.

There are several advantages that come with adopting the smoothbore main gun. First and perhaps most importantly, the L55A1 will be compatible with NATO-standard ammunition. This will have the benefits of reducing the cost of developing new ammunition natures and procuring existing rounds, while also improving interoperability with other NATO militaries. Secondly, the ability to employ NATO-standard ammunition such as the DM73 APFSDS round and the DM11 programmable high explosive (HE) round will respectively increase the lethality of the Challenger 2 against armoured targets, and targets such as buildings or emplaced infantry. On the former, this is because the Challenger 2's rifled gun uses two-piece ammunition that is separated into the projectile and bag charge which must all be loaded separately (technically it also requires a vent tube for initiation of the bag charge, though tankers don't tend to count this as part of the ammunition, in part because it doesn't need to be hand loaded). While this arrangement can make it easier to stow the smaller individual parts of the ammunition in the confined space of an MBT, the penetrator of an APFSDS projectile cannot be extended into the charge as it can be with unitary ammunition. Consequently, the length and therefore the density of the penetrator cannot be increased, limiting the potential for increasing its ability to perforate thicker armour.

Similarly, the Challenger 2's use of a high-explosive squash head (HESH) round and the absence of a conventional HE round for its rifled gun limits its performance against targets that are most effectively tackled by fragmentation. This particular shortcoming

Seen here undergoing firing trials in Germany, the Challenger 3 will be armed with Rheinmetall's L55A1 120 mm smoothbore main gun. [Crown copyright 2024]

has been documented by Ukrainian personnel operating the Challenger 2, as it has become more common for MBTs to be used to engage entrenched infantry or buildings than armoured targets or fortifications such as bunkers. One final advantage of adopting the smoothbore gun is that smoothbore barrels do not wear out as quickly as rifled barrels, easing the logistical burden of supporting the Challenger 3 in the field.

The Challenger 3's L55A1 gun is housed in a newly-designed turret with new GCE. One of the most prominent features of this new turret is an extended rear bustle, which is used to store 15 rounds of ammunition, the 16 remaining rounds being stowed in the hull. This bustle is isolated from the rest of the turret and equipped with blow-out panels that divert the blast away from the crew, increasing their survivability in the event of ammunition deflagration or detonation.

The survivability of the Challenger 3 against ballistic and blast threats is also enhanced by a series of other modifications. Of these, the most intriguing is the Epsom new modular armour (nMA) that replaces the Dorchester composite armour used on the Challenger 2. Very little detail has been disclosed on this passive armour array, but it appears to consist of modules fitted to the front and sides of the hull and turret, as well as on the underbelly of the hull. Due to its modular design, the armour modules can be more easily repaired, replaced, or upgraded, allowing the protection of an individual Challenger 3 to be tailored to its specific operational environment.

Two other notable survivability upgrades that reduce the likelihood of a threat impacting the vehicle in the first place include the Elbit Systems Enhanced Laser Warning System (ELAWS) and the Rafael Trophy Medium Variant (MV) hard-kill APS. Comprising four laser warning receiver (LWR) panels mounted on the turret sides and a central control unit, the ELAWS provides a warning to the crew when the vehicle is lased, allowing them to deploy obscurant smoke and/or take evasive action. Also mounted on the turret, the Trophy MV typically contains four radar panels and two effector launchers, which can detect and intercept incoming projectiles such as anti-tank rockets and anti-tank guided missiles. Rafael also claims to have modified the software in the Trophy system to enable it to detect and intercept unmanned aerial vehicles (UAVs), although the ability of the system to neutralise threats employing a lofted attack trajectory such as top-attack ATGMs is uncertain, but understood to be limited to certain angles. However, it is important to note that integration of the Trophy MV into the Challenger 3 remains a work in progress and it has yet to be seen fitted to a prototype, with Rafael having received a GBP 20 million (USD 26 million) contract to qualify and integrate the APS in July 2023. Furthermore, only 60 Trophy kits are expected to be purchased for the Challenger 3 for use in high-intensity operations, with the rest of the tanks delivered in a 'fitted-for-but-not-with' configuration.

The Challenger 3's capacity to accommodate such subsystems that demand more power from its electrical system is enabled by a new digitised architecture that is compatible with GVA standards. By standardising various electrical interfaces, this makes it easier for new subsystems to be integrated into the vehicle. One of these systems was expected to be the Morpheus tactical communications system, but the cancellation of Evolve to Open (EvO) – a key component of the Morpheus programme – in December 2023 indicates that Challenger 3 will use the Bowman ComBAT Infrastructure and Platform (BCIP) 5.6 communications system and its subsequent iterations. In addition to the communications, the sighting systems used by the driver, gunner, and commander will also be replaced with systems common to the Ajax family of AFVs.

Most significantly, the commander will receive the Thales Orion stabilised panoramic sight. Equipped with a day camera, thermal imager, and laser rangefinder, this provides the crew with a significant uplift in situational awareness, as the commander of the Challenger 2 had to make do with a fixed sight that did not have an independent night vision system. This made the commander reliant on a feed from the gunner's thermal imager and restricted their ability to independently survey the battlefield, hampering hunter-killer operations. Similarly, the gunner's sight will be replaced with the Thales DNGS T3 forward-facing stabilised sight that is equipped with a day camera, thermal imager, and laser rangefinder. Both of these sights will incorporate Thales's Signal Processing System (SPS), an automatic target tracking system that can alert the crew to potential threats or targets. The driver will benefit from a Rheinmetall Trailblazer camera system containing a low-light camera and a thermal imager. The feed from this system will be projected onto an Embedded Image Periscope (EIP) from G&H, which allows the driver to quickly switch between the digital image from the camera system and the direct optical view from their glass periscope.

The Challenger 3 has a sensor unit for the Rheinmetall Trailblazer driver's vision system mounted on the centre of the glacis. [Crown copyright 2024]

Yet notwithstanding these significant upgrades, the lacklustre powerpack will remain the Achilles' heel of the Challenger 3, particularly as the new subsystems could increase its weight beyond the approximately 75,000 kg of the Challenger 2 in its heaviest configuration. Prior to undergoing the Challenger 3 upgrade, the Challenger 2s slated to receive the upgrade will have their automotive components overhauled as part of the separate Heavy Armour Automotive Improvement Programme (HAAIP). This refresh involves rebuilding the 1,200 hp Perkins (now Caterpillar) diesel engine to the CV12-9A standard, refreshing the transmission, replacing the existing hydropneumatic suspension units with third-generation Horstmann Hydrogas (also hydropneumatic) suspension, replacing the hydraulic track tensioner, and installing a new cold-start system. However, despite reports in some media outlets to the contrary, this programme does not involve uplifting the powerpack to the 1,500 hp standard found in most other NATO MBTs. This would require an extensive redesign of the cooling system, a risky and costly endeavour that is beyond the scope of the HAAIP. This means that the Challenger 3 is destined to remain underpowered compared to its peers (see Table 1), limiting its battlefield mobility.

TABLE 1

Table 1: Power-to-weight ratios of select NATO MBTs

MBT	Power-to-weight ratio (hp/tonne)
Challenger 2	16.0
Leopard 2A8	21.7
Leclerc XLR	24.0
M1A2 SEPv3	22.3

Note that these figures are representative, as figures for the weight of MBTs can sometimes vary depending on configuration, and between sources.

Too little, too late?

While the Challenger 3 programme does appear to provide a much-needed upgrade to the Challenger 2's technical capabilities, looking beyond the technological perspective raises difficult questions about the viability of the British Army's tank fleet and its utility in a conflict involving NATO.

Most critically, only 148 Challenger 2s will be upgraded to the Challenger 3 standard. Although care should be taken when extracting general lessons from one conflict, the Russo-Ukrainian War is a reminder that a protracted high-intensity war against a peer-level opponent such as Russia will ultimately involve large losses of MBTs and other materiel. The Russo-Ukrainian War also suggests that losses will be amplified if – like the British Army – the force lacks a cohesive short-range air-defence network capable of protecting equipment against cheap unmanned aerial vehicles (UAVs). Even though the British Army is unlikely to field its MBTs in such a conflict without the support of its NATO allies and their much larger MBT fleets, the relatively small number of Challenger 3s available to its armoured brigades does raise questions regarding the Army's ability to sustain its commitment of providing an armoured division to NATO for any meaningful length of time, particularly when considering that a portion of tanks will need to be held for training and only a fraction will be equipped with the Trophy MV APS. This is exacerbated by the fact that the Challenger 2 is slated to only begin entering service in 2027, meaning that the fleet may not even be at full strength before the most pessimistic estimates indicate that Russia may have been able to regenerate its combat power to a level sufficient to threaten NATO.

The battlefield utility of the Challenger 3 will depend on the availability of supporting enablers including the Titan AVLB. [Crown Copyright 2007]

These concerns regarding mass also extend to the Challenger 3's supporting enablers, including the related Titan armoured vehicle-launched bridge (AVLB), Trojan armoured engineering vehicle (AEV) and Challenger Armoured Repair and Recovery Vehicle (CRARRV). Without the support of these vehicles, the British Army will face challenges in manoeuvring the Challenger 3 into favourable terrain and recovering damaged or abandoned vehicles. The British Army will therefore need to make sure that corresponding efforts to maintain and overhaul them are implemented quickly, or the operational effectiveness of the Challenger 3 fleet will be hampered. This may be complicated by the fact that these vehicles have limited commonality with the Challenger 2 and 3, as they are based on unique hulls.

The British Army's struggles to articulate a coherent force structure will also have a negative impact on the operational effectiveness of the Challenger 3. Having cancelled the Warrior Capability Sustainment Programme (CSP) in 2021, the British Army has been forced to rely on the obsolescent Warrior infantry fighting vehicle (IFV) to support its mechanised infantry. With this due to leave service in 2030 and no firm commitment to procuring a replacement based on the Ares variant of the Ajax platform, there is a real danger that the Challenger 3 will find itself operating alongside infantry without an appropriate IFV. Since MBTs often rely on infantry to identify and neutralise threats such as anti-tank guided missile (ATGM) teams, this deficiency could seriously impair combat operations involving the Challenger 3.

On an industrial level, the Challenger 3 upgrade may also be a case of too little, too late. As with the case of the Boxer 8×8 wheeled AFV, the decision to delay the implementation of these programmes has rendered it difficult to sustain sovereign AFV manufacturing, with the result that the Challenger 3 is now dependent on a majority German-owned company to deliver this capability. Worse still, it is difficult to see how the expertise and manufacturing capacity set aside for the Challenger 3 will be sustained after the final vehicles are delivered, unless the British Army decides to fund additional upgrades. The only other Challenger 2 operator is Oman, which operates just 36 vehicles, and it is unclear whether the Omani Army is interested in upgrading its fleet. Although the UK MoD and RBSL have claimed that it would be possible to export the Challenger 3's turret for use on other platforms, it is hard to imagine which markets they have in mind, as the effort to take on the risk of funding integration into a new platform is unlikely to be an attractive proposition.

Britain's last tank?

Considering all these factors, the arrival of the Challenger 3 will be a somewhat bittersweet moment for the British Army. On the one hand, the upgrade will finally bring many long-coveted developments in firepower, protection, and situational awareness to fruition, although the Challenger 3 will still remain underpowered compared to its peers. On the other hand, the Challenger 3 story is replete with missed opportunities and prevarication, with the result that this uplift is being delivered much later than it could (and indeed should) have been. Furthermore, the small number of Challenger 3s that will enter service raises doubts over the British Army's ability to uphold its obligations to NATO in any kind of protracted conflict.

The Challenger 3 will also be delivered by the majority German-owned RBSL joint venture, highlighting how British domestic industrial expertise in the AFV sector has withered over the decades since Challenger 2 entered service. With the epicentre of European MBT development now on the continent, the Challenger 3 will almost certainly be the last unique MBT used by the British Army. Perhaps the one silver lining of this otherwise lamentable decline is that the cooperation between British and German industry could put UK industry in a strong position to locally produce a future European MBT such as that envisioned under the Franco-German Main Ground Combat System (MGCS) programme.

Interview with ST Engineering's BG (Ret.) Chua Jin Kiat

In August 2025, BG (Ret.) Chua Jin Kiat, Executive Vice President and Head of International Business and Market Development, Defence and Public Security at ST Engineering was interviewed by Stephen Barnard, Publisher of ESD, to discuss the company's developments, and localisation efforts for European and NATO countries.

BG (Ret.) Chua Jin Kiat, Executive Vice President and Head of International Business and Market Development, Defence and Public Security. [ST Engineering]

ESD: Please update us on ST Engineering's developments and efforts in Europe.

CJK: There has been strong European demand for military capabilities and NATO partners' defence budgets have been growing aggressively. At June's NATO Summit, partners committed to investing up to 5% of their GDP in defence by 2035. And this year, all NATO partners are expected to meet or exceed the pre-existing 2% target of GDP.

Across the continent and other parts of the world, security challenges continue to evolve. We have hence intensified our engagements with various European partners and end users for our future-ready products that can help them meet some of their operational challenges quickly.

I can give you an example of our successful engagement in Europe. We've been collaborating with Babcock to promote our Ground Deployed Advanced Mortar System (GDAMS) to end users. This platform-agnostic system enables rapid shoot-and-scoot missions, and a live-fire demonstration was held in South Africa last year. Many European end-users were in attendance, and we have received multiple expressions of interest.

Our Bronco programme has also made inroads in Europe. We have established partnerships that will allow the Bronco to be produced locally to meet the needs of European customers. At DSEI, apart from showcasing the Finnish Sisu GTT variant at our booth, we will also be announcing a new partnership with a renowned Italian defence manufacturer. Suffice to say that there has been strong interest in the Bronco because of its unique all-terrain capabilities.

We have also been constructively engaging European nations in Scandinavia, Western and Central Europe, and Eastern Europe. In recent months, we have identified more opportunities and sensed greater urgency from the Baltic nations. These conversations are now progressing rapidly, and we are confident that our products will enhance their security.

The ST Engineering Bronco ATV articulated tracked vehicle. [ST Engineering]

ESD: You mentioned GDAMS. Tell me more about your localisation efforts for GDAMS and Bronco to meet the needs of EU and NATO countries.

CJK: We're actively working with UK partners like Babcock to promote our innovative 120 mm GDAMS mortar system. The British Army has a requirement for a weapon like the GDAMS. I know that several other NATO and MENA countries are also on the lookout for a low-cost, quick deployment mortar like the GDAMS. ST Engineering is working with our partners to offer localised GDAMS production, which also addresses larger strategic imperatives under the UK's Land Industrial Strategy. I can't tell you more now, but at DSEI UK 2025 we shall be announcing other partnerships to support our GDAMS offering. You will likely be able to see the GDAMS integrated onto a couple more other platforms, as we expand our collaboration with other OEMs. This is a unique proposition of the GDAMS – its flexibility to be quickly integrated with any OEM platform. We're also looking forward to completing qualifications and conducting another demonstration for potential end users by the end of 2025.

ST Engineering has strengths in building digitalised fighting forces, which stems from our long track record of supporting the Singapore Armed Forces. Singapore is a small country reliant on conscription, so digitalisation is vital to ensure that our products can be operated with fewer troops, are easy to train for and easy to use. This fits the profile of our young and tech-savvy soldiers.

In this vein we are working as a technology partner with Ultra PCS in the UK on defence platform electronics, to provide a digital backbone solution to digitalise new and legacy vehicles, to achieve seamless connectivity between shooters, sensors and decision-makers. At DSEI 2025, you will see the UltraEAK Electronic Architecture Kits displayed on various platforms, as Ultra PCS starts to form its own collaborations with various OEMs. Any military in the world will want a platform-agnostic digital upgrade kit, and we believe that ours is the most effective and affordable.

Our Bronco All Terrain Tracked Carrier is making inroads in Europe too. Besides our collaboration with the Finns and Italians, we aim to maintain a continued presence in Europe to produce, maintain and upgrade our vehicles in collaboration with our partners, and to develop customised Made-in-Europe variants that meet the unique and strategic needs of the various end users.

▲ **The Sisu GTT, whose design originates from that of the Bronco ATV family. [ST Engineering]**

ESD: I heard you're introducing a new concept, the Light Infantry Reconnaissance-Strike Concept. Can you enlighten me further?
CJK: Yes, this concept represents a bold vision for modern battlefields. One vital lesson from Ukraine is that light, dispersed and mobile units enjoy the best survivability in a battlespace that is increasingly dominated by drones and artillery. We believe our Light Infantry Reconnaissance-Strike Concept combines digital command architecture, autonomous systems, counter-UAS protection and organic indirect fires. We are providing a force-multiplying edge for disaggregated units operating in high-threat environments.

The Light Infantry Recce-Strike Concept has three pillars: mobility/survivability, precision/lethality and C4ISR/multi-domain integration. No longer is a dismounted mortar team at the mercy of the enemy, for instance. We're giving light forces a massive advantage with precise massed fires of their own. The other intention is to push a responsive firing/counter-fire solution down the command echelons. Fires could be decentralised from Battalion level, down towards Company commanders, for them to have their own 'organic' fire support.

At our DSEI stand, we will have a Tac-6 6×6 vehicle depicting this concept, but of course it can be integrated onto any 4×4 or 6×6 platform, whether new or an existing asset in the user's military ORBAT. Our representative vehicle features a 120 mm GDAMS that offers a shoot-and-scoot capability of being able to be deployed in just 15 seconds, the UltraEAK Electronic Architecture Kit that enables digitalisation as an open-architecture backbone, military-grade handsets from our partner EDGE-KATIM with ST Engineering's integrated battle management system, and our ADDER remote weapon station with integrated counter-drone systems.

To give you another example, ST Engineering's TAURUS 4×4 unmanned ground vehicle can also be part of Concept, providing support for functions like autonomous logistics and to export power to other users in the field.

Modular Light Infantry Recce-Strike systems, as described above, form a cohesive, mission-ready force package. The beauty is that ST Engineering can use any existing platform, sensor and weapon from an army's existing inventory to implement this concept. We're challenging conventional thinking, and our message is that light forces no longer need to be lightly equipped. Infantry don't have to rely on heavier formations for lethal effects, because with the Light Recce-Strike Concept integrated onto their platforms, they can detect, decide and deliver at speed.

▲ **The GDAMS 120 mm mortar system on Tac-6 6×6. [ST Engineering]**

ESD: That's an interesting concept, but what is its relevance to NATO and partner nations?
CJK: We're not displaying a patchwork of disparate technologies here. Instead, the Light Recce-Strike Concept is a cohesive mission capability delivering a full-spectrum, export-ready package designed for NATO and partner forces. We're not a platform provider in this case. Instead, ST Engineering is stepping forward as mission integration partner, ready to deliver real-world operational advantage at the battlegroup level and below.

As a strategic partner to Singapore's military, and as an accomplished integrator leveraging numerous relationships, we have the local expertise and the global reach to achieve this. Our systems are modular, scalable and ready for localisation, to be made in your country, via local partnerships. Employing our OEM-agnostic approach, we can implement this Light Infantry Recce-Strike onto relevant platforms for the UK or any other NATO partner.

In fact, the UK's Strategic Defence Review mentioned the need to accelerate the development and deployment of its 'Recce-Strike' approach – combining existing capabilities and technologies, such as armoured platforms, with constantly evolving technology – as part of efforts to modernise the strike reconnaissance complex.

This is just one example of how ST Engineering leverages innovative technologies to anticipate the needs of customers so they're ready for tomorrow's challenges. Seamlessly interoperable within NATO frameworks, these systems become sovereign. That means our customers build capability and strengthen local industry capacity. There does not need to be dependency on a foreign OEM.

MGCS: A status update

Alexey Tarasov

Launched in 2017, the Franco-German Main Ground Combat System (MGCS) programme aims to deliver a next-generation heavy tracked platform – not simply a successor to the Leopard 2 and Leclerc main battle tanks (MBTs), but a conceptually different approach to armoured warfare. This article explores the known aspects of the MGCS programme in detail.

▲ The KNDS EMBT-ADT 140 technology demonstrator on display at the Eurosatory 2024 exhibition. This model featured the 140 mm configuration of the ASCALON gun. [Mark Cazalet]

The timeline

Conceptualised in the early 2010s, the MGCS project was formally launched in July 2017 by French President Emmanuel Macron and the then German Chancellor Angela Merkel. On 19 November 2018, Germany was announced as the lead nation in the development of the MGCS. In June 2019, Germany's Rheinmetall joined the MGCS effort, which was initially led by the KNDS holding company, formed as a result of a merger between Krauss-Maffei Wegmann (KMW) and Nexter in 2015. Finally, in May 2020, the System Architecture Definition Study (SADS)–Part 1was awarded to Rheinmetall and KNDS.

AUTHOR

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Work on the MGCS programme was accelerated by the onset of the Russo-Ukrainian conflict. In July 2023, France and Germany agreed to develop a High-Level Common Operational Requirements Document (HLCORD) for the MGCS. This was followed by a meeting between the French and German defence ministers in September 2023, during which Boris Pistorius and Sébastien Lecornu agreed to move the MGCS project forward.

On 17 April 2025, the MGCS Project Company GmbH was established in Cologne. This step will enable negotiations with the Federal Office for Equipment, Information Technology and In-Service Support of the Bundeswehr (BAAINBw) later in 2025 and allow the programme to proceed to the next phase.

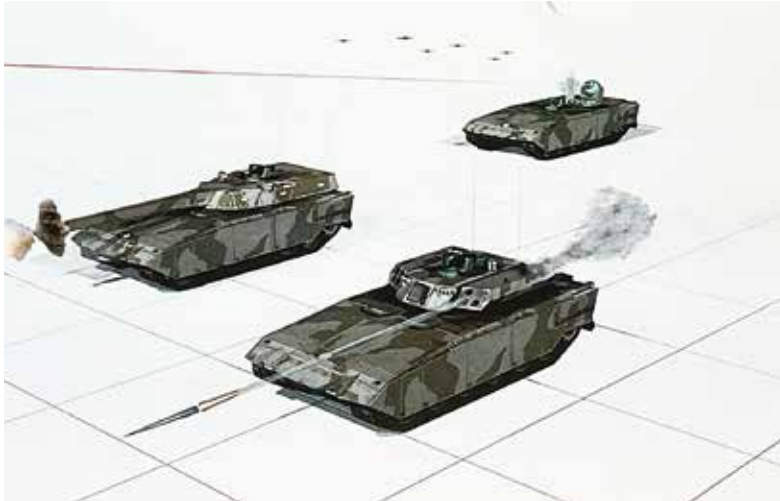
Initially, the plan envisioned fielding the MGCS in the 2030s, but later, the schedule was pushed back. In 2023, initial fielding and the start of serial production were expected in 2035, with full operational capability envisioned for 2040. However, since then the expected fielding date has been pushed back by around 10 years from initial plans. During a press conference on 21 September 2023, Boris Pistorius said that MGCS would enter service in approximately 20 years, while Sébastien Lecornu cited the period between 2040 and 2045.

By mid-2025, the total estimated cost of the programme included EUR 150 million for the SADS–Part 1, while the projected cost for SADS–Part 2 and the manufacture of technology demonstrators is expected to reach EUR 1.5 billion.

The concept

Conceptually, the MGCS is a 'system of systems' heavily influenced by the principles of network-centric warfare and the US-developed multidomain warfare doctrine. The MGCS concept integrates modern technologies such as robotics, artificial intelligence (AI), onboard unmanned aerial vehicles (UAVs), electronic warfare (EW) systems, networked radio datalinks, and more.

▼ The MGCS concept consists of three vehicles: a manned MBT (top left), a manned missile carrier (front) and an unmanned sensor and NLOS weapon carrier (rear right). [Bundeswehr]



On 26 April 2024, the French and German Defence Ministers, Sébastien Lecornu and Boris Pistorius, signed a memorandum of understanding (MoU) outlining the future system's capabilities, distributed across eight technology pillars. These include: platform, traditional firepower, innovative firepower, connectivity, sensors, simulation, protection and infrastructures.

As presently conceived, MGCS is a multiplatform system that includes three tracked armoured vehicles:

- A manned MBT,
- A manned missile carrier, and
- An unmanned support vehicle equipped with sensors, UAVs, and non-line of sight (NLOS) effectors.

These three vehicles will share the same base platform, which, according to the requirements, should have a weight of less than 50 tonnes. In theory, the multi-platform architecture would allow combat and support functions to be distributed among three vehicles while retaining the same level of tactical and operational mobility. At the same time, a unified platform would reduce production and maintenance costs through component commonality, simplified logistics, and allowing a degree of streamlining training.

The armament

There is still no final decision on the choice of main armament. The leading contenders are the 140 mm L48 configuration of the ASCALON gun, and Rheinmetall's 130 mm Rh 130 L/52 smoothbore gun, both of which would use autoloaders.

The ASCALON (Autoloaded and Scalable Outperforming gun) is a modular system featuring interchangeable 120 mm and 140 mm barrels. The remainder of the system's components remain the same, allowing for a high level of commonality between the two versions. The ASCALON is currently undergoing trials; it was previously expected to reach technical maturity by 2025. The system has already completed static stand firing tests in 2024. By the end of 2025, the system is expected to complete testing integrated into an actual tank turret.

In the meantime, Rheinmetall offers a 130 mm gun with a more traditional design. The advantages of this system lie in its technical maturity and the well-established manufacturing process. Although Rheinmetall's 130 mm gun is considered unlikely to be selected for MGCS, it may still prove valuable for 'intermediate MBT solutions', representing an advancement over current 120 mm tank guns.

The ASCALON gun was showcased in both 140 mm (left) and 120 mm (right) configurations at the Eurosatory 2024 exhibition. [Tank Encyclopedia courtesy photo]

Comparing these two systems, the ASCALON appears to be the preferred option, strongly advocated by its developer KNDS France. Its main advantages lie in its significant potential for future development, both in terms of the gun system and ammunition, as well as its flexibility to be used in 120 mm or 140 mm, which allows it to be adapted to a wide range of end-user requirements.

In terms of ammunition, the 140 mm configuration ASCALON uses case-telescoped (CT) tank rounds, while the 120 mm configuration uses conventional 120 mm NATO standard one-piece ammunition. The APFSDS round intended for ASCALON will feature a tungsten-core penetrator, as neither France nor Germany currently has the capability to process depleted uranium (DU) ammunition. There are several advantages offered by the CT design, including – such as greater compactness, modularity, and a reduced logistical footprint compared to traditional 'bottle-shaped' munitions. However, the shape and volume of CT rounds also provides greater scope for developing alternative ammunition natures. It is therefore reasonable to suggest that, over time, additional 140 mm rounds with various effects may be developed, such as a gun-launched anti-tank guided missile (GLATGM).

Secondary armaments of the MGCS platforms are slated to include a wide range of offensive and defensive systems, such as a hypersonic effector, and NLOS effectors to provide an indirect fire capability. Other weapons will likely include machine guns and automatic cannons, either mounted in remote weapon stations (RWSs) or coaxially, for the counter-UAV (C-UAV) role or engaging soft targets. A possible directed energy weapon (DEW) has also been discussed in prior years, but more recent presentations have omitted it.

Employment

At the moment, the concept of operations (CONOPS) for the MGCS has only been outlined broadly; however, the available information provides some understanding of how the three-vehicle system is likely to operate.

According to information from the IAV 2025 event, MGCS will focus on two key aspects – mobility and SDRI+T (surveillance, detection, recognition and identification plus targeting). These will be complemented with more traditional aspects of the 'iron triangle', such as firepower in form of vast array of direct and indirect effectors, and a sophisticated protection suite. In the latter case, each AFV within the group will include passive armour, a hard-kill active protection systems (APS) and electronic warfare (EW) systems. However, a collective defence system, where each AFV protects the others, is also possible.

One possible solution for the APS is the modular hard-kill Diamant system by Thales Group. Diamant is being developed under the French Ministry of Defence's (MoD's) PROMETEUS programme for integration with the vehicle being procured under the SCORPION programme. The system consists of radar sensors and multiple replaceable effector modules. Each mod-

ule contains two effectors: one upward-firing (for top-attack or high-angle threats) and one downward-firing (for direct-fire threats), enabling it to counter a wide array of threats.

The focus on sensors and mobility is based on observations of modern land warfare, as well as an understanding of battlefield conditions and the array of future threats. Today's battlefield is characterised by several important factors: an increased density of enemy ISR assets; a surge in the use of precision-guided munitions at the tactical level; and a new array of threats to AFVs and their combinations.

A mock-up of Thales' Diamant hard-kill APS was shown on the EMBT-ADT 140 prototype shown at Eurosatory 2024. It is shown here as a black strip of effector modules running along the top of the turret, with radars at the turret corners. [Mark Cazalet]

To survive on the modern battlefield, an AFV needs to be on the move – hence the focus on reduced weight and increased mobility. At the same time, an AFV (or a group, in the case of the MGCS system) needs to control a wider area all around and across different domains, including land, air, electromagnetic, and cyber.

This task, however, presents a challenge: the amount of data received by the system must not overwhelm the crews. From the perspective of Hensoldt, the solution lies in greater automation. Information gathered from various sensors – including optronics, radars, UAVs, and allied assets – will be consolidated and analysed with the support of artificial intelligence (AI) in real time. The results will be shared across MGCS vehicles within a group, and likely with higher echelons of allied command as well. At least in theory, this will reduce the burden on the crews while providing them with a comprehensive picture of the battlefield.

Notionally, all three vehicles are intended to operate as a single unit. However, combat scenarios in which one or more vehicles in the group are damaged or immobilised are likely. Therefore, it is reasonable to assume that MGCS vehicles will also be capable of operating individually or in smaller groupings, albeit with reduced capabilities.

Of course, many questions remain unanswered. What will the composition of an MGCS armoured unit look like? How will the MGCS, with its vast and diverse arsenal, be resupplied in the field? Will there be organic engineering capabilities for any of the AFVs, or an indirect fire capability for the main gun? How far apart can MGCS vehicles in a group disperse while retaining connectivity? While many of these remain the subject of speculation, the further the MGCS programme progresses, the more specific details will emerge.

Intermediate solutions

While initially understood as a replacement for the Leopard 2 and Leclerc MBTs, in April 2024 the German and French Ministers of Defence reiterated that MGCS is not intended to be a direct successor to today's Leopard 2 or Leclerc. "It's not about the tank of the future, but about the future of the tank," they said.

This position is understandable, given the complexity of the MGCS programme, its development timeline, and the history of delays. Until the MGCS is ready, at least for initial fielding in the 2040s, an 'interim solution' will be required.

This will most likely result in Germany upgrading the majority of their MBT fleet to the Leopard 2A7/2A8 standards, and France to Leclerc XLR variants, to fill the capability gap. If the MGCS programme proceeds according to schedule, in the 2040s both nations would operate fleets consisting of legacy

The Leclerc XLR MBT on display at Eurosatory 2024. The XLR features improved protection over earlier Leclerc family variants. [Mark Cazalet]

systems, possibly with further upgrades, alongside smaller numbers of newer and more sophisticated MGCS platforms.

On the one hand, this fleet configuration may impose additional financial and operational burdens, especially given the already high costs associated with the MGCS. On the other hand, the future composition of most tank fleets will likely include a mix of legacy and modern platforms. This is not a uniquely European phenomenon but part of a global trend, with notable examples such as the US Army fielding upgraded M1A2 SEPv3 tanks while developing the follow-on M1E3; Russia maintaining a vast fleet of upgraded T-72, T-80, and T-90 tanks alongside limited production of the Armata platform; and South Korea operating a mix of K1 and K2 MBTs while working on the NG-MBT concept developed by Hyundai Rotem.

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Closing thoughts

It is worth noting that despite the progress being made, attitudes toward the MGCS programme remain sceptical. Supporting this view, many observers point to the programme's complexity, disagreements among stakeholders, and the repeatedly shifting project schedule. Further confusion and even uncertainty are caused by the overwhelming number of tank-related programmes across Europe, which are at various stages of development.

Beyond the MGCS programme, other ongoing efforts include upgrades to the Leopard 2 and Leclerc, the KF51 Panther by Rheinmetall (currently marketed to Hungary and Italy), and a German-led joint battle tank development programme involving KMW and Rheinmetall on one side and Italy, Sweden, and Spain on the other. There is also the Leopard 2AX (also known as the Leopard 3 and 'Brückenlösung'), a synthesis of the Leopard 2A8 and Rheinmetall's KF51. Announced in September 2023, this programme may serve as a 'bridge solution' for the Bundeswehr until the MGCS arrives. Finally, there is the European MARTE (Main Armoured Tank of Europe) initiative. Launched in July 2025, it aims "to conduct study and design activities to create a future MBT system that adequately meets current and future threats, as well as the harmonised needs of the European Member States involved."

Programme/Model	Status/Timeline
MGCS	Entry into service expected around 2040-2045.
Leopard 2A7	In production, deliveries ongoing.
Leopard 2A8	In production, deliveries began in 2025.
Leopard 3/2AX	Technical studies ongoing, operational deployment expected by 2030.
Leclerc XLR	In production, at least 34 delivered in 2024-2025.
KF-51	In development, serial production is expected to begin in 2025.
MARTE	Research programme, further timeline is unknown.

While it is impossible at this point to predict the future of these programmes even in the short term, it is possible to draw some conclusions about the future shape of the European MBT and AFV landscape.

First, the sheer number of MBT programmes indicates a growing interest in improving conventional armoured capabilities across European nations, as part of a global trend. Many nations are seeking solutions to upgrade their existing AFV fleets, and even expand them. There is a well-established consensus that the tank is not dead, and the AFV market is responding accordingly.

Second, the variety of MBT programmes allows for offering tailored capabilities to meet the specific requirements of each operator. More importantly, there are (and will continue to be) different pricing options, enabling the selection of AFVs based on budgetary constraints. For instance, countries that find the MGCS excess to requirements may opt for alternative designs that still enhance the capabilities of their MBT fleets. At the same time, the vast majority of components for the existing programmes (excluding the purely theoretical MARTE initiative) come from the same vendors, such as KNDS, Rheinmetall, Hensoldt, and others. These components can be integrated to provide a high level of commonality across different platforms.

Third, the MGCS programme has no true alternatives within Europe or internationally, and no single European nation currently possesses the technological or industrial capacity to develop a next-generation MBT independently. A hypothetical scenario in which a non-European producer develops a next-generation MBT and secures European customers, all within the same timeframe as the MGCS, would represent a significant decline in strategic relevance for Europe's armoured vehicle industry. In other words, given the time pressure, abandoning MGCS would likely spell the end of any future MBT ambitions in Europe for the foreseeable future. In addition, such a decision could have long-term negative consequences, including the potential loss of international market share to competitors.

The Leopard 2A8 on display at Eurosatory 2024. This variant introduces the Trophy hard-kill APS. [Mark Cazalet]

A T-14 MBT at the Armiya-2024 exhibition. Thus far, T-14 is the only next-generation MBT accepted into service, albeit in very limited numbers. [Alexey Tarasov]

Despite recent progress, the MGCS programme still faces substantial risks, primarily political in nature. Differing national priorities, industrial interests, and shifting strategic outlooks continue to pose challenges to its development. Another critical issue is the question of industrial scalability: Can the European defence industry simultaneously deliver the MGCS programme, interim solutions for domestic operators, and fill the growing demand for MBTs internationally?

Regarding delays in the MGCS programme, it is important to note that they may ultimately prove beneficial. While many tactical and technological aspects of modern and future warfare were envisioned in the 2010s, a comprehensive understanding of the battlefield environment and the full spectrum of threats to AFVs has only emerged in recent years. A slower pace in developing requirements and refining CONOPS could prove advantageous for the MGCS programme as a whole, as well as for its future operators.

What is clear, however, is that Europe possesses both the technological expertise and financial resources necessary to complete the MGCS programme. Moreover, there is currently no viable alternative that could match the ambitions or strategic value of the programme. In this context, the MGCS programme is not just a question of military capability, but of preserving Europe's strategic autonomy and industrial competitiveness in the armoured warfare domain.

The Combat Air Flying Demonstrator: Rehearsing and preparing for GCAP

Jon Lake

BAE Systems has announced that its pioneering Combat Air Flying Demonstrator has reached a major milestone, with two thirds of the aircraft's structural weight now 'in manufacturing'. The company also issued the accompanying CGI render of the aircraft.

The UK-funded and developed Combat Air Flying Demonstrator is designed to test, develop and mature a range of new technologies in support of the trinational Global Combat Air Programme (GCAP) with the UK, Italy and Japan. It will allow GCAP partners to better understand risks much earlier than has been possible in any other programme. This important work collectively aims to dramatically reduce the time and costs involved in producing manned combat air programmes, while maintaining the sovereign design, engineering and manufacturing capabilities that are needed to keep the UK at the forefront of global aerospace innovation.

These images of Tempest studies do not represent an evolution, since several of them were undertaken in parallel. They do represent different emphases on elements of the requirement. The first to be seen was the 'Pregnant Pelican', as unveiled at Farnborough in 2018. The Concept Class Five aircraft was unveiled at Farnborough in 2022, while the Lambda-winged aircraft (the P189-17B) was first seen at DSEI Japan the following year. The so-called 'Big Delta' was revealed at Farnborough in 2024. [BAE Systems; Ministère des Armées/SITTA]

AUTHOR

Passionate about aviation and flying, **Jon Lake** grew up around aeroplanes, learned to glide before he could drive, learned to fly with the University of London Air Squadron, and has been in aviation publishing since 1984.

A once-in-a-generation effort

Tony Godbold, Future Combat Air Systems Delivery Director, for BAE Systems, said: *"This significant and challenging project will*

deliver the UK's first crewed combat demonstrator aircraft in four decades. The programme is accelerating the development of advanced design approaches and manufacturing techniques, helping to sharpen the UK's industrial edge and deliver benefits beyond the production of the aircraft. As well as developing a unique aircraft, we're building the technical foundations, workforce readiness and digital maturity essential to deliver the next generation of combat air capability."

The demonstrator aircraft has design features "that really define what a sixth-generation platform needs to be," according to a BAE Systems representative, but it is not in any sense a prototype for GCAP. The demonstrator may not even resemble the definitive production GCAP fighter, whose final configuration has not been decided. Rather, it is primarily intended to help BAE Systems to de-risk the forthcoming next-generation combat aircraft programme by rehearsing the application of advanced new-design solutions and digital manufacturing technologies. According to Godbold: "It's also about re-brigading ourselves and the wider UK industry about what it means to design and manufacture an aircraft from first principles again... it's been four decades since we've done something like this and been at this phase of the programme."

To a large extent, the demonstrator is about developing, facilitating and demonstrating industrial technologies and capabilities, and to develop skills in a cadre of suitably qualified experienced people (SQEP), rather than anything more operationally focused.

Air Commodore Johnny Moreton, a former UK Programme Director for the UK Future Combat Air Programme said that: *"So one of the life lessons here for a demonstrator programme is: 'do we have the suitably qualified experienced people that can actually build an aircraft from scratch, go and certify an aircraft, and go and fly the first one?' Because that's not something that the UK has done for a while. And actually, that's a skillset that's really quite important. How do we get to that world? It would be useful to have some form of design/methodology in sight that says: 'actually I can learn for the future'. So, the demonstrator is very much a 'let's get UK industry and the partners match fit for the future and exploit it downstream as well.'"*

Innovative design, engineering and manufacturing technologies used by the team will include model-based systems engineering and virtual simulation, 3D printing and additive manufacturing, cobotics (collaborative robotics), and digital twins. This will provide engineers from BAE Systems and the wider supply chain with invaluable experience, ensuring that they are at the forefront of the ongoing revolution in aircraft design and manufacture.

The existence of this 'once-in-a-generation' demonstrator programme was officially announced on the opening day of the Farnborough Airshow on 18 July 2022, some five months before the GCAP launch. More than one year before (on 20 May 2021), it had been reported that BAE Systems was using large-scale 3D printing to produce high-temperature mould tooling utilising Airtech Dahltram I-350CF resin (a high temperature-capable, carbon fibre reinforced, Polyetherimide (PEI)-based 3D print resin) for the production of a future combat air demonstrator. Around the time of the demonstrator programme announcement, then UK Defence Secretary Ben Wallace confirmed plans for a low-observable (LO) demonstrator aircraft, jointly funded by the MoD and industry, while UK MoD Director of Future Combat Air, Richard Berthon, said this would fly within the next five years (so, by July 2027) and would play a key role in proving the technology and design principles behind the Tempest Future Combat Air System (FCAS). The aircraft was described as being the first flying combat air demonstrator in a generation.

Testing the engine

In June 2023, BAE Systems revealed that testing of the aircraft's escape system and of its engine and intake duct had already been completed. Three intake ducts were built at Samlesbury – two for the demonstrator aircraft (by now being referred to as the Flying Technology Demonstrator), and one for the test programme preceding it. The test duct could be fitted with alternative intakes to simulate different operating conditions. A bellmouth intake was used to simulate cruising flight, with an intake representative of the actual aircraft design being used to simulate a 'pre take-off, brakes on, full throttle' condition, with air being sucked in from all directions, past the intake lip, and causing lots of intake turbulence.

One of the Combat Air Flying Demonstrator's engine ducts – looking forward from the point where it will attach to the front of an EJ200 engine. Its length and serpentine nature are apparent. [BAE Systems]

Engineers used advanced new manufacturing processes to produce the engine duct. This is shaped to slow the air from supersonic to subsonic speeds at the engine face without the need for variable ramps. The intake has fewer moving parts than a traditional fighter intake design, and incorporates diverterless supersonic inlet (DSI) 'bumps' to hide the engine from enemy radar, enhancing the aircraft's LO characteristics.

The full-scale duct was fitted to an unmodified Eurojet EJ200 turbofan – sourced from a Royal Air Force (RAF) Eurofighter Ty-

phoon, and testing was undertaken at Rolls-Royce's site in Filton, Bristol, from early November 2022 to mid-February 2023. The tests used the TP-14 test cell in which the Concorde's Olympus engine was tested in the 1960s. Testing was undertaken at a wide range of power settings, including reheat, with throttle slams and re-slams conducted. The engine performed as expected, without experiencing air distortion or resonance issues, and there is complete confidence that the engine/intake/duct will perform as advertised throughout the whole envelope.

The aim is to "provide the engine with the 'quality' of air that makes the EJ200 think that it's sitting in a Typhoon," said Conrad Banks, Chief Engineer, Rolls-Royce Defence Future Programmes, as this will enable the powerplant to be operated in the demonstrator using existing flight clearances.

Testing crew subsystems

The crew escape system for the demonstrator will be based on an unmodified Martin Baker Mk16A ejection seat (as used in the Typhoon), and aircrew will wear Typhoon flying gear, including the AEA and Mk 10 helmet, which were also used by the test mannequins.

The demonstrator facility at Warton includes a so-called hybrid rig, with four linked development rigs, employing a mix of hardware, emulators and digital models. One of these is for the cockpit, one for the flight control system, one for computing and models, and another for the utility management system. It was designed to provide the crucial evidence that will support real world live flight trials.

The cockpit rig incorporates a touchscreen large area display (LAD) but lacks the smaller high-integrity panels (HIPs), which now seem to be a feature of the similar LAD being developed for the Typhoon. Because of the size of the LAD, the aircraft will use a sidestick rather than a central control column, and may incorporate haptic feedback. The cockpit rig is being used to develop, test and evaluate flying controls, flight control laws and displays. It will eventually be used for pilot training prior to first flight.

The hybrid rig is connected to a triplex fly-by-wire flight control system, with a set of actual hydraulic actuators for the three flaperons on one wing, and one for one of the rudderva-tors, with the controls on the other side of the aircraft being digital models.

After an initial static firing at Chalgrove, ejection seat testing was undertaken at Langford Lodge in Northern Ireland. [BAE Systems/Martin Baker]

A series of ejection seat trials were undertaken, using an aerodynamically representative forward fuselage section mounted on a rocket-propelled sled. The crew escape system test campaign started on 16 December 2021 with a static firing at Martin Baker's factory airfield at Chalgrove, proving the canopy design – which was a cast acrylic design incorporating MDC technology from the BAE Hawk advanced jet trainer. This static firing was followed by a series of four sled test seat qualification firings at Langford Lodge in Northern Ireland between 31 March 2022 and the end of June that year. Firings were made at two speeds – 519 km/h (280 kn) and 833 km/h (450 kn), using a Class 1 mannequin (representing a lightweight female pilot in summer flying gear), and a Class 6 mannequin (representing a heavy male pilot in winter kit).

The Combat Air Flying Demonstrator cockpit rig has now been flown by more pilots, and for more flying hours, than the EAP technology demonstrator of the 1980s. [BAE Systems]

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The company said in 2023 that some ten pilots had amassed 170 flying hours, in 125 sorties, in the digital environment. Four of the pilots were Warton-based BAE Systems test pilots (Steve Formoso, Andrew Mallery-Blyth, Luke Gili-Ross and Glyn Gogerty), with a team of six pilots from the RAF's Rapid Capabilities Office (RCO) and the RAF's No.41 Test and Evaluation Squadron, led by Group Captain Willie Hackett. By July 2024, when BAE Systems announced that the demonstrator had passed its critical design review (CDR, in May 2024), the 'flying time' had increased to "more than 215 hours".

Manufacturing and assembly

The CDR would normally be the point at which a traditional combat aircraft programme would enter into the manufacturing phase. Modern digital design and manufacturing processes allowed BAE Systems to undertake production in parallel with the review activity.

BAE Systems said that more than half of the weight of the aircraft had been released into the manufacturing process, and that all of the major units were in build, including the front, centre, and rear fuselage, and the wings, with assembly of all having started in 2023. The centre fuselage was one of the earliest units into build. A centre fuselage is typically the long-lead time item, taking longest to assemble and involving a huge amount of complex design and manufacturing operations.

While assembly was underway by BAE Systems at Warton, Paul Wilde, the then Head of Tempest at BAE Systems, said that the "vast majority" of the demonstrator was being manufactured outside Warton, in the wider supply chain across the UK. Wilde also noted that the demonstrator project was taking advantage of the latest manufacturing processes, including the use of hot isostatic pressing (HIP) technology. This takes Titanium powder and fuses it together using extreme heat and pressure to create complex shape parts that could not otherwise be manufactured as a single piece. In addition, traditional casting methods might require a four-year lead time, while HIP might take just six months.

As well as developing the skills, tools, processes and techniques that will be needed to develop the definitive GCAP Tempest aircraft, Wilde said that the demonstrator would be used to test, evaluate and demonstrate key elements of the next generation combat air design, pushing technology boundaries. The aircraft will incorporate a combination of supersonic and LO features.

The aircraft will incorporate some stealth compatible features and low observability shaping techniques, similar to those that are likely to be employed on the Tempest platform, thereby exercising BAE Systems' LO design capabilities. Some of these stem from the company's learning on the Taranis unmanned combat aerial vehicle (UCAV), which was regarded as having been "cutting edge on a global scale" according to a company representative. BAE Systems says that it has been testing a lot of shape and mould line styles that will help to inform LO design features for GCAP concepting.

The demonstrator aircraft will embody LO design features and principles, and LO aspects have been incorporated through the design and manufacturing process. It will not itself be 'stealthy', however. The canopy, for example, will be of conventional construction, and will incorporate miniature detonating cord (MDC), while stealth coatings are unlikely to be applied. Significantly, it was revealed for the first time that an integrated payload bay would be included. Test and evaluation of the integrated bay was expected to form an important part of learning for the GCAP programme.

This image of the forward fuselage of the Combat Air Flying Demonstrator 'in build' was taken in the early summer of 2024. [BAE Systems]

What we know so far

On 16 July 2025, BAE Systems announced that it was revealing "the design of the UK's flagship Combat Air Flying Demonstrator", as the aircraft reached a major milestone, with two thirds of its structural weight by then in manufacturing. In fact, the CGI render of the aircraft was deliberately unrevealing, and the company was careful to give little away in briefings and in answering questions from journalists.

Unsurprisingly, the demonstrator aircraft is a large, twin-finned, twin-engined design, without horizontal tails. Superficially, the aircraft resembles a tailless F-35 or Kaan, with forward-swept

BAE Systems issued this CGI render of the demonstrator aircraft on 16 July 2025. It remains the only image showing the whole aircraft. [BAE Systems]

intakes (without obvious DSI 'bumps' though these are believed to be a feature of the aircraft). The demonstrator has a 'boxed in' rear fuselage section, giving a broad, flat upper fuselage, like that of the original Tempest model revealed in 2018. The front three-quarters view showed a slightly cranked inboard leading edge – perhaps a simple leading-edge root extension (LERX) – which would seem to be sub-optimal from an LO point of view, but BAE Systems declined to explain the reason for this.

The remainder of the wing planform was not apparent from the CGI, but BAE described it as having a "cropped delta" configuration, unlike the Lambda wing of the original 'Pregnant Pelican' Tempest concept and several subsequent designs, and quite unlike the unusual planform of the 'Concept Class 5' study. It may be that this 'simpler' shape was chosen for cost/structural complexity reasons, but BAE Systems refused to confirm this speculation. BAE also declined to say whether the trailing edge was swept back, swept forward, or straight, and did not answer whether the wingtips were parallel to the aircraft centreline or slightly 'clipped'.

The company acknowledges that the demonstrator aircraft is large, and says that it has to be, "in order to demonstrate some of the technologies... some of that requires a material size, a platform to be able to do so, in terms of the relative scale to GCAP."

The vertical tailfins look rather more conservative than those seen on previous Tempest concepts, being more 'upright' (less canted and also less 'swept' in side elevation), and more 'rectangular' (or trapezoidal) with a more conventional 'straight' trailing edge than the 'five-sided' fins seen on previous GCAP/Tempest concepts. BAE Systems did not answer questions as to whether this had been chosen for cost/complexity reasons, or for some other reason.

In the CGI image, the aircraft has a single-piece windscreen and canopy, but the aircraft will actually have a separate windscreen and canopy, like the ejection seat test sled. In fact, the whole of the wide, heavily chined forward fuselage is (for obvious reasons) identical to the forward fuselage section used for escape system testing.

BAE Systems says that the demonstrator aircraft's main structure, wings and tail fins are all now taking shape, using advanced robotics, cobotics and digital manufacturing and assembly technologies. Godbold said that: "We're pushing the boundaries of not just how we're designing it, but also how we're assembling some of these products."

The company has manufactured what it calls: "The biggest flying Carbon thick skin that we've ever made up in the Northwest," in the shape of the centre fuselage skin. The demonstrator has allowed the company and the supply chain to make good, complex shapes in Carbon for the first time of asking – quite an achievement given that it can be particularly tricky to predict how Carbon 'springs', and a testament to the modelling capabilities now available.

The final set of Carbon wing skins for the aircraft were delivered to the company's Warton site on 14 July, having been manufactured by an unnamed company within the supply chain – described coyly as a high-value manufacturing catapult. The wing skins were, Godbold said, "made using a different set of technology than we're used to." Though BAE Systems refrained from saying so, using very large single-piece skins is advantageous from an LO point of view.

According to a BAE Systems representative, various parts will be sourced from "a number of different aircraft that the UK operates", though there has been nothing as major as was incorporated on the EAP, which used an entire Tornado back end, including the tailfin. Two EJ200 engines donated by the UK MoD will be installed in the aircraft, and the landing gear will be modified from a Tornado undercarriage.

'North of 13' Test pilots from BAE Systems, Rolls-Royce and the RAF have now flown more than 300 hours of the Combat

BAE Systems displayed the escape systems testing rig to invited journalists in Warton's hangar five in June 2023, along with an intake duct and the hybrid rig. [BAE Systems]

Air Flying Demonstrator in the bespoke hybrid rig. Using these simulated flight trials, pilots and engineers can rapidly assess the flight control systems during more complex flight manoeuvres, capturing crucial data about how the jet will handle and perform, years before the aircraft makes its first flight.

BAE Systems says that the first flight window remains as per the July 2022 announcement, commenting that the Flying Combat Air Demonstrator will be ready for first flight by the end of 2027 – the exact date will be finalised nearer the time to optimise learning and maximum benefit to GCAP.

The aircraft is currently set to fly within three years, but company spokespersons say that there is "nuance between when the aircraft will be ready to fly versus when the programme will determine the best date to fly." To avoid any confusion or suggestion that the programme has been delayed, BAE Systems stressed that it will be ready for a first flight by the end of 2027, but that the exact date will be finalised/selected nearer the time based on a number of facts around the core GCAP programme, regulator, and various others. An uncharitable observer would note that the company is now talking about the end of 2027, rather than the end of July 2027, which would mark the end of the originally announced 'within five years' timescale.

The Combat Air Flying Demonstrator still lacks a name, and its Warton Project number remains unknown (it may be close to the P189 designation applied to some Tempest concepts). If the wind-themed Tornado/Typhoon/Tempest naming convention is to be followed, an obvious choice might be Hurricane. The six journalists briefed on the Combat Air Flying Demonstrator on 14 July were urged to submit suggestions to a certain someone at BAE Systems.

New developments in multirole helicopters

Paul 'Foo' Kennard

The role of the military helicopter is evolving. New technologies and changing mission demands are triggering a move towards lighter, more adaptable multirole platforms. Traditional boundaries between attack, scout, and support/utility roles are increasingly being blurred.

The global military helicopter market has rarely been in such a state of flux. Whereas for decades it seemed that the US Army's 'big three' platforms, the AH-64 Apache, UH-60 Black Hawk and CH-47 Chinook, dominated proceedings, the result of increasing costs, both acquisition and operating, and a stream of 'lessons identified' from the ongoing conflict in Ukraine threatens to shake this long-established dominance. Indeed, the very concept of helicopters for specific tasks now appears increasingly less certain.

The pre-eminence of dedicated attack helicopters has been challenged recently by the emergence of the unmanned aerial vehicle (UAV) as a key battlefield presence, in both the 'find' and 'fix/finish' categories.

The CH-47 Chinook remains, in its current 'digital' incarnation (CH-47F Block II), the most popular heavy lift helicopter currently in production. The even more powerful CH-53K King Stallion remains an expensive 'rare bird' with only the US Marine Corps (USMC) and Israel willing to stomach the steep acquisition costs (sitting somewhere between two to three times the unit cost of the CH-47F). The King Stallion is very much the heavy lifter the USMC wanted to replace its increasingly obsolete and tired legacy CH-53Es and its requirements set reflects this. It is likely that the Israelis are acquiring the aircraft, at least partially under US funding arrangements,

French helicopters operating in Mali. Shown here are the Tiger (Top), H225M (background left), and NH90 (foreground, right). [Airbus]

in order to provide Sikorsky with an export customer. The Germans looked closely at the CH-53K as a replacement for their legacy CH-53 fleet but decided to opt to join several European partners in becoming a Chinook operator.

However, the 'continuum' of light utility helicopters (LUH) and medium support helicopters (MSH), and their potential to be armed, is starting to blur the lines between what is an attack helicopter, a scout helicopter and a battlefield medium-lift asset. At the smaller end of the scale, the 'armed scout' is becoming an increasingly popular choice – especially when complemented by uncrewed systems and loitering munitions. This is exactly the choice the German military has made recently.

Tiger troubles and the rise of H145M

Germany, as a key partner in Airbus Helicopters, was one of the three nations, alongside France and Spain, that funded the development of the Tiger – an armed helicopter that has fulfilled similar, but different missions, for its original user nations. Its subtly different configurations have enabled the

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CONTROP Strengthens its European Footprint Amid Rising Security Demands

Europe's defence landscape is changing at pace. From heightened geopolitical tensions to rapidly evolving threats in the maritime, border and urban domains, the continent's security stakeholders are under increasing pressure to boost their operational capabilities. For CONTROP, a global leader in EO/IR surveillance solutions, this moment is a **'Call to Action'** — and a catalyst for deepening its commitment to the European ecosystem.

The established Controp Europe team, (left to right) Hanan 'Benda' ben David and Moti Elyashiv are dedicated to NATO and Europe's security. [CONTROP]

'Global means Local'

"While we are a global company, we understand the importance of locality," says Hanan ben David ("BENDA") , Head of Europe Regional Marketing &BD at CONTROP. "It's about being close to the customer, close to the challenges, and tailoring solutions that are as much local as they are global."

Investing in European Defence

For decades, CONTROP has been an integral partner in European defence programmes, with its Electro-Optical payloads integrated into airborne, naval, and land platforms across the continent. Today, the company is expanding and enhancing its offering in Europe, driven by the urgent need for enhanced situational awareness and rapid-response capabilities.

In Germany, CONTROP is working closely with a trusted local partner to integrate the cutting-edge SIGHT-25HD observation system into a range of platforms, including special forces capabilities. This programme reflects the company's approach to long-term collaboration — building on mutual expertise to deliver advanced, mission-ready solutions close to the END USER.

Guarding Europe's Shores

Maritime security is another priority. CONTROP is making massive investments in providing coast guard capabilities across Europe, enabling nations to monitor and protect their coastlines with precision and efficiency. From anti-smuggling operations to search and rescue, CONTROP's systems are helping agencies make critical decisions faster, with a clear, battle-proven edge.

Border Defence with a Local Partner

A flagship example of CONTROP's "locality in action" is its strategic partnership with Poland's Telesystem-Mesko S.A. Together, the companies are working on advanced border defence solutions, combining CONTROP's EO/IR payload expertise with Telesystem's technology and development capabilities, local manufacturing, integration, and operational know-how. The collaboration aims to address Poland's urgent needs for border security while providing a scalable model for other European nations facing similar challenges.

Showcasing at MSPO and DSEI

In a time when Europe must move quickly to adapt, CONTROP's message is clear: local presence, strategic partnerships and alliances, global expertise and battle-proven technology are the keys to strength, growth, and staying ahead of the threat curve.

aircraft to be tasked as an attack/anti-tank, escort and scout platform. However, Tiger has not been without its problems. Its development was prolonged and expensive, and in the case of one of the early adopters, Australia, littered with issues and complications. The Australians finally lost patience with the aircraft's low availability and poor reliability, agreeing to retire the aircraft over a decade earlier than expected and switching horses to Boeing's AH-64E. Germany has elected to follow suit, claiming that they perceived the cost/risk of updating their Tiger fleet to 'Tiger III' configuration to be unacceptable. Instead, they have elected to go 'back to the future' by ordering a large batch of H145M helicopters – some 60 airframes plus 20 'options'.

The H145M offers a flexible and reliable platform. It harks back to the Cold War, to the days before the Tiger, when Germany used a fleet of small and agile MBB Bo105 helicopters in the scout / anti-tank roles. Deployed in large numbers, carrying up to six HOT family anti-tank guided missiles (ATGMs) – broadly equivalent in concept and performance as the US BGM-71 TOW – the highly manoeuvrable Bo105 was tasked with extracting the maximum attrition on Warsaw Pact armoured formations for relatively little cost. If a Bo105 managed to get all six shots off, and achieve at least a couple of 'kills', it was probably a fair return. The Bo105 was replaced by the Tiger, in much the same way that the TOW-armed Westland Lynx was replaced by the Apache in UK service, due to fears that the organic short-range air defence (SHORAD) systems increasingly embedded in armoured units made the 'juice not worth the squeeze' in terms of risk. A dedicated attack helicopter with improved sensors, longer-ranged stand-off weapons (such as the Hellfire air-to-surface missile) and an integrated gun system – as well as a comprehensive platform protection suite and airframe / cockpit armour – was deemed essential to prosecute repeated attacks on invading units at a tolerable risk. So, what has changed?

Not only has the Tiger proven an expensive and troublesome airframe, with low availability (regularly less than 40%) and often poor supply chain resilience, but advances in technology have enabled smaller, cheaper, and lighter helicopters to carry better sensors and more powerful weapons. The H145M Germany is purchasing will exploit the 'HForce' system, equipping the aircraft with a Stores Management System (SMS), weapon pylons, an L3 Wescam MX-15 gimballed optronic sight (with laser range finding, designating, and targeting capability) and a Thales Scorpion Helmet Mounted Display and Cueing System (HMDCS). In terms of weapons, the H145M can carry gun and cannon pods, unguided 70 mm (2.75") rockets, along with laser guided 70 mm rockets, such as the FZ275. The latter are a true game changer – suddenly a light helicopter, such as the H145M, can carry a relatively powerful load of low-cost, accurate, guided weapons.

In a recent sortie in the H145M, I was able to use HForce, MX-15 and Scorpion to simulate FZ275 attacks on a number of targets of opportunity. It was simplicity itself – find the target on the MX-15, squirt the laser range finder to obtain an accurate range to 'target', switch to target mode, place the laser spot on the target, then put the velocity vector on the HMDCS flight display over the firing cue and pull the trigger. Closing to the nominated target, I could select 'Guns' and run the 'pipper' over the 'target' to simulate a strafing run. Heady stuff, but the H145M's 'talents' don't end there.

The aircraft has also been cleared for carrying and launching Rafael's SPIKE ER2 anti-tank missile. The SPIKE ER is capable of engaging targets up to 16 km away (if employing a datalink), with a tandem high-explosive anti-tank (HEAT) warhead for attacking main battle tanks (MBTs) or a penetration, blast and fragmentation (PBF) warhead for use against structures. It's a significant upgrade from the HOT-equipped Bo105. With SPIKE ER2, the H145M can exploit a networked common operating picture (COP) and its powerful onboard sensors to position itself to ambush enemy formations from a relatively safe stand-off distance (up to 16 km) – with its relatively small size and acoustic signature helping it to remain masked, yet with agility and the ability to have a defensive aids suite (DAS) fitted if required. Against perhaps the most pertinent threat of today, UAVs, the H145M can offer a cost-effective intercept capability, employing its gun system or laser-guided rockets – provided, of course, that the aircraft is positioned between the incoming UAV and the intended target. The H145M, like many rotorcraft, doesn't have the straight line speed to pursue and overtake many UAVs, especially fixed-wing designs, so intercept geometry needs to be considered.

Airbus' H145M design has shown itself to be a highly flexible and versatile platform. [Airbus]

However, of course, the H145M is a multirole machine. Remove the HForce system and the aircraft reverts to being a capable LUH with enough cabin space to carry up to ten (at a squeeze) lightly equipped troops, nearly 2,000 kg of internal supplies or 1,600 kg of external cargo. Retain the MX-15 and cabin-mounted hoist, and the H145M becomes a credible search & rescue (SAR) platform for disaster relief and other tasks supporting civil authorities. The US Army National Guard uses the H145 for exactly these types of tasks. As the LUH-72 Lakota, the helicopter is employed within the US for disaster relief and border patrol style duties. This enables the service to offload the tasking on the larger and more expensive platforms, such as the UH-60 Black Hawk, for more combat-orientated overseas roles.

Shaping the night – How Photonis sets the standard for modern warfare

Frédéric Guilhem, Chief Commercial Officer - Night Vision at Exosens, shares how nearly 30 years of expertise, relentless innovation, and a commitment to European sovereignty has made Photonis (The NV brand of Exosens Group) a critical partner for modern armed forces.

▲ Frédéric Guilhem – Chief Commercial Officer (Night Vision). [Photonis]

How has Photonis evolved to become a market leader, and what makes your solutions stand out in today's defense landscape?

Photonis is today the world leader in image intensifier tubes, the heart of any night vision device. Over nearly 30 years, we've grown from modest beginnings into a 300 million Euro business through strategic acquisitions, organic growth, and constant innovation. Our two major production sites in France and in the Netherlands each account for about half of our global output. Combined with our proven ability to deliver in times of crisis and a strong European supply chain, this enables reliable supply even during global disruptions, giving customers confidence we can deliver large quantities quickly, a decisive differentiator in today's uncertain geopolitical climate.

Our tubes are designed, manufactured and fully tested in the EU, ensuring a 100% European supply chain free from ITAR restrictions and giving customers full independence, a key advantage for European armies seeking operational autonomy.

How have geopolitical events and evolving user doctrines changed the demand for night vision and how has Photonis responded?

Even before the war in Ukraine, we saw growing orders from NATO and allied countries. Anticipating these needs and following the huge trends, we more than doubled our European production capacity. The conflicts confirmed that night vision is no longer optional but essential: soldiers must see clearly to act decisively. Our proactive investments enable us to deliver reliably and respond quickly to urgent demands, a key strength for our customers.

Meanwhile, armies' use of night vision has evolved dramatically. Twenty years ago, many bought it without fully understanding its potential. Today, with dedicated training and mature doctrines, soldiers exploit night vision to its fullest, making it a decisive battlefield asset.

What are your R&D priorities and how is Photonis preparing for future needs?

Relentless innovation is at the core of what sets us apart. We constantly improve tube performance, image clarity, contrast, and reduce size and weight for better comfort. Our R&D also explores digital night vision for video recording and integration with connected battlefield systems, aligning with the digitalisation of combat. Yet we keep solutions robust, intuitive, and mission-ready, earning and keeping the trust of NATO and European forces.

What can visitors expect from Photonis at DSEI 2025, and what new applications drive your innovation?

Without revealing too much, we're preparing a breakthrough that will significantly enhance night vision, setting a new benchmark for performance. This advancement, based on years of R&D and feedback from elite units, will boost performance of NVD but more importantly reduce the workload of operators in the field, a decisive edge in modern warfare. This product will address the Tier One end users to start with: Special Forces.

How does Photonis ensure reliable deliveries and maintain independence in a tense industrial environment, and why is night vision a necessity today?

Our strategy combines full control of core technologies with a secure double sourcing European supply chain. During the COVID crisis, we proved our resilience by avoiding delays through strong supplier relationships and buffer stocks. We're expanding capacity in Europe and setting up production in the United States to meet growing demand and support NATO and allied countries even when other suppliers fall short.

Despite being a mature technology, night vision remains irreplaceable. Unlike thermal systems that only detect heat, our tubes deliver real-time images essential for situation awareness and precise identification, a decisive tactical advantage. Combined with low operating costs and exceptional reliability, night vision remains a critical asset on today's complex battlefields. At Photonis, we aim for a simple ambition: 'one soldier, one goggle', this is our mission!

Differing approaches to multirole: UH-60 and NH90

The venerable Black Hawk was, and remains, the epitome of the multirole helicopter. There are few roles that Sikorsky's stalwart hasn't fulfilled over the decades since its first flight in 1974. Its immediate predecessor, the UH-1 Huey, saw service as a troop transport, gunship, command and control (C2) machine and in the medevac role.

▲ **A US Army UH-60M Black Hawk. Over the course of its service life, the UH-60 platform has been adapted to a truly impressive number of roles. [Lockheed Martin]**

The UH-60 has completed all of those tasks and more, adding electronic warfare, combat search and rescue (CSAR) and VVIP to its roles. It has also become a crucial platform for the Special Operations community in the US, where, as the MH-60K/M Direct Action Penetrator (DAP), it brings almost AH-64 levels of firepower at the speed and range required. Most famously, of course, it has also been heavily modified into an unacknowledged low-observable special forces (SF) insertion platform, as apparently employed on the mission to kill Osama Bin Laden in Pakistan. The basic UH-60 airframe has also been adapted for maritime use – the MH-60R Seahawk has become the default anti-submarine warfare (ASW) helicopter for the US Navy, while the MH-60S is the maritime multirole specialist – capable of littoral insertion, anti-surface warfare (ASuW), maritime interdiction and the more prosaic moving personnel and cargo around a deployed fleet.

▼ **A Dutch Navy NH90 NFH operating off the coast. Though the design secured major orders, variant differences among its user base have hampered logistics. [NHI]**

Where the Huey and the Black Hawk have led in the multirole arena, others have followed – albeit with varying results. In Eastern Europe, the mass produced Mi-8/17 family has been employed as a multirole platform, as has the Puma/Cougar lineage. The NH90 was, perhaps, the peak of Western European attempts to deliver a true multirole helicopter. Although on paper the NH90 is a success, with some 600 orders, it has developed something of a reputation for being – much like the Tiger – expensive, unreliable and with poor logistics support. Belgium is the latest nation to announce that it is prematurely retiring its tactical transport helicopter (TTH) variant of the aircraft, following closely behind Australia, Norway and Sweden.

The NH90 is, perhaps, a victim of trying to be 'all things to all people' with a number of sub-versions trying to cater to the diverse requirements of its customers. The aircraft is available in TTH form for air-mobility missions (equipped with a ramp) and as the maritime-optimised NATO Frigate Helicopter (NFH). However, several sub-variants of each have been tailored to suit the needs of individual customers. Therefore, it could be suggested that although the NH90 family is a 'multi role' airframe, each interpretation of the aircraft is somewhat bespoke. This mixed fleet has been part of the NH90's resilience and supportability woes. Unlike the UH-60, which has a global fleet of over 5,000 airframes and huge primary customers in the US Army (over 2,000) and US Navy (500+), the NH90 has dozens of subtly different 'fleets within a fleet', creating a logistics headache, and in some cases, bottlenecks. A true multi-role machine should, in my opinion, be capable of switching seamlessly between a number of roles and missions rapidly, often between sorties.

Looking ahead

Such seamless mission/role switching is very much what the future of the multirole helicopter looks like. The US Army has enshrined the Modular Open Systems Approach (MOSA) as a requirement for all its new equipment. While some enduring designs, such and the CH-47F and UH-60M can accommodate some aspects of MOSA, only a new 'born digital' design can be truly 'open'. The Bell MV-75 (formerly known as V-280 Valor) tiltrotor will be the first of the new breed of highly adaptable vertical lift machines. It has been designed from first principles to be a multirole aircraft – covering many of the missions assigned to the UH-60M, albeit with far greater speed and range. The US Army has acknowledged that the requirements from the SF community have already been 'baked into' the MV-75's baseline, making it a true multirole option from the start of its service life.

In Europe, the issues that have marred the NH90's career have been noted by the user nations. Many have signed up to the Next-Generation Rotorcraft Capability (NGRC) programme, which is currently defining the requirements for a MSH to replace the NH90, Puma/Cougar, Mi-8/17 and Merlin in the 2030s. A series of studies are currently underway to support the requirements definition; some, such as propulsion and air vehicle configuration, have been given to industry to complete, while others are retained at the government level. The NATO Industrial Advisory Group (NIAG) has completed a number of studies supporting next-generation rotorcraft (NGR) work, including examining how to ensure the NGR is a multirole as possible. MOSA is key, but NIAG has also highlighted modularity at the platform level as being a key tenet of multirole flexibility. The potential to change aircraft configurations in the field – includ-

A Bell MV-75 tiltrotor in flight. The craft has been designed for the US Army's Modular Open Systems Approach (MOSA) requirement from the outset. [Bell Textron]

ing engines, DAS, degraded visual environment (DVE) sensors and rotor blade characteristics – is being assessed. A vertical lift platform that that can rapidly adapt to be optimal for any mission that it is called upon to deliver is multirole nirvana and seemingly the next logical step to take. The challenge will be ensuring that regulatory agencies are suitably assured that multiple configurations can still be certified as airworthy.

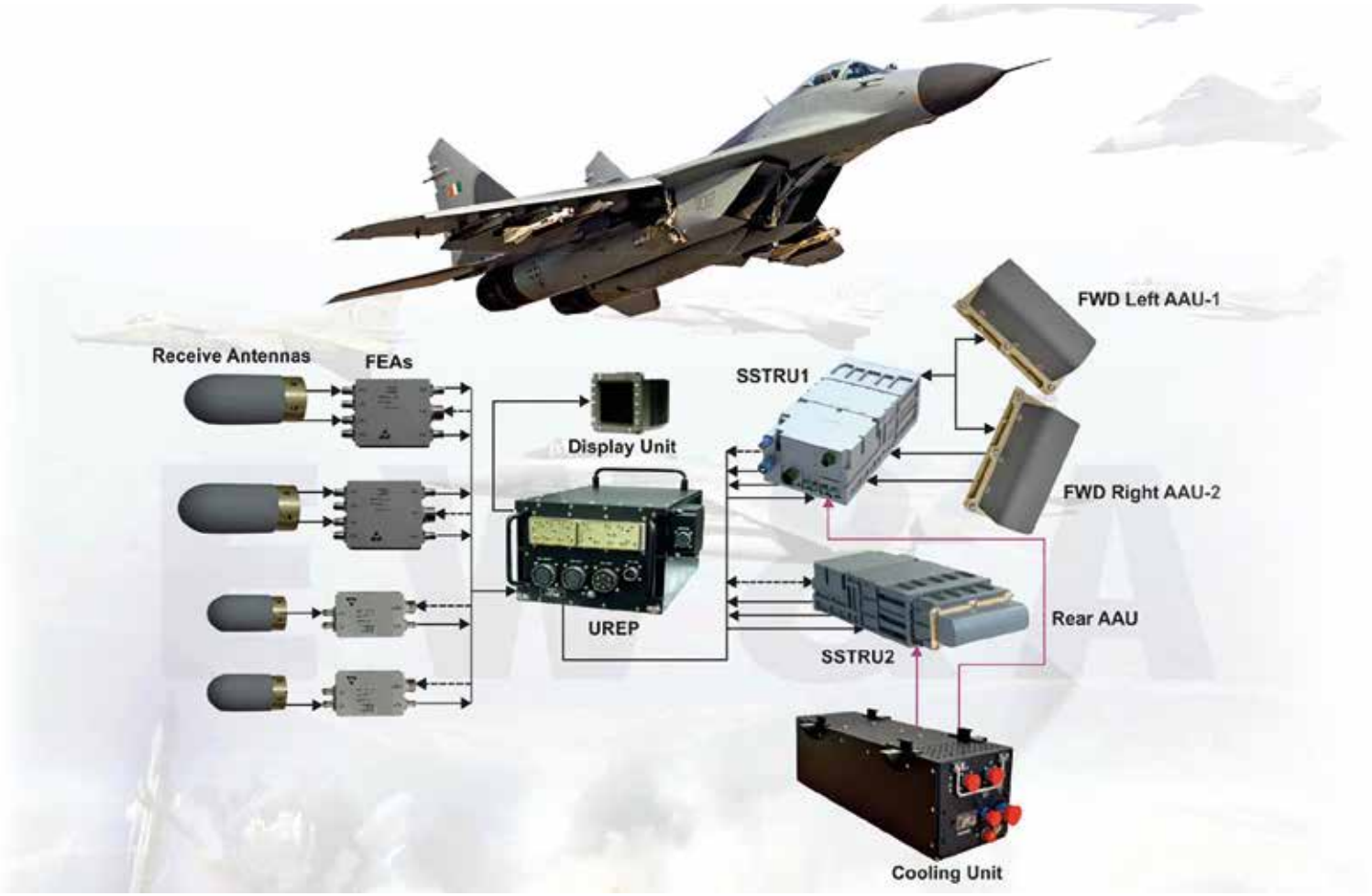
The flexibility of the helicopter has ensured that there are few 'one trick ponies'. With the exception of dedicated attack helicopters, most rotorcraft are multirole to one extent or another – some are just 'more multirole than others'. The sweet spot seems to be in the LUH/MSH area, where aircraft have enough room to carry different payloads, be equipped with a variety of subsystems and have the required power to continue to deliver effective military output.

The future moves towards MOSA and platform modularity will doubtless make vertical lift adaptability even more broad, and being genuinely 'multirole' will, in time, be viewed as just another rotorcraft attribute, alongside the ability to hover.

Doing everything at once

Dr Thomas Withington

Multifunction antennas performing multiple tasks from radar sensing to communications, electronic warfare missions and radio navigation could help revolutionise combat aircraft design.



This image gives a good indication of how many RF antennas a modern combat aircraft must have; these are just for the plane's electronic warfare system. [BEL]

Pity the poor fighter aircraft. It must carry at least two radios. A fire control radar is necessary, along with a transponder to identify the aircraft to air traffic control (ATC); additionally, an identification friend or foe (IFF) interrogator/transponder must be carried. This equipment transmits an encrypted radio frequency (RF) signal to blue forces to let them know the aircraft is friendly. The IFF interrogator will also be able to send an encrypted 'challenge' RF interrogation signal to another aircraft. Friendly planes will send an encoded 'reply' to confirm their identity. Hostile aircraft will be unable to do so unless red forces intelligence have successfully deduced the encoded response to that day's IFF challenge.

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Very-high frequency (VHF) and ultra-high frequency (UHF) radios, usually one of each, allow the pilot to send and receive voice and data traffic. The radios also let pilots communicate with ATC, with other military aircraft and other forces. Some aircraft may also have high frequency (HF) radios onboard for added connectivity. Satellite communications (SATCOM) terminals allow the pilot to send and receive voice and data traffic across space-based constellations and a radio altimeter provides additional advice to the pilot on the aircraft's height above the surface. An electronic countermeasure (ECM) forms part of the jet's integrated self-defence system (ISDS). The ECM transmits powerful RF jamming signals against hostile radars threatening the aircraft, or radar-guided surface-to-air or air-to-air Missiles (SAM/AAM). All these systems must transmit RF signals of varying frequencies, strengths and modulations to perform their tasks. For the uninitiated, modulation is the process by which a radio wave is altered to perform a particular task. A suitably modulated radio signal is known as a waveform.

AT-7000 Series

Multifunctional Communications & SIGINT Antenna System

[AEROMARITIME]

AEROMARITIMEs AT-7000 Series Multifunctional Communications & SIGINT Antenna System for submarines was developed to meet both the multifunctional communications and signal intelligence requirements to detect and evaluate communicative (COMINT) and non-communicative (ELINT) signals. The AT-7000 series antenna has the same form and fit factors as its predecessor, the AT-4000 Series.

The emerging communication technologies in the civilian sector provide an opportunity for the naval industry to expand military communication needs and new combat requirements as they are available in the market, technically mature and affordable. While communication technologies such as VHF, UHF, etc. remain an essential part of naval military communication, other technologies such as 2G, 4G, 5G, WLAN, etc. can expand the scope of naval military communication services.

Certain naval communication systems already include the tactical private 4G LTE communication network to achieve sufficient throughput for reliable data collection in real time and over long distances (1). The attractiveness and high efficiency of 5G technology make it necessary to consider the implementation of civilian standards in the military domain. Since the direct use of civilian standards in military systems cannot simply be adopted due to various premises, the civilian 5G standard is currently being evaluated for its usability in military applications (2). In addition, 5G NTN (Non-Terrestrial Networks) is also being developed as a future communication technology. 2G technology can be retained as a backup solution for military naval communication systems. WLAN technology can be used to set up tactical private ad hoc networks (3).

In addition to the need for mobile communications, navies around the world also need signal intelligence systems to combat all modern threats, e.g. to detect and neutralize drones.

To enable all these functions, navies around the world prefer a powerful, compact all-in-one multifunction and signal intelligence antenna and antenna subsystems, especially for submarines, due to limited space.

The AT-4000 multifunctional communications antenna system for submarines is one of the best-selling antennas that Aeromaritime Systembau GmbH has supplied to various navies around the world over the last 40 years. It includes VLF/HF-Rx, VHF, UHF, IFF, Link-16 and L-Band SatCom functionalities. The AT-4000 antenna system was developed as a communications antenna and is not intended for signal intelligence. As a consequence, a new antenna system has been developed that is suitable for both the signal intelligence and military naval communications, including the communication technologies mentioned above.

The AT-7000 series antenna system consists of the antenna itself, a communication interface (COM-IF), a SIGINT interface (SIGINT-IF) module that can be connected to most third-party signal analyzers & recording systems, and the Aeromaritime's Radio Frequency Distribution Unit RFDU.

As a multifunctional communications antenna, the AT-7000 covers VHF-LoS, UHF-LoS, IFF, Link-16 and L-band services, with Inmarsat-C and Iridium being the most popular L-band services. In addition, the AT-7000 also provides 2G, 4G and 5G cellular- and WLAN services. It has receive-only functionality for VLF and HF bands.

In signal intelligence mode, the AT-7000 captures electromagnetic signals from its environment in the range from 10 kHz to 6 GHz and evaluates the captured signals in the signal analyzer and recording system after passing through various interfaces.

The communications interface (COM-IF) module serves as an interface between the AT-7000 antenna and various communication radio devices. The main functions of the COM-IF include supplying the electronic components in the COM-IF itself and the antenna with DC power and control signals, switching between different communication paths, and filtering. The COM-IF also provides an interface to the signal intelligence interface (SIGINT-IF) module which performs filtering and multiplexing of signals received via various antenna elements and provides an interface to the signal analyzer and recorder system.

The Radio Frequency Distribution Unit (RFDU) is an optional component of the AT-7000 antenna system. If a communication system contains more than one VHF LoS, UHF LoS and GPS antenna, these multiple antennas can be easily and efficiently connected to the corresponding radios using the RFDU unit.

The Signal Analyzer & Recorder system evaluates the signals detected by the AT-7000 antenna. Although the Signal Analyzer & Recorder system is a central component of the signal evaluation, it is not offered by Aeromaritime Systembau GmbH. There are several signal analyzer & recorder systems on the market and the AT-7000 antenna system is compatible with most of them.

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Good listeners

Combat aircraft are not confined to transmitting RF signals – certain signals only need to be received. This is the case for PNT (position, navigation and timing) signals from global navigation satellite system (GNSS) constellations. Additional navigation assistance comes from DME (Distance Measuring Equipment) which receive, and process, data transmitted by VOR (VHF omni-directional range) radio beacons. TACAN (tactical air navigation) is a military-only version of the DME-VOR ensemble. Landing at airfields is greatly assisted by instrument landing systems (ILSs), which provides a safe 'glide path' a pilot can follow to land safely. ILS is particularly important when landing in reduced visibility or inclement weather. Furthermore, the ISDS must detect potentially hostile radar signals that may need to be jammed. Threat detection to this end is achieved using a radar warning receiver (RWR). All these disparate systems which send and/or receive RF signals can result in scores of antennas being installed on the aircraft's fuselage, wings and tail. A fighter pilot informed the author that up to 30 antennas, or more, may equip a contemporary combat aircraft.

Why are so many antennas necessary? You can blame physics. All the aforementioned systems transmit an array of different radio frequencies. For example, the aircraft's V/UHF radios will use frequencies of between 108 MHz and 137 MHz for radio navigation and ATC communications. Military air-to-air and air-to-ground communications use UHF frequencies of 225 MHz to 400 MHz. A combat aircraft's radar typically transmits and receives in X-band (8.5 GHz to 10.68 GHz). The UHF radios may also send and receive tactical traffic across UHF Tactical Datalinks (TDLs) like Link-16 (960 MHz to 1.215 GHz). Link-16 is primarily used by NATO and Allied nations to support air operations. Some aircraft may use TDLs like Link-11/22, which mainly supports naval operations, and moves across HF and V/UHF conduits. Civilian ATC and military IFF transponders use frequencies of 1.030 GHz and 1.090 GHz. Aircraft can use several SATCOM frequencies stretching from UHF (399 MHz to 470 MHz) upwards. Combat aircraft must detect and jam radar signals across wavebands of at least 2 GHz to 18 GHz. This waveband is sometimes increased to 40 GHz to encompass radar threats higher up the spectrum. GNSS PNT signals are received on a waveband of 1.1 GHz to 1.6 GHz. VOR signals on frequencies of 962 MHz to 1.150 GHz are received by aircraft DME; aircraft ILS systems receive transmissions of frequencies of 329.3 MHz to 335 MHz, while TACAN uses a waveband of 960 MHz to 1.215 GHz. Last, but not least, radio altimeters use frequencies of 4.2 GHz to 4.4 GHz.

Aircraft, military or civilian, by their very nature regularly cross countries and continents. As such, the radio frequencies they use are guarded by organisations like the International Telecommunications Union (ITU), the specialised UN agency acting as the global custodian of the radio portion of the electromagnetic spectrum.

Pointy bits

All radio-dependent systems need some form of antenna to send and/or receive signals. Several of the systems discussed use blade antennas fitted to the ventral and dorsal portions of an aircraft's fuselage. Except for HF (which can be 'bounced' off the ionosphere, allowing beyond line-of-sight communication), most radio signals operate via line of sight. This means the transmitting and receiving antennas need to 'see' each other. The ISDS's RWRs are usually mounted on the tail of the aircraft and the wingtips. This configuration helps to provide a 360° spherical field-of-view around the plane. There are two issues with antennas: Blade antennas can create drag which can be detrimental to an aircraft's aerodynamic performance in a small way, but detrimental nonetheless. Aerodynamic performance can also be impinged by the box-like or cylindrical antennas the ISDS depends on for the RWR and ECM.

Air forces and aeronautical engineers spend considerable time and effort to ascertain the visibility of aircraft to radar. Testing regimes can include mounting aircraft on plinths like these shown here and illuminating the aircraft with representative radar signals from a myriad of angles to ascertain RCS size. [USAF]

The other problem with antennas is that they can be good reflectors of radar signals. An aircraft's visibility to radar is governed by the size of its radar cross section (RCS) and broadly speaking, the smaller the RCS, the harder the aircraft is to detect, identify and track with a radar. Most importantly, a small RCS makes it difficult to guide a SAM or AAM accurately to the plane. RCS is a measure of how much of an incoming radar signal will be reflected to that same radar. The more energy that is reflected, the easier it will be for the radar to follow the aircraft and potentially help cause it harm. Radar signals are reflected well by perpendicular structures like blade antennas; a mirror mounted on a wall will give the best reflection of your face but a mirror canted at a 45° angle will not.

Some aircraft, manned or otherwise, and air-launched weapons are designed to have as low an RCS as possible. Their fuselage and surfaces will have smooth curves, or highly angular designs to reflect incoming RF signals away from the transmitting radar antenna. Combat aircraft radars are mounted in the nose and hence usually nicely concealed within an aerodynamic radome.

One size fits all

What if a combat aircraft could have a smaller number of antennas that could do many, if not all, of the functions discussed above? Imagine if the nose-mounted radar antenna could also function as an ECM, RWR, SATCOM terminal, provide V/UHF communications, work as an IFF/ATC interrogator/transponder. Perhaps it could also act as a radio altimeter and receive all the radio navigation signals the aircraft depends on? Aeronautical engineers could make their aircraft as 'stealthy' as they like with no need for pointy blade antennas messing up the RCS. All RF signals simply move to and from a multifunction antenna, for instance, one hidden in the aircraft's aerodynamic nose; not only will RCS be reduced, but aircraft performance will improve helping save fuel, extend range and probably improving manoeuvrability.

Some advancements have already been made to this end. Leonardo's ECRS Mk.2 radar will equip the Royal Air Force's Eurofighter Typhoon F/GR4 Tranche-3 jets, according to the UK's Ministry of Defence. Not only will the ECRS Mk.2 perform all the functions one would expect of a combat aircraft radar, including air and surface search and tracking, but it can also work as an ECM system against radar threats. That the ECRS Mk.2 uses an active electronically scanned array (AESA) radar design helps immensely in this regard. A whole article could be dedicated to AESA design but to summarise, these are mounted with hundreds, if not thousands, of transmit/receive modules (TRMs) comprising the antenna array. Each TRM is effectively a miniature radar. The module generates the RF signal, modulates and transmits the signal and receives the reflection. The TRMs can electronically steer their transmissions in a particular direction to look towards the surface, for example. The multitude of TRMs means the pilot can task the radar to do several tasks simultaneously or in quick succession. Some TRMs may be looking upwards for potential targets, some may be looking downwards for the same reason. Other modules may be transmitting a jamming signal against a radar-guided AAM.

Why is this already impressive radar not performing additional functions beyond traditional radar tasks and jamming? RF engineering is advancing the multifunction antenna, but it is still some years away. Part of the problem is that the RF signals discussed above do different things and hence use different waveforms. A family station wagon, a four-wheel drive and a rally car all take people from one place to another. Nonetheless, these vehicles are vastly different in design and performance, something that is also the case for these waveforms and their antennas. Furthermore, antennas must have a size proportionate to the signals they handle. A basic RF rule of thumb is that antennas must be between one-half and one-quarter length of the frequencies they handle. Therefore, a VHF frequency of 225 MHz has a wavelength of 133.4 cm meaning that the antenna will need to be between 66.62 cm and 33.31 cm in length. A TACAN receiving antenna will need to be between 15.61 cm and 7.87 cm long for frequencies of 960 MHz, and between 12.34 cm and 6.17 cm for TACAN's 1.215 GHz signals. Another factor altering antenna design is desired gain; gain is a measure of an antenna's ability to focus an RF signal in a particular direction and is measured in dB. The better an antenna's gain, the sharper the focus shall be. Gain is the result of the antenna's physical design, and how powerful a signal the radio or radar can generate.

Current efforts

Germany's Fraunhofer Institute is one organisation heavily involved in the realisation of this multifunction antenna holy grail. The author was recently briefed on some of the interesting work it is doing in this regard. Using the analogy of a smartphone or Swiss Army knife, researchers from the institute defined a multifunction system as a single architecture performing multiple tasks. A key attraction of a multifunction antenna, particularly in the airpower domain, is that it would weigh less compared to several disparate systems. Likewise, a single antenna performing multiple functions may cost less to procure and support compared those conventional, disparate systems. There may be further weight and cost reductions if a multifunction antenna works with a common 'back end', which contains all the hardware and software needed for processing incoming and outgoing RF signals. Combat aircraft and unmanned aerial vehicles (UAVs) remain the most likely platforms for the initial future uptake of multifunction antenna technology. This makes sense as both are size, weight and power (SWaP)-constrained platforms.

Initial plans call for the development of multifunction antenna technologies to support radar, communications and ISDS tasks. The researchers are currently thinking about systems that would cover an ultra-wide waveband of 5 to 18 GHz which, as readers will note, would already encompass some of the systems discussed

Leonardo's ECRS Mk.2, destined to equip part of the RAF's Eurofighter Typhoon-F/GR4 combat aircraft fleet, represents an important first step in the realisation of true multifunction antennas for air platforms. [Leonardo]

It seems possible that future 6th-Gen combat aircraft such as the SCAF, pictured here, could be equipped with multifunction antennas to enable these platforms to benefit from the advantages such architectures bring. [Airbus]

above. However, working with such a wide waveband requires novel approaches to antenna design due to the frequency and gain strictures discussed above. Metamaterials, which the author has discussed in previous ESD articles, offer promise. Space here is insufficient to describe metamaterials in detail; however, to summarise, they can be designed to transmit or receive certain frequencies, but not others, effectively acting as an RF filter. Other requirements include transmit and receive hardware to handle signals across this considerable waveband.

Consider the following with regard to the complexity of multifunction antenna design: The Fraunhofer Institute researchers noted that radars like to generate a highly-focused signal that can be steered precisely in a specific direction. ISDS RWRs like to hear potentially very weak signals coming from any direction. This is because radar threats will try to be as discreet as possible to avoid detection, and a threat can emanate from any vector. While radars must send out a signal and listen for the reflection, RWRs do not need to transmit, just listen. To further complicate matters, a radar will transmit and receive its signals in X-band. The RWR will have to monitor a much wider waveband of potential threats because the ISDS must be ready to counter numerous threats across a range of frequencies. Radar signals can be very 'loud' i.e., relatively strong when they leave the radar. This strength may momentarily block out other X-band signals on the same frequency the RWR needs to detect. Nonetheless, for a multifunction antenna to be effective it must do simultaneous threat and target tracking.

Some of Fraunhofer's endeavours are focusing on the realisation of ultra-wideband receivers working in the 5 to 18 GHz waveband. The researchers are also perfecting techniques to prevent the injection of strong outward signals into RF receivers. Allied to this is ensuring the electromagnetic compatibility of the multifunction antenna's respective functions. In short, all the disparate capabilities (radar, communications and ISDS functions etc.) must 'play nice' – a challenge made more vexing given how RF signals behave. An outgoing transmission will cause additional (but progressively weakening) signals in 'harmonic' frequencies. For example, a 5 GHz transmission will create 10 GHz and 15 GHz harmonic signals. These could cause interference for an RWR also monitoring these latter frequencies.

The institute is taking some important steps forward in realising true multifunction antennas. Systems like the ECRS Mk.2 are blazing a trail, but are still relatively limited, performing only two tasks, radar and ECM. It seems likely that true multifunction antennas are some years from routine use on military aircraft and UAVs. Fraunhofer's work in advancing this discipline will play a major role in perfecting this technology.

We may see such antennas on platforms such as the Franco-German 6th-Gen Système de Combat Aérien du Futur (SCAF), an aircraft that is expected to begin entering service during the first half of the 2030s, according to reports. Multifunction antennas will help in no small measure to improve the aircraft's performance and reduce RCS. Advancements in metamaterials may mean such antennas can be mounted conformally on the aircraft's skin to ensure a degree of redundancy. Other antennas on the aircraft can pick up the slack should one become unserviceable. Additional, conformal antennas, would provide additional lines-of-sight across which to send and receive RF signals. Although 5th-Gen and some upgraded 4th-Gen aircraft have already made great strides in this area, it may only be a matter of years until pointy, disparate antennas become a thing of the past in combat aircraft design.


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Future soldier programmes: An overview

Sidney E. Dean

'Future Soldier' programmes aim to upgrade infantry capabilities through technology. Disparate nations take different approaches to the Future Soldier concept. Some pursue fully integrated development and procurement programmes, sometimes involving dozens of different components. Others favour separate programmes to improve individual elements of soldier kit.

Many of these programmes include physical hardware to enhance soldier survival, reduce physical stress, and/or directly enhance lethality. Improved armour, harnesses, and infantry weapons and accessories are frequent elements. However, most current future soldier concepts are centred around the force multiplier capabilities of cutting-edge electronics including sensors, communications and networking systems, and increasingly, artificial intelligence (AI) features.

A soldier with the 1st Battalion 87th Infantry Regiment, 10th Mountain Division using IVAS during a training exercise at Fort Drum, New York, on 31 July 2024. [US Army/Spc Mason Nichols]

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United States

The United States Army is among the services pursuing disaggregated soldier enhancement programmes. Key programmes under the Army's Program Executive Office – Soldier (PEO Soldier) are divided into six key modernisation categories including Soldier Lethality (SL). The SL portfolio includes the Next Generation Squad Weapon (NGSW) programme and situational awareness/visual aid programmes including the Integrated Visual Augmentation System (IVAS). Individually and jointly, these new systems are designed to enhance both survivability and lethality. A third technology set, the Soldier Protection System (SPS), is being developed and fielded through the PEO Soldier's Soldier Survivability programme office, and aims to introduce new body armour.

NGSW

The NGSW consists of the M7 Rifle and the M250 Automatic Rifle, both chambered in a new 6.8 × 51 mm (also known as .277 Fury) cartridge. The new firearms, developed by Sig Sauer, will replace the M4 carbine and the M249 squad automatic weapon, respectively, with frontline fighting units; each weapon is equipped with the Vortex Optic XM157 sight and fire control system (FCS). Fielding began in March 2024 with the 101st Airborne Division and on 20 May 2025, the Army announced that NGSW system had proven that it meets the service's standards for operational performance, safety, and sustainment. In extended evaluation before and since fielding, the Pentagon has concluded that the new weapons will significantly increase range and accuracy over legacy firearms. A dissenting opinion published in April 2025 by an infantry officer who criticised the accuracy, reliability and weight of the M7 has been rejected by the Army as being based on incomplete observations. That being said, the latest annual report by the Department of Defense's Director, Operational Test and Evaluation (DOTE) did note negative soldier feedback regarding the XM157 optic. Usability was described as below average/failing, according to the 2024 DOTE Report released in January 2025. Unlike the two firearms, the optic is still officially classified as being in testing.

IVAS

The IVAS programme has been plagued by technical difficulties as well as negative user feedback since its inception. The device is based on the Microsoft Hololens augmented reality/mixed reality (AR/MR) headset. The military IVAS is intended to enhance each soldier's situational awareness and tactical decision-making capability. It consists of a visor-like heads-up display (HUD), a body-worn computer (the 'puck') and a networked radio. The combination goggle and AR/MR HUD's capabilities include daylight vision, image intensification (I2) technology to enhance visibility in low-light conditions, ther-

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mal imaging, and augmented reality supported by situational awareness software. Additionally, the puck and radio can create a wireless connection between the HUD and a weapon-mounted digital sight, permitting soldiers to surveil their surroundings or engage targets while under cover.

In February 2025, Anduril Industries assumed management of the programme from Microsoft. One month earlier, the Army Contracting Command issued a request to industry "seeking information (...) regarding capabilities to develop and manufacture the IVAS Next system". Both the information request and the restructuring of the existing programme indicated that a production decision regarding IVAS would not be made in 2025.

SPS

The multiple-component, modular SPS provides equal or greater protection to the head, neck, eyes, torso and groin than legacy body armour, at a reduced weight and improved comfort. The main components are: Torso and extremity protection (TEP), including the modular scalable vest (MSV), the lightly armoured ballistic combat shirt, and the blast pelvic protector; the vital torso protection (VTP) set of front, back and side armour plates for insertion into the MSV; and the integrated head protection system (IHPS) consisting of a base helmet, which can be augmented with mandible armour and goggles.

A soldier with the 1st Cavalry Division conducts military operations on urban terrain training while wearing the Soldier Protection System armour suite. [US Army/Sgt Brandon Banzhaf]

The SPS was introduced in 2016–2019, but three upgraded components are currently being procured. Fielding of the second-generation MSV and the third-generation VTP began in 2021 and is slated to be completed in 2028. Fielding of the Next Generation IHPS began in February 2024 with the 82nd Airborne Division undertaking testing and refinement of design ongoing to ensure that both protection and comfort are appropriately addressed for the full range of body types, including women. The Army plans to acquire 150,000 of each system subset.

Nett Warrior

The Army also continues to modernise the Nett Warrior system first introduced into service in 2012. Designed to provide dismounted tactical unit leaders (team level and above) with enhanced situational awareness and the ability to access the brigade-level integrated tactical network via ruggedised smartphones or 'end-user devices' (EUD). Dedicated mission software including the Tactical Assault Kit (TAK) provide access to real-time maps, messaging, and mission data feeds. As part of the ongoing upgrades, Elbit America has been contracted to supply 33,000 wearable next-generation USB hubs to connect EUDs to navigation aids, targeting devices, night and thermal imaging sensors, including sensors carried by unmanned systems.

A soldier from the 2-506, 101st Airborne Division checks his Nett Warrior end-user device (EUD) during a full mission test event. [US Army/Justin Sweet]

Europe

ACHILE

The European Union initiated the Augmented Capability for High-end Soldiers (ACHILE) programme in June 2023 with a EUR 40 million grant from the European Commission. ACHILE is among the priority projects supported through the European Defence Fund (EDF) 2021. According to the EDF, the goal is to develop "highly innovative solutions in view of the next-generation Dismounted Soldier System by specifying, designing and demonstrating the benefits of open-system architecture based on GOSSRA and promising disruptive technologies improving survivability, sustainability, mobility, lethality, observation." GOSSRA refers to the Generic Open Soldier System Reference Architecture, another EU defence initiative dating to 2018.

ACHILE has a 48-month timeline, during which it will proceed through sequential stages of harmonising operational concepts, defining user and system requirements at a European level, and demonstrating full-size prototypes under realistic conditions and in large-scale demonstrations. This involves collaboration among a wide consortium of industry partners from nine EU countries, as well as Norway. Ensuring interoperability among allies is a major concern of the programme. Safran Electronics and Defense acts as programme coordinator.

Development paths are split into four main areas: the Soldier Core and Soldier Extension both address individual capabilities, while the Team Core and Team Extension concentrate on squad-level functionality, networking, robotics, and interactions with advanced weapon systems. This segmented approach ensures that both personal protection and collective coordination can be enhanced in parallel.

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Technologies being pursued for enhanced individual soldier capabilities include: augmented reality (AR) HUDs to provide soldiers with real-time battlefield data such as navigational cues, threat alerts, and tactical maps overlayed into the soldier's field of view; more robust navigation systems beyond traditional GPS, integrating multiple tracking and sensing technologies to offer more precise localisation; and next-generation weapon sights to enhance targeting precision and speed-up engagement processes (smart systems that can interface with other soldier equipment to provide a synchronised operational picture, reducing the time required for target acquisition), as well as reduction of size, weight, and power (SWAP) requirements for personal equipment. Additionally, improved ergonomics designed to lessen physical strain while providing robust protection and functionality is also being pursued. Companies within the consortium, such as Spain's Cyber Human Systems, are developing advanced combat exoskeletons designed to augment soldiers' physical capabilities by reducing fatigue and increasing load-bearing capacity.

Augmented team capabilities being pursued under ACHILE include networked communications that ensure real-time data sharing between soldiers and command units, ensuring a shared operational picture, enhancing coordinated team manoeuvres and faster reaction times, in addition to robotics team integration for support functions such as unit equipment carriage or autonomous support during manoeuvres.

France: CENTURION

France executed its Fantassin à Équipement et Liaisons Intégrés (FELIN) "Infantryman with Integrated Equipment and Communications" programme in 2010–2015, improving situational awareness and combat effectiveness while reducing the burden on soldiers. The modular and mission-configurable system included improved communications gear and sensors, infantry weapons and advanced aiming aids, ballistic protection and ergonomically optimised uniforms and harnesses. In 2015, Paris issued Safran Electronics and Defense a contract to upgrade FELIN to the V 1.3 version, with deliveries to frontline units beginning in 2016. The upgrade included software enhancements to aid sharpshooter and mortar support, as well as hardware reconfiguration designed to improve observation and combat functions while reducing the system's weight by up to 40% under certain conditions.

The next stage of the French Army's infantry modernisation is the Cadre d'Études de Nouvelles Technologies et nouveaux Usages pour une Rapide IntégratiON au combattant (CENTURION) programme, led by Safran in partnership with Thales. Initiated in late 2019 by the French government's Direction Générale de l'Armement (DGA), the seven-year programme is a rapid-innovation accelerator for maturing individual technologies up to TRL6. The process begins with open calls for technology providers to propose solutions addressing operational needs. Proposals are evaluated by a scientific and technical committee including representatives from the DGA, the Agence de l'Innovation de Défense (AID), and the armed forces. Promising projects receive targeted support and funding for rapid development and testing to facilitate system integration.

Concept of a near-future French soldier with technologies developed through the CENTURION programme. [Ministère des Armées]

The programme's goals include enhancing soldier mobility, agility, survival and lethality. CENTURION's foundation is based on open architecture frameworks including GOSSRA in order to facilitate rapid integration of new technologies. The system aims to improve infantry readiness for multi-domain operations (MDO) by integrating them into the networked land combat ecosystem. Collaborative warfare will enable personnel to understand, decide and act faster than their opponent. Key features include: advanced networked communication systems for real-time data sharing; improved protection and mobility through lightweight ballistic armour and ergonomically optimised carriage systems; AI integration for tactical operations and decision-making; next-generation night vision, thermal imaging, and target acquisition sensors; reduced power consumption; and modular equipment customisable for mission requirements. CENTURION leverages new materials and micro-technologies to create lightweight yet robust components.

Approximately 25 individual projects are being pursued under CENTURION, though none have been declared fielded as of mid-2025, despite ongoing operational testing and demonstrations, with some technologies reaching Technology Readiness Level 6 (TRL-6). Graphics and videos released by the French MoD portray incremental enhancement of soldier protection, mobility and lethality via the CENTURION programme, with fresh upgrades evolving through the 2020s and beyond. These enhancements will ultimately flow into the Système d'Information du Combat de Scorpion Débarqué (SICS DEB), supporting full operational integration of dismounted infantry with the armoured platforms such as the Griffon and Jaguar being procured under the SCORPION programme.

Germany: IdZ

Like France, Germany has one of the most notable 'future infantry' programmes for enhancing both light and mechanised units. The initial Infanterist der Zukunft (IdZ) programme was initiated in 2004 and realised using commercial off-the-shelf (COTS) systems. The follow-on IdZ-ES (Erweitertes System; ENG: Expanded System) 'Gladius' was a clean-sheet development which began deliveries in 2013, with 6,600 individual kits being distributed. IdZ consists of three subgroups: BST (Bekleidung, Schutz- und Trageausstattung – clothing, protective and load-carrying equipment), WOO (weapons, optics and optronics), and C4I (command, control, computers, communications and information).

Soldiers equipped with the IdZ-ES can access all communications, data and situational awareness systems via chest-mounted interface gear. [Rheinmetall]

The modular system permits mission-specific assembly of equipment from each subgroup, whereby soldiers and units can select from approximately 80 individual components. The IdZ-ES common core centres around vest-mounted communications and networking equipment including the CeoTronics CT-MultiPTT 3C USB hub (into which electronic communications, data and sensor devices are plugged for cross-platform interface), tactical radios, digital navigation devices, multiple conformal batteries, as well as a hand-held control and visual display unit, as well as a communications headset. Squad and platoon leaders additionally are equipped with a ruggedised tablet computer.

As defined by the German Army, the system's C4I component integrates the dismounted infantry into the networked operational command structure. Squad-level personnel are networked with one-another, while small unit leaders connect with higher echelons. This provides small units and individual soldiers with an up-to-date picture of the tactical situation and the current status of the forces in combat. Tactical decisions are made more quickly and based on more complete information. Lethality, survivability, manoeuvrability and endurance are enhanced.

The IdZ system continues to be improved. Designed for the specific needs of the German contingent leading the NATO Very-high-readiness Joint Task Force (VJTF) in 2023, deliveries of the VJTF 2023 variant began in 2021. This variant placed a premium on updating command, control, communications, situational awareness and networking technology to the latest level, and integrating dismounted infantry with their infantry fighting vehicles for optimal coordinated operations. Together with vetronics and communications upgrades on the Puma infantry fighting vehicle (IFV) and other armoured combat vehicles, the VTJF 2023 also forms the basis for the System Panzergrenadier, which fully networks vehicle sensors and weapons with those of the mounted and dismounted mechanised infantry.

In February 2025, Rheinmetall was awarded a contract for a further modernisation of the IdZ-ES on the basis of the VJTF 2023 configuration. According to Rheinmetall, this new "VJTF 2023 obsolescence-adjusted" design eliminates all technically obsolete components. It also "implements communication and data exchange capabilities with the Boxer armoured transport vehicle and Puma infantry fighting vehicle platforms as well as preparing it" for the airmobile forces' new Caracal vehicle. Furthermore, the revised basic hardware of the soldier systems is also designed to integrate with the comprehensive Digitalisierung Landbasierter Operationen (D-LBO) information and communication network. By 2030, this Digitisation of Land-Based Operations system is expected to connect 10,000 tactical vehicles and platforms, as well as sensors. D-LBO will optimise the German armed forces for MDO and improve interoperability with allied forces on the digital battlefield.

The February 2025 framework contract has a value of EUR 3.1 billion and runs through 2030. It encompasses the procurement of up to 368 platoon systems. This includes the regeneration of 68 platoon systems currently in use to a digital standard, and production of 300 equivalent units built to the new standard. A platoon system comprises 34 individual soldier systems plus peripheral components including IT equipment, optics, optronics, clothing, protection and carrying equipment.

Spain: SISCAP

Spain initiated the Sistema de Combatiente a Pie (SISCAP) dismounted combat system programme in 2017. It aims to prepare the infantry component for the Army's all-encompassing Fuerza 35 modernisation programme which will enable ground forces to manoeuvre and fight seamlessly in so-called "digitalised theatres of operations" in a network of systems adapted to the new combat cloud. The programme is administered by the Spanish MoD's Dirección General de Armamento y Material (DGAM). Indra Sistemas, S.A. and GMV Innovating Solutions, S.L. partnered in 2017 to develop and demonstrate the SISCAP. Members of the Army's elite Spanish Legion conducted an in-depth operational evaluation of the system in June 2024. According to GMV, this successful demonstration wrapped up Phase 1-b of the programme, placing SISCAP into a consolidation phase as new components and capabilities are added. The companies next hope to deliver seven prototypes in platoon leader configuration, then provide 40–50 pre-production kits of the operational configuration for evaluation in real-world missions. Indra predicts that full-rate production could begin by 2030.

▲ Spanish infantry soldiers with the developmental SISCAP suite. [Indra]

According to GMV, the SISCAP programme is divided into seven subsystems: weapons and ammunition; fire effectiveness; information and communication; maintenance; survivability; energy supply; and readiness (training). The first two phases of the programme focused on fire effectiveness, the information and communication system, and the power supply, considered to be the most critical aspects. Key components include helmet-mounted, AR-augmented optics to provide situational awareness, targeting data, blue/red force tracking, and the ability to wirelessly view the image from the weapon's optic; along with optical and thermal cameras; networked digital voice and data radios; and a tablet connected to the battlefield management system (platoon leader). The soldier-worn system can integrate with the Dragón 8×8 IFV, which will serve as a communications node between the unit and the tactical command and control centre.

Middle East

Israel: 'Edge of Tomorrow'

In May 2022, the Israeli MoD's Directorate of Defense Research and Development (DDR&D) and project integrator Elbit Systems unveiled the 'Edge of Tomorrow' programme. As defined by the MoD, the programme is designed to prepare infantry soldiers of the future and "aims to strengthen the synergy between individual soldiers and their teams through the adoption of the Soldier as System (SAS) and the Platoon as System (PAS) approaches". The project builds upon collaborative R&D and concept development between the DDR&D, Army headquarters, and Elbit which began in 2016. The May 2022 press release cites a recent tactical demonstration by IDF personnel using wearable technologies reflecting the programme's groundwork and internal validation, demonstrating initial abilities in the fields of lethality, survivability, and synergy between the individual soldier and the team.

At both the soldier and team level, the focus is on enhancing situational awareness, survivability, and lethality via a base layer of networking and assured positioning capability, according to an Elbit statement; at the unit level, the emphasis is on connectivity, collaborative time sensitive targeting, and data fusion to support distributed operations and faster decision-making in MDO environments.

While many details of the programme remain confidential, the MoD in 2022 did specifically cite *"augmented reality goggles, a computerized assault rifle system, a digital head-mounted display system, hostile fire detection technology, a location-tracking system in GPS denied environments, tactile sleeves for nav-*

IDF soldiers test Edge of Tomorrow technology. [Elbit Systems]

igation and command transmittance, and a voice command system (similar to systems used on smartphones)" as objective components. In July 2025, Elbit confirmed that this was an illustrative but not exhaustive list of technologies; additional subsystems under evaluation include (but are not limited to) AI for sensor fusion, energy-efficient power management, biometric monitoring, and adaptive camouflage. Additionally, stand-off sensing technologies, predictive analytics, and robotics will enhance both lethality and survival by permitting IDF personnel to operate with reduced exposure to their opponent.

According to Elbit, Edge of Tomorrow is structured as a multi-phase, evolutionary programme. Rather than culminating in a single fielding event, it introduces technologies incrementally as they mature. It runs in parallel with the Digital Army Program (DAP), a modernisation initiative launched in 2004 and aimed at transforming the Israel Defense Forces (IDF) into a fully networked, data-driven force. Elbit confirms that the programme is currently in advanced prototyping and operational experimentation. Components which have undergone field evaluation include SmartSight AR goggles, a next-generation weapon-mounted fire control system, dismounted blue-force tracking for GPS-denied environments, and a modular EUD. Some subsystems are already in limited field use with infantry units, while others are undergoing lab integration and environmental testing. Lessons learned from recent conflicts are informing the next development cycle.

Networking for the digital battlefield

While different nations have separate approaches to modernisation of infantry equipment programmes, many share the emphasis on digitisation and networking. Terms such as 'digital battlefield' and 'combat cloud' are consistently repeated in one form or another. Nations are in a literal race to make their armed forces – including dismounted infantry – faster, more agile, more accurate, and less visible. While hardware in one form or another, from uniforms and body armour to weapons and radios, forms the visible aspect of Future Soldier systems, electronics provide the decisive edge. Once the Future Soldier infantry networks are established, the next step becomes integration of dismounted personnel, vehicles, and other platforms including unmanned air and ground systems. The invisible web tying soldiers together – from the infantry squad level up to strategic headquarters – becomes the ultimate goal.

Nanotechnology: Threats and prospects in the CBRN sector

Dan Kaszeta

Nanotechnology is a double-edged sword in the CBRN sphere, offering possibilities for both new vulnerabilities and promising countermeasures. The real-world practical implications range from threat delivery systems capable of circumventing protective gear, to more capable detection and protection technologies.

▲ US Airmen from the 426th Air Base Squadron conducting chemical, biological, radiological and nuclear (CBRN) training at KNM Harald Haarfagre, Stavanger, Norway, on 20 May 2025. [USAF/A1C Adam Enbal]

Nanotechnology is the manufascture and manipulation of materials at the scale of one to one hundred nanometres. A nanometre is one billionth of a metre. Modern science and technology have made great progressive leaps in this area. Some of these advances have either direct or indirect implications in chemical and biological defence. While there may at some point be also some implications in radiological and nuclear defence, this article will explore the numerous implications in the chemical and biological defence realm. Some of this will, by necessity, delve into some of the finer technical points of CBRN science, but your correspondent will endeavour to explain it in clear language. As there are literally thousands of diverse lines of inquiry in this space, the term 'nanotechnology' is necessarily a broad one and a relatively wide interpretation is used herein.

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Threats: Making bad things worse

Nanotechnology does not just make smaller objects, it can also provide ways to contain, move, or manipulate materials in ways that could increase their utility as threats. In this correspondent's mind, encapsulation is one of the more serious areas of concern. Nano-encapsulation and micro-encapsulation are serious threats in the chemical and biological arena. In full disclosure, encapsulation at micro-scale rather than nano-scale would achieve some of these goals, but this article looks at the problem broadly, and the tools to perform encapsulation are being driven by nanotechnology.

Much effort is being made at the micro- and nano-scale to encapsulate materials. The nanomaterial itself is used to provide a coating around or carrier for some other things. Most chemical warfare agents and biological warfare agents are, despite a century of talk of 'war gases', liquids at room temperature. Some of them are volatile, and give off vapours. Others are non-volatile. What happens if you take one of these dangerous chemicals or biological pathogens and put them in a protective encapsulation? In effect, you are taking a liquid and, for tactical purposes, you are making it into a fine powder. A finely divided powder makes for good aerosols, and this has numerous implications in CBRN defence. It is alleged, but by no means substantiated, that the 'Novichok' materials used to poison Alexei Navalny in 2020 were encapsulated in some sort of nanomaterial.

Perhaps the starkest prospect is that nanotechnology provides a way in which some chemical compounds that normally are not useful as chemical warfare agents might be rendered into a form that makes them useful for warfare or terrorism. Substances that might be too volatile (for instance, evaporating too easily), lighter than air (wafting away in open air too easily), solid at room temperature (by using nano-particle dust, you are effectively taking a solid and making it act like a gas or vapour by putting it in aerosol), or too vulnerable to the environment (reacting with moisture, sunlight, etc.) could all be theoretically drafted into service as weapons. Nano-encapsulation could theoretically broaden the spectrum of compounds available for aggressive purposes by an adversary.

US Airmen walk in their Level A suits, the highest level of protection against any chemical vapour or splash field, during a field training exercise at Goldwater Air National Guard Base, Phoenix, on 31 January 2025. [US ANG/MSgt Michael Matkin]

Another troubling aspect arises when we look at the implications on protection. CBRN protection typically involves a filter-based respirator and some type of clothing. Typical military protective clothing consists of impermeable (rubber or equivalent) boots and gloves but suits made of selectively permeable textiles. The concept is to keep large and small droplets of chemicals from hitting the skin and to provide a layer of protection from gases, aerosols, and vapours, all of which need a pretty high concentration to directly harm through skin contact alone. Impermeable clothing works very well, of course, but the heat burden associated with it is very high and often unsuitable for combat soldiers for any extended period of time. The broad arc of protective clothing has been that of developing better and lighter ways of allowing some moisture and heat to escape, while keeping droplets off the skin. However, the arc of progress in chemical protective clothing might be circumvented by nanoparticles.

When confronted by an aerosol of very small particles at the nano-scale, this raises the prospect of such particles working their way through the clothing. In principle, filter-based respirators, as long as they are fitted properly and working properly, are a fine form of protection against this sort of threat to the respiratory tract. However, there is every prospect that nano-scale particles may be able to work their way through protective clothing that has been engineered around liquid droplets. This is a valid concern and the vulnerability will probably vary significantly depending on the exact clothing in question. But in theory, encapsulation could transform a molecule that really isn't much of a threat by means of skin contact into one that is, by evading the protective value of specialist clothing.

Another logical question that one could ask is 'how would these nanoparticles affect detection?' After all, masks and suits are no good if nobody knows when to wear them. Real-time biological agent detection is a bit like nuclear fusion, in that it shows promise but is permanently years away. Yet real-time detection of chemical warfare agents is very much a current capability and myriad useful products are available. However, the various technologies in use in chemical warfare agent detection are largely based on the assumption that they are trying to detect liquids, gases, vapours, and aerosols of liquids. Encapsulation changes the physical state of the chemical warfare agent, effectively turning it from a liquid (or even gas in some cases, theoretically) into a solid. Furthermore, that encapsulation process puts a thin barrier around the chemical warfare agent. Many chemical warfare agent detectors would be frustrated by an aerosol of nano-particles. Would some of the particles degrade in a field environment, leaving enough chemical agent to be detected? Possibly, but the answer to that is difficult to calculate and will vary greatly on the nanomaterial used and the exact detection instrument used. Is there an operational requirement for a generic nanoparticle aerosol detector, based on the assumption that anyone spreading an aerosol of nanoparticles is up to no good? This is a space to watch.

So what if one breathes nanoparticles in? A reasonably well-educated CBRN specialist would ask an obvious question at this point. Does this really represent an aerosol threat by inhalation? After all, particles lower than one micron in size (i.e. still above the top end of the nano-scale), are generally too small to be effectively absorbed into the body through the lungs. They tend to be too light to get stuck in the alveoli, the tiny pockets in the lungs. Conversely, particles larger than ten microns in size are too big. They might cause problems elsewhere, but getting directly into the blood stream would be problematic for such particles, due to their size.

Surely, this aerosol biology one-to-ten-micron rule of thumb rules out nanoparticles as CBRN threats? Sadly, no. What presents itself here is, effectively, two issues. First of all, there's no reason why someone making nano-encapsulated materials as a deliberate military or terrorism threat would go to all that effort without understanding the basic issues of aerosol biology. One could find a lot of ways to make nano-particles portions of larger particles. Clumps of toxic nano-particles bound together to be, say, 2 microns in diameter, would be a very bad thing for someone to breathe in, since they would be the right size to get into the lungs.

Arizona Army National Guard Soldiers from the 2220th Transportation Company are engulfed by coloured smoke after putting on their protective masks during a simulated chemical attack on 5 August 2017, at Florence Military Reservation in Florence, Arizona. [US ARNG/SSgt Brian A. Barbour]

What then? Now here is a crucial issue. Much work is being done in the pharmaceutical world to use nano-technology to help drug delivery. But the difference between a drug and a poison does not matter to a nanoparticle. The difference between a drug and a poison is dose and context. By engineering better ways to deliver medicinal compounds to particular tissues in the human body, nanotechnology seeks to improve the quality of medical care. However, the same pathway can be taken by poisons and pathogens. A key example is the use of nano-scale particles to cross the blood-brain barrier. For those readers who need a refresher, the blood-brain barrier is a set of cells in the body that do a very good job of keeping substances in the blood stream from passing into brain cells. This barrier is one of the more efficient systems in human physiology. While preventing much damage to our brains, it also has befuddled pharmacology, which has developed drugs that might need to transit this barrier. One such strategy involves nanoparticles which could be small enough to slip through the semi-permeable border between blood stream and brain tissue. However, if you do this with some poisonous materials, it makes them more toxic to the human body by giving them an express route to brain tissue. So, not only does nanotechnology increase the list of possible threats, it can make the threats more deadly than they already are.

Prospects: The good news

Nanotechnology gives with one hand and takes away with another. Some aspects of this emerging field contain some prospect of improved defence against CBRN threats. Various technical advances that represent possible threats can be flipped on their head and used to improve various aspects of defence, such as detection, decontamination, and medical countermeasures.

Miniaturisation is one area where there may be some prospect for improved CBRN defence. Nanotechnology is developing tools to make very small devices. The tools used for other aspects of nano-scale manufacturing could be used to manufacture detection equipment that is much smaller than currently available. A NATO conference on this exact subject in 2019 yielded dozens of interesting papers ranging from across numerous areas of technology that quickly get beyond your correspondent's technical scope to comprehend. An entire book (Denizli, A, ed. ***Plasmonic Nanosensors*** for Biological and Chemical Threats, CRC Press, 2024) discusses a dozen possible frontiers in this area.

One nanotechnology subdiscipline that appears to be doing a lot of the lifting in the field is nanofluidics – the field of manipulating small amounts of fluid, at nano-scales. Where this comes into play in CBRN defence sciences is particularly in chemical and biological warfare agent detection. A number of different approaches for detecting and identifying chemical or biological substances may involve handling of fluids, and this is particularly true in the current biological detection segment. Handling very small samples of air or fluid can possibly reduce the size needed for various methods of chemical and biological interrogation. Imagine a test strip like a COVID-19 test, but with literally dozens of agents that it could detect. Could a number of complex processes for interrogating an air sample or a liquid specimen be reduced to a single small chip? Not quite yet. But that day is not far away.

Nanoparticles may also be a pathway for improvements to both filter-based protection and decontamination. Manipulation of materials on this scale, particularly in the realm of Carbon-based molecules, can increase the prospect for materials that are used in filtration and decontamination. This assertion requires a little bit of explanation. The filter on a modern military CBRN mask actually uses a lot of different methods to screen the air being inhaled by the user. Two of these are absorption and adsorption. Casual readers may need to look at that closely to see that I did not use the same word twice. 'Absorption' means taking something inside. 'Adsorption' means, broadly, sticking to the outside. Carbon molecules in mask filters do both. To use a crude analogy, absorption is like have an underground parking garage inside a building. The building can take in a number of outside vehicles. Adsorption is like having a row of parking spaces next to the building. The building can take a number of cars right next to it.

A 22nd Medical Group medical technician inspects a simulated M8 chemical detection paper during Exercise Lethal Pride at McConnell Air Force Base, Kansas, on 9 May 2024. [USAF/A1C Gavin Hameed]

By crafting nanoparticles in the right way, in theory a material can be made that increases the ability to absorb and adsorb. In other words, nanomanipulation can likely take materials that already have, to use the metaphor from above, a lot of parking spots, both outside and inside the particle. This could, in theory, give a mask filter (or a collective protection filter on a tank or onboard a naval vessel) more protective capabilities. A cynical observer would be right to point out that absorption and adsorption only apply to gases, vapours, and liquid droplets, not solids like, say, nefarious nanoparticles. Fear not, another aspect of filters is electrostatic attraction. The air flow generates a static electricity charge that makes particles stick to the filter media. This already happens in filters and could even possibly be improved in newer nanotechnology filters. Whether any of this is achievable at a reasonable price for a useful improvement over the already good characteristics of an existing activated Carbon filter is another question entirely, as none of this nanotechnology comes cheaply at the moment.

There has also been some work on incorporating nanoparticles and nanofibres into textiles for use in protective clothing. While this does not appear to alleviate the threat of nanoparticles themselves, it gives the prospect of making permeable chemical protective clothing even lighter than the present generation of equipment. A number of articles in technical publications address this possibility, suggesting that some manufacturers may already be venturing in this direction.

The same improvements in absorption and adsorption can also, in theory, lead to improved materials for decontamination. The same 'more parking spaces' analogy applies to decontamination. There has been a long history of using various types of powders for decontamination purposes, whether it be the mineral Fuller's Earth or the special resins in the US M291 and M295 decontamination kits. Such powders work by absorbing and/or absorbing liquids off of surfaces, even skin. The sorbent (absorption or adsorption) properties of various nanomaterials have been investigated for numerous applications. Studies has pointed to the possibility of zinc oxide or cerium oxide nanoparticles being useful for skin decontamination. Whether or not chemical warfare agents thus absorbed or adsorbed by specialist powders become, in effect, the new threat vectors defined above, is a complicated question.

Yet another area where CBRN countermeasures may improve based on nanotechnology is in medical treatment of CBRN injuries. As of mid-2025, a simple Google Scholar search on the terms "nanotechnology 'drug delivery'" yielded over 1 million results, with over 25,000 papers and articles since 2024. Some of the proposed developments would have direct, indirect, or tangential aspects relevant to administering necessary medications. For example, a study in India postulates the use of atropine nanoparticles in a respiratory inhaler as a possible modality for treating nerve agent victims. Another study explored transdermal administration of scopolamine – a drug similar in its anti-nerve agent effects to atropine. Perhaps

A USMC CBRN specialist with the 31st Marine Expeditionary Unit assists with decontaminating a simulated casualty during chemical decontamination training aboard the USS America (LHA 6), in the Coral Sea, on 25 June 2025. [USMC/LCpl Gerardo Mendez]

inhalers and patches may join autoinjectors as a less invasive method of treatment. Other drugs that exploit the ability of some nanoparticles to slip through the blood-brain barrier may allow for delivery novel compounds that prevent or mitigate brain damage from nerve agents.

Drug delivery is, of course, only one aspect of medical treatment of CBRN-related illnesses and injuries. Diagnostic technology may improve along on some of the same lines that CBRN detection technology. Regardless of CBRN detection and protection, there will always be a need to conduct post-exposure diagnosis. With biological warfare agents, field detection will probably remove elusive and, at best, sporadic. Yet early detection of infections by pathogens can be lifesaving, particularly with biological warfare agents such as anthrax. Improved diagnostic techniques using one or more nanotechnology components have been heavily discussed in the scientific literature.

Overall prospects

It is clear that nanotechnology is both a threat and a boon in the CBRN defence space. This correspondent has come to the view that it is more of a boon than a threat. The scientific and industrial space for the defensive aspects appears to have a lot of weight behind it, and aside from unproven allegations of one aspect of Russian state terror, there has been scant evidence of nefarious activity. But any blossoming of CBRN defence based on nanotechnology is only going to go ahead if the economics work out.

Specialist devices and prototype systems relevant to CBRN defence already exist. Others are not far behind in technology readiness level (TRL). As has always been the case, much improvement in CBRN defence technology is theoretically possible but economically impractical. None of this stuff is cheap. Some aspects of nanotechnology are ruinously expensive. A chemical detection device that is smaller and faster than the current state of the art devices may be possible with nanotechnology, but if it costs 5 or 10 times the current offering, is the marginal improvement worth the extra expenditure? Some nanomaterials cost more by weight than gold. Would a nanoparticle decontamination powder that is very expensive be worth the cost differential over soap and water, which are ubiquitous and cheap? No army would buy a chemical protective suit for widespread issue to soldiers if it cost USD 10,000 a set.

One thing the world has learned from other fields of technology is that the prohibitive expense of new technologies does come down quickly as products go from lab to factory to product. We should not be daunted by the theoretical cost of some of the prototype items. Nanotech will get substantially cheaper. Whether or not the major players (for that, read the US and other NATO members) decide to invest in the CBRN defence aspects of nanotechnology over time, particularly given other demands on defence budgets. But with defence budgets on the rise across NATO, a rising tide will raise many boats, so to speak, and nanotechnology is an obvious front for spending more money to buy better capability. Defence technologies can have civil applications. It works the other way around, possibly even better. The existing investments in, say, nanomaterials in medical applications could easily be leveraged for CBRN defence. It will be an interesting space to watch over the coming decade.

Specialists with the CBRN response element (CRE), 31st Marine Expeditionary Unit, detect and report possible chemical contamination while conducting CBRN response training at Camp Hansen, Okinawa, Japan, on 1 February 2017. [USMC/Cpl Darien J. Bjorndal]

Ballistic missile moves

Tim Guest

The use of various types of ballistic missiles during recent and ongoing conflicts has highlighted their importance in future warfare, not only in terms of the need for participants to possess them in quantity, but also of being able to defend against them, effectively. Additionally, with repeated, foreboding threats by Russia over the past three years, alongside its changing nuclear doctrine, the need for the West to maintain effective ballistic missile capabilities is also growing in importance.

This article examines the appearance of one of the newest tactical ballistic missiles in the Russo-Ukraine conflict. It also touches on Ukraine's efforts to develop its own tactical system as US ballistic missile supplies remain uncertain or depleted. The article moves from the tactical to strategic, offering a brief update on strategic ballistic missile developments of the land-based element of the US nuclear triad. Ballistic missile explosion

More ballistic missiles have been used in anger over the past three years than at any time since WW2, when over 3,200 of the world's first tactical ballistic system, Germany's V2, were launched by the Nazis, mainly against targets in the UK. Fast forward to today, and Russia's ongoing war against Ukraine, has seen more than 10,000 Russian missiles launched against the defenders since the start of 2023, although some 800 Iskander-Ms short-range ballistic missiles (SRBMs) were used against Ukrainian targets in the early weeks of the war during the six-month period between April and September 2022. Add to the mix recent hostilities between Iran and Israel throughout June 2025, and the early-May tension and clashes between India and Pakistan, all of which involved the use of tactical battlefield ballistic missiles by one or both sides.

In Ukraine, while most of the missiles used, including Russia's Iskander-Ms and US-supplied Army Tactical Missile Systems (ATACMS), have been around for years, on a more recent Russian development appeared for the first time.

Oreshnik

That new arrival is Russia's Oreshnik, (ENG: Hazel Tree), an apparent intermediate-range ballistic missile (IRBM), with a range claimed as 5,500 km according to Russian sources on Telegram, with some other sources claiming a 5,000 km range. The missile is thought to be based on the RS-26 Rubezh intercontinental ballistic missile (ICBM), according to Pentagon sources. Unsurprisingly for a weapon of this class, the missile can reportedly exceed Mach 10, (12,300 kph), and reports from Ukraine's Defence Intelligence Directorate, suggest it carries six multiple independently targetable re-entry vehicles (MIRVs), which re-enter the atmosphere at hypersonic speeds, and each MIRV thought to contain six submunitions of their own. It's worth noting that the RS-26 programme was meant to have been discontinued at the end of 2017, though the US Defense Intelligence Agency reports suggest that either the programme has been re-started, or elements were retained and used to develop Oreshnik.

A 9M723 Iskander-M SRBM being launched from the Kapustin Yar proving ground in March 2018. [Russian MoD]

As for its first use in anger, the weapon's opening appearance was in the skies over Ukraine on 21 November 2024, in what Moscow would cynically describe as a test; the missile was launched from Russia's Astrakhan region, targeting the PA Pivdenmash factory in the city of Dnipro. According to Russian President Vladimir Putin, Oreshnik was employed in response to Ukrainian strikes on Russia with US and British missiles; both countries having previously lifted restrictions for their use against targets inside Russia. Indeed, Russian claims, prior to Oreshnik's initial use, were that six ATACMS had been used against Russian targets, taking

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advantage of Washington's new directives, thereby eliciting a 'suitable' response from the Russians. Interestingly, adhering to an old rule of warfare, US DoD general staff were alerted, pre-launch, by the Russians that the missile 'test' would take place. According to Ukraine's Defence Intelligence Directorate, the missile launched against Dnipro came from the 4th Missile Test Range at Kapustin Yar and took just 15 minutes to cover 800 km before striking the town, and did, indeed, carry six MIRVs, each deploying six submunitions over their target. Ukrainian sources put the re-entry speed of the Oreshnik MIRVs as 3-4 km/s (Mach 8.7-11.6). Oreshnik numbers, likely low at this time, are apparently set to increase, following a June 2025 announcement by Vladimir Putin that the missile has now, supposedly, entered full-scale production, together with the threat to deploy them, during the second half of 2025, in Belarus. Whether this is purely posturing is yet to be seen.

A screengrab of video footage from the 21 November 2024 Oreshnik attack. A wave of submunitions is seen striking what was identified as PA Pivedenmash. [via @ Felisrevolt X account]

Nevertheless, following the November 2024 Oreshnik attack and in line with its threatening political dimension, a mid-December 2024 TV appearance by Vladimir Putin, saw him explain the menacing changes to Russia's nuclear doctrine, but also refer to Oreshnik as 'the country's new intermediate-range ballistic missile', its use late November 2024, and suggest its capabilities could be further demonstrated if it were to be launched again against Ukrainian targets to see if Western-supplied air defence systems, such as, PATRIOT and SAMP-T, would be able to bring it down. It is worth mentioning in response to that challenge, that while the PATRIOT systems have been successful intercepting other Russian SRBMs and cruise missiles, drones, and aircraft, some defence analysts and certain Ukrainian sources consider it unlikely for either to be able to reliably intercept Oreshnik, due to the latter's high speeds, flight parameters, and MIRVs, enabling it to effectively evade being engaged, unless multiple interceptors can be used to achieve success against each MIRV during the terminal phase of flight. The long range of Oreshnik also puts it at an advantage over these air defence systems, which were not intended for use against IRBM-class weapons; examples of more suitable alternatives for engaging such threats would include THAAD and SM-3.

Ukraine's short-lived affair with ATACMS – so far…

Despite its heavy reliance on the US, European, and other allies for the supply of ammunition and equipment to defend itself since Russia's 2022 invasion, Ukraine's own defence industry has played the major role in keeping its defensive war effort going. Indeed, according to the Royal United Services Institute (RUSI), the US has accounted for about 20% of materiel supplied, Europe and other allied nations some 25%, while Ukraine's own defence industry itself produces around 55% of the military hardware its forces rely on. However, amongst the US munitions supplied, though not in great numbers, has been the ATACMS tactical ballistic missile (TBM). Kyiv is said to have received ATACMS M39 Block I TBMs, with a range of 165 km, used in combat for the first time on 17 October 2023, while the

ATACMS supplies for Ukraine have now run out, though they remain urgently needed. Pictured: ATACMS during a 2021 Flight Test. [Lockheed Martin]

longer-range M39A1 with bomblets and M48 with a unitary warhead (both 300 km range) were also reportedly supplied and used starting in March 2024.

However, according to recent reports in Ukrainian and other media, all supplied variants of ATACMS to Ukraine ran out during the first few months of 2025. It still has launchers capable of launching them, but no missiles. That said, fewer than 40 of the ballistic systems were reportedly supplied by the US in the first place, with restrictions on using them against targets over the border in Russia only lifted by the Biden administration in November 2024. Since then, the few 300 km range ATACMS that remained were used effectively against high-value targets such as S-400 air defence systems and air fields.

…and Ukraine's own ballistic missile foray

Add to this situation the uncertainty regarding ongoing US supplies and supply reliability, and it's no wonder that Ukraine has, reportedly, developed its own domestically-designed TBM, which has already been used in anger and successfully targeted and, allegedly, destroyed a Russian command post at the missile's maximum range of some 300 km, according to Ukraine's UNITED24 Media.

Measuring slightly larger than ATACMS, the Hrim-2, also known as 'Sapsan', is capable of carrying a 400 kg payload and has already entered serial production, though at what scale is another question. The missile is designed by KB Pivdenne, and manufactured by PA Pivdenmash. Apparently, the missile's development began not long after the invasion, in May 2022, with first test launch during mid-2024. A Ukrainian aviation expert quoted in UNITED24, Kostiantyn Kryvolap, suggested that future variants of the new Ukrainian missile might achieve extended range by trading warhead mass for an increased fuel capacity and modified engine, which further suggests that the full potential of Hrim-2 has yet to be revealed, as Ukraine joins an exclusive club of just ten other ballistic-missile-producing nations in the world.

Beyond Ukraine – replacing ATACMS: PrSM

While Ukraine continues to need additional supplies of ATACMS, the US is already moving forward with its replacement. The new Precision Strike Missile (PrSM) from Lockheed Martin is an SRBM now being fielded to replace ATACMS in the US Army. Its surface-to-surface, indirect, deep-fire capabilities are intended to be effective out to ranges of at least 499 km, with the system compatible for use with HIMARS and M270 MLRS platforms. Latest developments with the programme include the March 2025 US Army award to the company of a USD 4.94 billion indefinite delivery indefinite quantity (IDIQ) contract to produce additional PrSMs as and when required, with the production line able to respond flexibly to meet any growing or sudden demand. Carolyn Orzechowski, VP of Precision Fires Launchers and Missiles at Lockheed Martin, said the company was focused on advancing the production of PrSMs at speed and scale.

In mid-April 2025, Lockheed Martin and the US Army conducted a short-range, production-qualification test at the White Sands Missiles Range in New Mexico, to demonstrate platform integration and readiness, by launching a PrSM from an M270A2 MLRS launcher for the very first time. According to a Lockheed Martin press release, the Increment 1 missile was launched "at multiple targets, including a radar and rotary wing platform, engaging them with precise and lethal impact". The test validating its performance and its integration with the M270A2 launcher. The missile's ability to manoeuvre and maintain accuracy was also demonstrated during the short-range flight. Orzechowski added that although PrSM's primary mission is long-range fires, the company also validates accuracy and reliability of the missile, even at the shortest distances, before handing it over to the Army. It is also worth noting that Northrop Grumman produces the solid rocket motor for the PrSM Increment 1.

Stateside strategic developments

Meanwhile, in the US – but this time at the strategic level – efforts continue to maintain the 50-year-old LGM-30 Minuteman III intercontinental ballistic missile (ICBM) nuclear deterrent without interruption. At the same time, progress is being made on its replacement: the LGM-35 Sentinel ICBM Ground Based Strategic Deterrent (GBSD) from Northrop Grumman. This is intended to remain in service for at least 50 years once it enters operational use.

In the meantime, Minuteman's capabilities have to be maintained to ensure a full and seamless transition of the nuclear deterrence between the two systems. Currently, some 400 Minuteman IIIs remain at readiness, all armed with a single warhead, either the W78 (335 kt) or W87 (300kt) warheads, and located among some 450 silos dotted around thousands of square kilometres across several states – a notable reduction compared to the roughly the 1,000 Minuteman I, II, and III incarnations deployed during the 1970s. With the New START treaty due to expire in 2026, the US is planning to field Minuteman III ICBMs with three warheads again. To this end, a test launch of a three-warhead Minuteman III was conduct-

Lockheed Martin and the US Army conducted a production qualification test at White Sands Missiles Range in New Mexico on 10 April 2025, to demonstrate platform integration and readiness by launching a PrSM from an M270A2 MLRS launcher for the very first time. [PEO Missiles & Space/Darrell Ames]

For the Minuteman III test in May 2025, the unarmed missile was carrying a single-payload Mk-21 high-fidelity re-entry vehicle (RV) designed to carry the W87 warhead. [USSF/Kadielle Shaw]

ed from Vandenberg Space Force Base (SFB) in California, on 5 November 2024.

Minuteman IIIs most recently proved their continued operational readiness on 21 May 2025, when US Air Force Global Strike Command (AFGSC) conducted a test launch, from Vandenberg SFB, of an unarmed missile carrying a single-payload Mk-21 high-fidelity re-entry vehicle (RV); these are designed to carry the W87 warhead. The test launch was routine and long-planned, with Vandenberg the main testing ground for the AFGSC's total nuclear deterrent ecosystem; such events are designed to evaluate all aspects of the system's continued effectiveness, reliability, safety, and security. According to AFGSC, the Minuteman III ICBM's RV travelled some 7,780 km (4,200 NM) westwards across the Pacific Ocean to the Ronald Reagan ballistic missile defence test site on the Kwajalein Atoll in the Marshall Islands. Part of the US Army Space and Missile Defence Command, the test site is equipped with a range of sensors, including high-fidelity radar and optical systems, which gather telemetry data during the missile's terminal phase, the analysis of which helps determine overall system performance. The test launch was conducted by Vandenberg's 337th Test and Evaluation Group; its only function is the continual test and evaluation of the US's ICBM force to ensure it remains at a complete state of readiness at all times. This same unit will eventually perform the identical functions for the Sentinel Programme.

Sentinel cost overruns fund an Air Force One, of sorts

One of the most curious aspects of the latest LGM-35A Sentinel programme has been a decision to reallocate excess funds from the programme's 2024 budget to the refurbishment project to convert the Boeing 747 donated by Qatar to the Trump Administration, into an interim Air Force One. Reassuringly, Secretary of the Air Force, Troy Meink, is reported to have confirmed Sentinel as fully funded, despite the reallocation of funds, which was only made possible by the programme's restructuring and a full cost-overrun review.

Indeed, one of the unforeseen additional infrastructure costs has been in relation to silo construction; where previous costings had budgeted the programme based on 450 existing Minuteman III silos simply being refurbished and re-used for Sentinel, it eventually became clear that completely new silos would have to be built at considerable additional costs in order to accommodate the Sentinel missiles. The programme was originally expected to cost USD 77.7 billion, but had been on course to reach a staggering USD 160 billion. This initiated the Nunn-McCurdy Act in January 2024, requiring the Department of Defense (DoD) to report the programme's expected cost overruns to Congress; a breach or critical breach of the act occurs when a programme's unit cost exceeds certain thresholds, beyond which it's down to the Secretary of Defense to decide whether to close a programme down, or keep it going if it's vital to national security, which, in the case of

An unarmed Minuteman III ICBM launches during an operational test at Vandenberg SFB on 21 May 2025, designed to demonstrate total deterrence readiness. [USSF/A1C Jack Rodriguez Escamilla]

▲ **LGM-35A Sentinel ICBMs will eventually replace existing Minuteman IIIs, including the W87 warhead being replaced by the new W87-1. [Northrop Grumman]**

Sentinel, it is. So, restructuring and reallocations took place, the programme continues, even as the President's aircraft receives a makeover boosted by some unexpected ICBM funding. Nevertheless, Sentinel is still, according to the Pentagon, set to cost almost USD 141 billion by the time it's operational. Each missile alone is now expected to cost USD 162 million.

Around the same timeframe as all this was going on, the Air Force Nuclear Weapons Centre (AFNWC), together with Sentinel programme prime contractor, Northrop Grumman, and sub-contractor, Aerojet Rocketdyne, conducted a static-fire test of the LGM-35A Sentinel ICBM's third-stage solid rocket motor, on 16 March 2024, at the Arnold AFB Arnold Engineering Development Complex in Tennessee, the third such test of Sentinel's three-stage propulsion system. In January 2024, under the terms of Northrop Grumman's engineering, manufacturing, and development (EMD) design contract for Sentinel, the second-stage solid rocket motor had already been tested successfully at the same location in a vacuum chamber to simulate the environmental conditions the motor would experience during high-altitude and space flight. The company is designing and producing stages one and two of the three-stage Sentinel missile, and with these early-2024 tests successfully completed, has now moved forward with the USAF to qualification testing, with the data from the rocket motor tests informing ongoing modelling and designs. The first-stage solid rocket motor static-fire and hypersonic wind-tunnel tests were previously conducted under the same EMD contract.

Some 634 Sentinel ICBMs are slated to be procured by the USAF, with a further 25 acquired to enable live training test firings with inert warheads. 400 of the missile inventory are to be deployed in operational readiness in new silos, while the remaining 234 will presumably be kept in storage. The programme also involves modernising 450 silos and 600 facilities among the wider Sentinel ecosystem of command and control (C2) centres, monitoring and administration facilities spread over some 100,000 km2, across several states: California, Colorado, Nebraska, North Dakota, Montana, and Wyoming.

A warhead for the future

While Minuteman III ICBMs are equipped, as mentioned earlier, with the W87 warhead, a W87-1 Modification Programme has been in play to reinvigorate and transform the US's nuclear warhead production complex, which has deteriorated since the Cold War, and to produce the new warhead that will eventually equip Sentinel ICBMs. The programme will ensure the US's Nuclear Security Enterprise (NSE) once again becomes a turnkey producer of all of the components required to make a modern nuclear warhead. In fact, the W87-1 will be the first 100% newly manufactured nuclear warhead to enter the US stockpile since the end of the Cold War. On the path to make that happen, the US Department of Energy's National Nuclear Security Administration (NNSA) announced a milestone, in October 2024, that it had completed and 'diamond-stamped' the first production unit (FPU) of a Plutonium pit for the new W87-1 warhead. Plutonium pits are a necessary component of each US nuclear warhead and the NNSA is currently rebuilding the nation's capability to manufacture them at the rate of at least 80 pits per year – hundreds were made each year during the Cold War, but production ceased when the Berlin Wall came down in 1989 and the Cold War ended.

The NNSA said that "achieving an FPU for the W87-1 pit is an important milestone for the US's nuclear weapon stockpile modernisation", particularly as the new warhead supports the Sentinel ICBM programme. Its diamond stamping means that the FPU pit meets all requirements to join the US nuclear stockpile at 'war-reserve' quality. To reach this milestone, scientists from Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), the Kansas City National Security Campus (KCNSC), and the Nevada National Security Site worked with NNSA over eight years, with the Livermore Laboratory responsible for pit design, and eventual pit manufacturing completed at LANL.

According to the NNSA, consistent Plutonium pit production is vital to the nuclear stockpile; a target capacity to reach 30 pits per year at LANL is the current aim, though by an unspecified timeframe, with equipment installation and other facility improvements still required to ensure an "increasingly dependable production capability". Meanwhile, the Savannah River Plutonium Processing Facility at the Savannah River Site in South Carolina is under construction and, as part of the NNSA's nuclear weapons complex, is slated to reach a 50 pits-per-year capacity "in the mid-2030s", the NNSA said.

Whether this rate of pit production meets Sentinel's intended in-service dates and requirements remains to be seen, as the new ICBM is expected to begin replacing Minuteman IIIs in 2029, with an initial operational capability set for 2030. With much at stake, it's probably safe to say someone, somewhere, is coordinating this essential correlation.

Poland's armed forces modernisation: SITREP

Dr Robert Czulda

Poland continues to modernise its armed forces, but the process is increasingly challenged by structural issues, particularly financial constraints.

Poland expects to buy an additional 180 K2 tanks, with some to be manufactured in Poland. [Polish Army/Piotr Szafarski]

In 2024, total defence spending reached EUR 32.4 billion, marking a 23% increase compared to 2023. According to local outlet *Dziennik Zbrojny,* while the government had planned to allocate 4.2% of GDP to defence in 2024, actual spending amounted to 3.78% of GDP. In 2023, the figure stood at 3.26%. The same outlet, widely regarded as the most authoritative Polish source on the financial aspects of defence and modernisation, has repeatedly warned of mounting budgetary pressures.

For instance, in early April 2025, *Dziennik Zbrojny* reported that multi-year contracts signed in previous years have consumed the majority of the Ministry of National Defence's (MoND's) modernisation budget for the 2025–2028 period. As a result, the remaining available funds may be insufficient to meet other critical procurement and ammunition needs that have not yet been contracted. The planned expansion of the Polish Armed Forces further complicates the situation, as it drives up operational costs while reducing the funds available for investments in equipment and ammunition.

Another key concern is Poland's placement under the European Commission's excessive deficit procedure, which further limits the government's ability to finance defence programmes. In short, Poland will have limited financial capacity for signing new modernisation contracts through 2028, as it is already committed to more than 470 contracts worth over EUR 131.9 billion, including EUR 87 billion that needs to be paid between 2025–2035. Future modernisation needs are projected to require additional agreements totalling more than EUR 153 billion.

Tanks

One of the latest developments is the announcement of a second executive contract for South Korean K2 tanks. The first contract, signed in 2022, covered the delivery of 180 tanks, scheduled to be delivered by the end of 2025. The framework agreement between Poland and South Korea provides for a total of 1,000 tanks. However, the conclusion of the second contract, including details on technology transfer and the relocation of production to Polish facilities, has faced significant delays and challenges.

In early July 2025, Deputy Prime Minister and Minister of Defence Władysław Kosiniak-Kamysz revealed the details of the new contract (worth about EUR 5.7 billion) covering K2 and K2PL tanks, as well as support vehicles based on the K2 platform, including armoured recovery vehicles (ARVs), armoured engineering vehicles (AEVs), and armoured vehicle launched bridges (AVLBs). It was disclosed that the second contract includes 180 tanks, more than 60 of which will be in the Polish K2PL variant. A portion of the tanks will be produced in Poland, specifically at the Bumar-Łabędy plant in Gliwice. The agreement also includes technology transfer, logistical and technical support. The first 30 tanks under this new contract are expected to be delivered in 2026 and are intended for potential export. Furthermore, Polish media have reported interest from Slovakia.

By the end of 2026, the Polish Armed Forces will operate a total of 779 modern tanks, including 116 M1A1FEP, 250 M1A2SEPv3, 180 K2, and 233 Leopard 2 tanks (the Leopard 2A4 variants are currently being upgraded by Poland's defence industry to the more advanced 2PL and 2PLM1 configurations, which are better adapted to national requirements and industrial capabilities). The M1A1FEP tanks were ordered in January 2023 for EUR 1.2 billion, with deliveries carried out

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from June 2023 to June 2024. As a result, Poland will field six ABRAMS tank battalions, each consisting of 58 tanks, along with an additional 18 vehicles assigned for training at the Land Forces Training Center (CSWL). Deliveries of the M1A2SEPv3 tanks commenced in January 2025, and are scheduled to run through to the end of 2026.

Other land vehicles

A long-awaited modernisation priority for the Polish Land Forces is the introduction of the domestically designed and manufactured Borsuk tracked infantry fighting vehicle (IFV). The Borsuk is intended to replace the obsolete BMP-1s currently in service. So far, the MoND has ordered 111 Borsuks at a cost of EUR 1.5 billion, with deliveries scheduled to run from 2025 through 2029. A framework agreement for the delivery of up to 1,000 vehicles and 400 specialised support vehicles was signed in February 2023 by representatives of the Armament Agency and the consortium of Huta Stalowa Wola (HSW) and the Polish Armaments Group (PGZ). The Borsuk is based on a universal modular tracked platform and is equipped with the ZSSW-30 remote turret.

111 Borsuk vehicles have been ordered thus far, with deliveries scheduled between 2025 and 2026. [HSW]

Poland is also planning to acquire a heavier IFV (CBWP – Ciężki Bojowy Wóz Piechoty), which will feature greater armour than Borsuk, but will lack the latter's amphibious capabilities. Final decisions on the programme have not yet been made. Several foreign designs are under consideration, including the South Korean AS21 Redback, the Turkish Tulpar, and the German KF41 Lynx. At the same time, Huta Stalowa Wola, the manufacturer of the Borsuk, has been working on a domestic solution. This new platform will be developed using experience and components from the Borsuk programme as well as other projects conducted by HSW. Poland is considering acquiring up to 700 CBWP vehicles.

In June 2025, the Armament Agency placed an order for another batch of Rosomak-WEM medical evacuation vehicles based on the Rosomak 8×8 wheeled platform. By 2028, the Polish Armed Forces will receive 12 additional Rosomak-WEM vehicles along with a training package. The total value of the contract is approximately EUR 61.5 million. The first 37 WEM vehicles were delivered to the Polish Army between 2008 and 2011, followed by a second batch of 29 vehicles ordered in 2022, with deliveries starting in December 2024 and continuing until 2026. Thanks to the latest contract, the total number of Rosomak-WEMs in service will increase to 78.

Poland is also steadily acquiring Homar-K multiple rocket launcher systems (MRLS). Initially, 212 units of this Polish variant of the K239 Chunmoo were ordered, but this number was increased to 290 following the signing of a second executive agreement in April 2025. These launchers are mounted on domestically-produced Jelcz 882.57 8×8 truck platform. The deal also includes CGR-080 239 mm rockets with a range of 80 km, as well as CTM-290 tactical ballistic missiles (TBMs) with a range of 290 km. In April 2025, a joint venture agreement was concluded to establish a dedicated ammunition production company. The first rockets produced domestically under this venture are expected to be available in 2029. According to estimates by Defence24, the Polish Land Forces currently operate at least 81 Homar-K systems.

A persistently unresolved issue is the enhancement of Poland's artillery ammunition production capacity. Although more than three years have passed since Russia's full-scale invasion of Ukraine began, Poland has yet to significantly increase its capabilities. In early April 2025, the Polish Armaments Group (PGZ) was awarded four contracts to co-finance the production of 120 mm and 155 mm ammunition, valued at EUR 565 million. The companies receiving funding to expand their technological base include Dezamet, Mesko, Nitro-Chem, and ZPS Gamrat. According to government plans, a production capacity of 150,000 rounds of large-calibre ammunition is expected to be achieved by the end of 2027. Currently, PGZ is fulfilling a contract signed in December 2023 for the delivery of approximately 280,000 rounds of 155 mm ammunition, with deliveries scheduled through 2029.

Aviation

Currently, the most attention is being devoted to plans involving FA-50 Golden Eagle light fighter aircraft from South Korea. A deal worth EUR 2.5 billion was signed with KAI in September 2022. Poland ordered 48 light combat jets, including 12 units in the interim FA-50GF (Gap Filler) version and 36 units in the FA-50PL version, which is tailored to Polish requirements. All ordered FA-50GF aircraft were delivered to Poland in 2023, while the FA-50PLs are scheduled for delivery from November 2025 to September 2028 under the agreement. Ongoing controversies surround the programme's cost, the aircraft's ability to integrate more advanced weapon systems, and the currently limited combat capabilities of the FA-50.

Much debate has also been sparked by the MoND's decision in June 2025 to lease AIM-9P Sidewinder air-to-air missiles (AAMs) from South Korea. Poland has also placed an order for the more modern AIM-9L variant. This is an interim solution, as

A Polish F-35A pilot executes ground operations at Ebbing Air National Guard Base, Arkansas on 29 January 2025. Poland will ultimately have three F-16 squadrons, two F-35 squadrons, and three FA-50 squadrons. However, it is widely believed that Poland's needs are greater, with a target of ten combat squadrons. [USAF/SrA Abigail Duell]

Poland ultimately plans to arm the FA-50s with the latest AIM-9X variant. Officials argue that leasing the older missiles will enable the FA-50s to be deployed more quickly for airspace defence missions. At the same time, it has been confirmed that a mid-life upgrade (MLU) programme for Poland's in-service F-16s is also planned.

A key ongoing modernisation programme is the introduction of the F-35 into service. Poland signed a contract in January 2020 to purchase 32 F-35A Lightning II fighters as part of the Harpia programme. The contract is valued at USD 4.6 billion and includes a comprehensive logistics and training package. Once fully operational, Poland will have three F-16 squadrons, two F-35 squadrons, and three FA-50 squadrons. However, it is widely believed that Poland's needs are greater, with a target of ten combat squadrons (approximately 160 aircraft). In this vein, the MoND has acknowledged its interest in acquiring air superiority fighters, but final decisions will depend on available financial resources.

In terms of unmanned aerial vehicles (UAVs), in 2023 Poland began leasing MQ-9A Reaper drones, but more recently has commenced efforts to procure newer models. In December 2024, the Armament Agency signed a contract for the delivery of the first batch (up to three) of MQ-9B Skyguardian) for reconnaissance missions. These drones will be equipped with optronic sensors, synthetic aperture radar (SAR), and signals intelligence (SIGINT) capabilities. The Polish MQ-9Bs are also planned to be armed with missiles and guided bombs. Further purchases of MQ-9B Skyguardian UAVs are planned under the Zefir programme, and the acquisition of a naval variant for the Polish Navy is currently under consideration.

Helicopters

There has been considerable controversy surrounding Poland's helicopter procurements. Until recently, most public attention focused on the acquisition of AH-64E Guardian helicopters to replace the aging Mi-24D/W fleet. In 2024, Poland signed an intergovernmental agreement to purchase as many as 96 AH-64Es. At the same time, it leased eight used AH-64Ds for EUR 255 million as a temporary solution for the 1st Army Aviation Brigade. The AH-64E contract, which covers deliveries from 2028 into 2032, and includes armaments and training, is valued at approximately EUR 8.5 billion. As part of the programme, Poland plans to acquire two types of anti-tank missiles: up to 1,844 AGM-114R2 Hellfire missiles and up to 460 more advanced AGM-179A JAGM (joint air-to-ground missiles). Despite the high costs, the acquisition is going ahead.

Currently, public debate is dominated by the cancellation of a planned purchase of 32 helicopters for the Land Forces. Officials have explained the decision as a result of shifting priorities. The original plan envisioned the acquisition of 32 S-70i Black Hawk helicopters for Poland's airmobile units. These helicopters are assembled at the PZL Mielec plant, owned by Lockheed Martin. At present, the Polish Special Forces operate eight S-70i Black Hawks.

Meanwhile, deliveries are underway for 32 AW149 helicopters, which are being produced at the Leonardo-owned PZL Świdnik facility. The contract for these helicopters, signed in 2022, is

Three frigates of the Miecznik class are to be delivered to the Polish Navy by the end of 2031. [PGZ]

worth over EUR 1.9 billion. According to official plans, Poland currently prioritises several categories of helicopters: combat-trainer helicopters, multi-role maritime helicopters for the *Miecznik* class frigates (primarily for anti-submarine warfare), heavy transport helicopters for army aviation, SAR helicopters, as well as platforms for special operations. These include a multi-role special operations helicopter, a light special operations helicopter, and a multi-role support helicopter intended for use by the Land Forces.

Navy

Poland is currently building three multirole frigates under the Miecznik programme, with these based on Babcock's Arrowhead 140 design. All three vessels are to be delivered to the Polish Navy by PGZ Stocznia Wojenna (War Shipyard) by the end of 2031. The first unit, named ORP *Wicher*, is scheduled to be launched in mid-2026 and is expected to enter service in 2029. The ships built under the Miecznik programme will form the core of the surface combat forces of Poland's naval branch.

In late March 2025, PGZ Stocznia Wojenna handed over the ORP *Mamry* minehunter (Project 207M) to the Polish Navy. The ship, launched in 1981, had undergone a comprehensive overhaul. The company had previously refurbished two other minehunters – ORP *Niecko* and ORP *Nakło* (both Project 207P), under a contract signed in 2022. Meanwhile, another Polish shipyard, Remontowa Shipbuilding, launched the first of two ships being built under the programme codenamed 'Delfin', which will provide Poland with SIGINT and ELINT capabilities. The equipment for this programme is supplied by Saab, and the first ship is expected to be ready by 2027. The first ship of the class, ORP *Jerzy Różycki*, was named after a Polish mathematician and cryptologist who, along with other Polish experts, broke the codes used by early (three-rotor) German Enigma machines as early as 1933, and later contributed to the work of British codebreakers at Bletchley Park in cracking the later five-rotor and eight-rotor versions of Enigma machines. The entire Delfin contract is worth EUR 620 million.

In December 2024, Poland ordered a new rescue vessel, scheduled to be launched in 2027. However, the future of Poland's submarine fleet remains unresolved. After retiring all four Kobben class submarines in recent years, Poland currently operates only one submarine, ORP *Orzeł* (*Kilo* class). The submarine modernisation project, dubbed 'Orka', has been ongoing unsuccessfully for several years though the current government promises that a contract will be signed soon. Offers have been submitted by the French Naval Group, Spanish Navantia, Italian Fincantieri, German ThyssenKrupp Marine Systems, Swedish Saab Kockums, and Korean Hyundai Heavy Industries. One key factor in the decision will be the ability of the selected foreign partner to provide Poland with so-called bridging capabilities, with submarines that Poland could use for sailor training until the delivery of the final vessels.

Assessing Serbia's ground forces procurement efforts

Chris Mulvihill

Serbia has undertaken a sustained effort to modernise its land forces, balancing legacy Yugoslav-era weapons with new domestic developments and selective foreign acquisitions.

As a diplomatically neutral state in a region increasingly integrated into Western-aligned political and military structures, Serbia faces growing pressure to maintain sovereign and credible defence capabilities, having faced painful consequences from the conflicts of the 1990s – most notably the de-facto independence of Kosovo. This pressure has only intensified with the recent Joint Declaration on Defence Cooperation signed in Tirana in March 2025 by Albania, Croatia, and Kosovo, further highlighting Serbia's regional isolation. While Serbia's procurement is limited to air and land platforms, this article will focus solely on Serbia's land programme acquisitions which have received less comprehensive coverage in recent times. These land programmes reflect Belgrade's attempt to build a credible sovereign defence capability, deter adversaries from potentially targeting Serb territory or ethnic Serb populations, and discourage what Belgrade often views as escalatory actions by Pristina in the areas of northern Kosovo predominantly populated by ethnic Serbs.

Serbian defence policy

Serbia has long pursued a policy of military neutrality, formally prohibiting membership in defence alliances. This places Serbia in a strategically disadvantageous position, as it cannot rely on external alliances for military defence, while the broader region is largely integrated into NATO structures and, in many instances, the EU as well.

Despite remaining outside formal military alliances, Serbia actively cooperates with several major security structures, including the Russian-led Collective Security Treaty Organization (CSTO), the EU's Common Security and Defence Policy (CSDP), and NATO. Serbia holds observer status within the CSTO and has previously participated in the annual 'Slavic Brotherhood' exercise alongside Belarus and Russia. Under the EU's CSDP, Serbia has contributed to multinational operations in the Central African Republic and Somalia, and participates in the EU's Greek-led HELBROC Battlegroup – also known as the Balkan Battlegroup – located in Larissa, Greece.

The most substantial cooperation, however, is with NATO. Beginning with the Partnership for Peace (PfP) programme and later through an Individual Partnership Action Plan (IPAP), Serbia has participated in numerous joint exercises primarily aimed at enhancing interoperability in peacekeeping operations. Apart from select engagements such as annual air defence drills with Bulgaria and the Slavic Brotherhood exercises, Serbia's defence cooperation remains largely confined to training for peacekeeping-related interoperability.

Recognising the absence of an external security guarantee, Serbia must maintain credible national defence capabilities capable of deterring external armed threats and contributing to domestic and regional stability. In 2009, Serbia re-adopted the 'total defence' concept, once practised in the former Yugoslavia. This holistic approach extends beyond the armed forces, involving civil organisations, private actors, and the general public in national defence planning. By blurring the lines between military and civilian roles, the total defence concept seeks to mobilise all sectors of society in support of territorial defence – vastly expanding the potential human resource base. However, in Serbia's case, the practical implementation of this policy remains limited. Compulsory military service was suspended in 2010, and no concrete steps have yet been taken to reinstate it.

A further part of Serbia's defence policy is the development of a domestic arms industry. While Serbia inherited a substantial defence industry from the former Yugosla-

Exercise Platinum Wolf 25 hosted in Serbia, supported by the United States European Command, saw 11 countries participating in training to improve interoperability in peacekeeping operations. [Serbian MoD]

via, this industry was not designed to function independently and was deeply integrated across various republics of Yugoslavia. The breakup of Yugoslavia and ensuing conflicts effectively dismantled these supply chains, leading to the collapse of many defence enterprises. Serbia was not immune to this disruption but has made considerable efforts to rebuild specific sectors to enable the domestic design and production of defence materiel.

Serbia's leading defence enterprises are predominantly state-owned. Among Serbia's predominant activities include the manufacture of ammunition across all calibres and the production of land-based platforms. In addition to manufacturing, Serbia retains a moderate capacity to service and upgrade Yugoslav-era platforms. Amid heightened global tensions, the Serbian defence industry has capitalised on rising international military spending. In 2023 alone, defence exports exceeded USD 1.6 billion. While this represents a valuable revenue stream, Serbian-manufactured equipment has occasionally appeared in conflict zones, potentially undermining Serbia's declared neutrality. Most notably, reports in May 2025 alleging Ukrainian use of Serbian-supplied ammunition prompted diplomatic inquiries from Moscow, following allegations from the SVR (Russia's Foreign Intelligence Service), although no retaliatory measures were ever announced by Russia. In late June 2025, Serbian President Aleksandar Vučić declared that Serbia had halted all exports of arms and ammunition for the time being, citing national security and economic interests.

Serbia will likely continue investing in domestic defence production to meet its national security needs while seeking to expand its export footprint. The long-term ambition looks to penetrate higher-value and more prestigious international markets, enhancing the reputation and competitiveness of Serbia's defence industry.

Main battle tanks

The Serbian Army's main battle tank (MBT) fleet has undergone notable modernisation and expansion over the past decade. In 2006, Serbia possessed a relatively large but outdated tank force comprising 204 M-84s, 28 M-84As, 61 T-72Ms, and an unspecified number of T-55s. Serbia gradually retired the T-55s from active service by 2010, leaving the M-84s and T-72s as the core of the tank fleet.

In 2020, Serbia began receiving newer T-72B1MS 'White Eagle' tanks, with delivery of the entire batch of 30 understood to have been completed in 2021. Today, the Serbian Army maintains four tank battalions, each subordinated to one of its four brigades. All but one of these battalions are equipped exclusively with M-84 tanks. The exception is the 46th Tank Battalion of the 4th Brigade, which fields one company (typically 13 vehicles) equipped with T-72B1MS tanks. Additionally, a separate T-72B1MS battalion is controlled directly by the Army Command, rather than being integrated into a brigade. This latter case illustrates the support Serbia has received from Russia in recent years.

Aside from this one-off Russian donation, Serbia has not actively pursued foreign acquisitions to complement or replace its legacy MBT fleet. Instead, the focus has been on upgrading existing in-service platforms. While there was discussion in the mid-2010s about initiating a domestic tank design, this ambition is widely regarded as unfeasible, due to the high costs involved and a lack of the technical and industrial base required to develop such a complex system. Although the M-84 is a Yugoslav-developed platform, its final assembly line was located in present-day Croatia, and its components were sourced from all across the former federation. Consequently, Serbia did not inherit the complete infrastructure or expertise necessary to start full-scale MBT production.

This has not deterred efforts to modernise the M-84 fleet domestically. Several previous upgrade attempts were either export-oriented or failed to gain traction. Notable examples include the M-84AB1, which bore a strong visual resemblance to the Russian T-90S, and the M-84M, which was mainly focused on explosive reactive armour (ERA) application. However, it was not until 2020 that a domestic upgrade programme gained official backing from the Serbian Ministry of Defence (MoD).

The M-84AS1 (2017) was unveiled at the Partner 2017 defence exhibition in Belgrade. Developed by the Military Technical Institute (MTI) in Belgrade, this vehicle introduced significant enhancements in protection and situational awareness, but the design continued to evolve. By 2020, a revised variant appeared, referred to as the M-84AS1 (2020), as well as the very similar-looking but more refined M-84AS2.

In terms of recognition, the M-84AS2 appears very similar to M-84AS1 (2020), with the main visual differences being the M-84AS2's full ERA coverage on the glacis, more steeply-sloped ERA arrangement on the turret cheeks, laser warning receivers (LWRs) on the turret sides, a taller commander cupola to reduce blind spots caused by roof-mounted ERA, revised panoramic sight for the commander, and the presence of mudguards above the toe plate to prevent fouling of the headlights and driver periscope.

The T-72B1MS is currently the most modern main battle tank in active service with the Serbian Army. It has Kontakt-1 explosive reactive armour across the hull and turret, a PKP-72 independent panoramic day/thermal sight for the commander, and a Sosna-U day/thermal sight for the gunner. In addition, it also possesses an auxiliary power unit and a remote weapon station armed with a Kord 12.7 mm heavy machine gun for the commander. [Serbian MoD]

Both the AS1 (2020) and AS2 models were seen on exercises, and undergoing trials in the early 2020s, but the latter design appears to have been favoured. According to Serbian sources, the M-84AS2 upgrade is being rolled out gradually. As of 2024, around 20 units were believed to have entered service, with at least nine displayed during the Zastava 2024 event at Batajnica air base. It remains unclear whether this modernisation will be extended across the entire M-84 fleet or confined to select battalions.

The M-84AS2 is a comprehensive upgrade of the M-84 platform, and sees lethality, protection, and situational awareness improvements. [Chris Mulvihill]

The M-84AS1 (mod. 2020) and M-84AS2 reportedly feature a new domestically-developed ERA package applied to the glacis, hull sides, and turret front, sides, and roof. Additionally, both feature a remote weapon station (RWS) armed with a 12.7 mm heavy machine gun (HMG), along with a day/thermal sight, and a 360° panoramic camera suite integrated onto an updated meteorological sensor. Interestingly, although an early AS2 prototype displayed in 2021 was fitted with the Safran PASEO commander's panoramic sight (and prior to that 2020, an AS2 seen on the 'Support 2020' exercise used a different model), more recent presentations – such as at Partner 2023 and the Zastava 2024 display in late 2024 – omitted this feature. This is probably a cost-saving measure, since the commander already has an RWS, which can serve as a panoramic sight. The gunner is believed to use a domestically produced DNNS-2TI thermal sight, while the driver also gained a thermal camera. The AS2 retains the Soviet-era V-46-6 engine, upgraded to 840 hp. With a combat weight of approximately 46.5 tonnes, this yields a power-to-weight ratio of around 18.1 hp/tonne, which is modest by contemporary MBT standards.

The upgrade's export potential hinges on its applicability to the broader userbase of the T-72. With Russia currently constrained in its ability to offer comprehensive support to these countries, Serbia could potentially leverage its experience with the M-84AS2 to market upgrade solutions abroad, providing a valuable capability within the MBT upgrade market.

Infantry fighting vehicles

As with its main battle tank fleet, Serbia retains a fleet of Yugoslav-era infantry fighting vehicles (IFVs), namely the BVP M-80 series. The first serious attempt to modernise this platform came in the early-2000s with the BVP M-80A/98. The programme saw little success, and development was effectively paused until 2016.

The BVP M-80AB1 (2016), initially unveiled in 2016, was developed by the Military Technical Institute (MTI) and built upon the M-80A/98 concept. Its most significant improvement was the addition of appliqué armour across the hull. According to MTI, the latter upgrade enables the vehicle to withstand 30 mm projectiles on the frontal arc and 14.5 mm fire on the sides, a substantial enhancement given the modest baseline protection of the original M-80. It was provided with an M91 E-I single-person turret armed with a Zastava M86 30 × 210B automatic cannon. In 2021, a modified version was presented, the BVP M-80AB1 (2021). Following further development and refinement, during which another version was seen in 2020, the final variants were revealed at the Partner 2023 defence exhibition in the form of the BVP M-80AB1 (2023) and the BVP M-80AB2 variant. The former was fitted with the Yugoimport RCWS 20 remote turret, armed with a Zastava M55 20 × 110 mm automatic cannon.

The BVP M-80AB1 has seen several iterations, but this appears to be the latest of its kind, showcased at Partner 2023 in Belgrade. Aside from the substantial appliqué armour coverage, its most notable differences are a redesigned headlight assembly and crew compartment that also includes a rear ramp. It also integrates an unmanned turret armed with a 20 mm automatic cannon, with the addition of a 7.62 mm co-axial machine gun, a 30 mm automatic grenade launcher, and a pair of Malyutka anti-tank guided missiles. [Chris Mulvihill]

The second variant shown, the M-80AB2, shares the same hull structure and armour package as the AB1 but incorporates a manned turret fitted with a 30 × 173 mm M12 cannon, a NATO-standard evolution of Zastava's M86 design. It also features an upgraded anti-tank guided missile (ATGM) system based on the domestic Malyutka platform, supporting the Malyutka 2T, 2F, and 2TS variants, also developed by MTI. At the Zastava 2024 event, only one M-80AB2 was presented, compared to up to 13 examples of the M-80AB1 (2023).

It remains unclear which of these variants will be adopted as the standard for upgrading the existing M-80A fleet. The greater numbers of the M-80AB1 present at Zastava 2024 suggests a preference for the unmanned turret variant, which continues to employ the older 20 mm M55 cannon used on the original M-80A. It is possible that development is underway to adapt the unmanned turret to support the newer 30 mm cannon, or possibly that the Serbian Army is content to retain the M55 for the foreseeable future given the likely abundance of domestically-made 20 mm ammunition. While no definitive decision has been announced, the M-80AB1 currently appears to be the leading candidate for at least a partial modernisation of the M-80A fleet.

Armoured personnel carriers

Serbia has achieved notable success in developing a domestic line of wheeled armoured personnel carriers (APCs) that are entirely new designs, rather than modernisations of legacy Yugoslav-era platforms. This progress is exemplified by the Lazar family of 8×8 APCs. Since the launch of the Lazar 1 project in 2008, the series has undergone several iterations, culminating in the more refined Lazar 3, which has been adopted by the Serbian Army and has also secured export orders.

The Lazar 3 with the 30/2 mm RWS. While this particular manifestation is not in service, it showcases the interest Yugoimport SDPR has invested into developing a plethora of variants based on the Lazar chassis, both for domestic and export opportunities. [Chris Mulvihill]

he Lazar 3 is believed to have entered service in 2017 in the APC role with the Serbian Army, with smaller procurement by the Serbian Gendarmerie. The vehicle accommodates a crew of three and nine dismounts, for a total of 12 personnel. It has a maximum weight of 28 tonnes, a top speed of 110 km/h, and can ford water obstacles up to 1.6 m deep, although it is not amphibious. The chassis is reportedly built around the T900 axle set, developed by Timoney Technology and manufactured by Texelis.

As of 2025, the Lazar 3 remains the only vehicle in the family operational with the Serbian Army, with approximately 80 vehicles in service out of a total order of 125. The exact breakdown of variants ordered has not been publicly disclosed.

However, known configurations include a base APC variant fitted with an M15 remote weapon station (RWS) armed with a 12.7 mm HMG, a version with the Kerber unmanned turret armed with three 20 mm cannons, an ambulance variant, and an anti-tank guided missile (ATGM) carrier.

Yugoimport, the primary contractor for the Lazar family, has also developed the Lazar 3M – a variant fitted with the Russian 30 mm 32V01 turret. This model omits the small side windows and firing ports found on the Lazar 3, presumably to improve protection. A heavier APC variant is also in development under the name Lazanski, which has been displayed with a mock-up of the Russian AU-220M 'Kinzhal' unmanned turret armed with a 57 mm cannon. However, given both the Lazar 3M and Lazanski rely on Russian-supplied weapon systems, their viability may be in question due to ongoing difficulties in securing and delivering Russian defence products.

In a surprising development, Serbia has also procured surplus Hungarian BTR-80A vehicles, with estimates ranging from 50 to 70 units. The rationale behind this acquisition remains unclear. Hungary has already begun phasing out its BTR-80 fleet, suggesting that Serbia may have acquired the vehicles at favourable rates. It is also possible that production rates for the Lazar 3 have fallen short of expectations, necessitating an interim solution. Alternatively, the deal may reflect deepening bilateral defence cooperation in the region, following the signing in Belgrade of a Strategic Defence Cooperation Plan between Serbia and Hungary in April 2025; this was seemingly a reaction to the defence cooperation pact formed by Albania, Croatia, and Kosovo the month before.

Protected mobility vehicles

Alongside the Lazar family of armoured personnel carriers, Serbia has also developed and produced its own protected mobility vehicle, the BOV M16 Miloš, which is employed as a general-purpose patrol vehicle and in a number of specialised variants. Like the Lazar, the Miloš uses a Texelis-manufactured axle set, the T700, reflecting continued reliance on key foreign subcomponents within Serbia's defence industrial base.

The Miloš is another relatively successful platform, given it has been exported to Cyprus and Senegal. In addition to a patrol role, Yugoimport markets other variants including command, ATGM carrier, artillery reconnaissance, and ambulance variants. [Yugoimport]

Yugoimport has also unveiled the Miloš 2, although its only notable distinction from the baseline variant appears to be the integration of the same 20 mm M55 unmanned turret found on the BVP M-80AB1 (2023). The vehicle has a maximum weight of 18 tonnes and accommodates up to 10 personnel, including both crew and dismounts. At least 30 baseline Miloš vehicles are known to be in service with the Serbian Army, in addition to an undisclosed number operated by the Gendarmerie. In January 2024, President Vučić announced an order for an additional 112 Miloš vehicles. If fulfilled, this would bring the total fleet to approximately 142 units. The breakdown of the ordered variants has not been publicly disclosed.

The Nora B52 NG can be differentiated by its base platform, now using a MAN-based truck, whereas previously the system relied on a KamAZ truck. [Yugoimport]

Beyond its domestic developments, Serbia has also benefitted from foreign military assistance, notably from Russia, which donated 30 BRDM-2MSs alongside the T-72B1MS tanks. These armoured reconnaissance vehicles serve within the Army's dedicated reconnaissance battalion. While the BRDM-2MS is still a relatively limited platform, it offers significantly greater utility and survivability than the older BRDM-2 models in use by Serbia.

Serbia has also expanded its inventory of High Mobility Multipurpose Wheeled Vehicles (HMMWVs), having originally received 47 units as US donations between 2012 and 2017. To augment this fleet, Serbia placed an order for up to 118 additional vehicles, with at least 66 known to have been delivered by 2023. The rationale behind this procurement appears to be an effort to expand the pool of interoperable vehicles for deployment in multinational peacekeeping operations. However, Serbia has also deployed UN-marked Miloš vehicles as part of its contribution to the United Nations Interim Force in Lebanon (UNIFIL), indicating that local designs are also used for expeditionary roles. The additional HMMWV acquisition may therefore also reflect limited annual production capacity of the Miloš rather than a purely tactical preference.

Tube and rocket artillery

One area in which Serbia has retained significant expertise from the former Yugoslavia is the design and production of artillery and rocket systems. This tradition continues today, with Serbia actively developing such systems for both domestic use and export markets. Recent procurements in this sector include updated variants of the 155 mm Nora B52 truck-mounted howitzer and the reported acquisition of the Israeli Precise and Universal Launching System (PULS) rocket artillery system.

Until the more recent Nora B52 M21 and Nora B52 NG variants, both of which were based on a MAN 8×8 truck platform, the system was mounted on a KamAZ platform – the latter may become increasingly difficult to procure and export due to geopolitical constraints. As a result, Yugoimport may shift entirely to using the MAN truck platform, even for domestic service. The Nora B-52 NG weighs up to 40 tonnes and is armed with a 155 mm L52 main gun. The gun uses an automatic loading system, allowing a maximum firing rate of four rounds per minute. The vehicle carries 30 rounds in the autoloader, with an additional six stored on the vehicle. In 2021, former Defence Minister Nebojša Stefanović confirmed that six additional systems had been ordered, supplementing the 12 already in service at that time. However, rising costs and continued reliance on imported components, particularly the chassis, may limit broader production and procurement for domestic use.

While the Nora B52 represents the modern element of Serbia's self-propelled artillery fleet, the legacy 2S1 Gvozdika remains in service as a secondary platform. A domestic modernisation package developed by the Military Technical Institute (MTI) and implemented by Srboauto has extended the vehicle's operational life. Upgrades include a new fire-control system, a 7.62 mm machine gun mounted for the commander, and a thermal imaging camera for the driver. These enhancements will support the continued use of the 2S1 Gvozdika in the near term.

In the rocket artillery domain, Serbia has reportedly signed a contract with Israel's Elbit Systems for the acquisition of the PULS. While Elbit's official press release in November 2024 referred only to an "unnamed European customer", President Vučić hinted at a press conference later that month that Serbia may have been the buyer. The exact configuration of the PULS variant destined for Serbia has not been disclosed. The modular PULS launcher can launch a range of rocket types with varying calibres and ranges – from shorter-range 122 mm rockets to long-range 370 mm Predator Hawk tactical ballistic missiles (TBMs) with a range of 300 km. As the PULS is capable of launching 122 mm rockets, it remains to be seen whether Serbian-manufactured munitions can be integrated into the system, potentially expanding domestic industry involvement and reducing long-term logistical reliance on imports.

Air defence

Serbia's air defence network has undergone significant investment over recent years, marked by the acquisition of foreign systems and sensors, as well as efforts to develop indigenous short-range air defence (SHORAD) capabilities. While Serbia continues to rely heavily on legacy Soviet-era platforms, its procurement strategy has increasingly pivoted toward Chinese systems, as Russian hardware has become difficult to acquire. As a result, Serbia has become the first European operator of both the FK-3 (the export variant of the HQ-22) and the HQ-17AE systems. Concurrently, domestic projects such as the PASARS-16 and the newly unveiled Harpas self-propelled anti-air gun and missile (SPAAGM) systems remain ongoing.

The FK-3 had its first components delivered in early 2022, air-lifted to Serbia by Chinese Y-20 heavy transport aircraft – a rare deployment of the Chinese People's Liberation Army Air Force (PLAAF) to Europe. A medium- to long-range system-of-systems, the FK-3 complements Serbia's legacy S-125M and 2K12M2 Kub systems and is likely to form the long-range backbone of Serbia's air defence network. With an advertised maximum engagement range of 100 km, the FK-3 is roughly analogous in range capability to older variants of the S-300P series, having comparable missile characteristics. FK-3 reportedly achieved full operational capability in early-2025 and is assigned to the 2nd Air Defence Missile Battalion, which is tasked with the defence of Belgrade. The system's entry into service may allow for the eventual retirement of the static S-125M.

First revealed in June 2024, the HQ-17AE is Serbia's second purchase of Chinese air defence equipment, just two years after the FK-3 purchase. Each transporter launcher and radar (TLAR) vehicle can hold up to eight missiles and, according to a Serbian MoD specification board for the HQ-17AE, has a maximum engagement range and altitude of 15 km and 8 km, respectively. [Serbian MoD]

In a surprising move, Serbia also procured the HQ-17AE, a wheeled variant of the HQ-17, itself derived from the Russian Tor-M1 system. The acquisition, revealed in 2024, was even more unexpected than the FK-3 deal. Previously, in 2019, Serbia had acquired the Pantsir-S1, and by late 2021, expressed interest in the Pantsir-S1M. However, logistics and political constraints – specifically the inability to deliver Russian systems through NATO airspace – likely rendered this impossible. In that context, the HQ-17AE perhaps offered an alternative system for SHORAD that would not have entailed the same difficulty and consequences that would have emerged from purchasing a Russian system.

On the domestic front, Serbia continues to develop the PASARS-16, a 6×6 truck-mounted SPAAGM platform armed with a single licensed-produced 40 mm L/70 Bofors cannon. While previously it had a notable absence of any radar systems, the model showcased at Partner 2023 did have RADA Electronic Industries' multi-mission hemispheric radars, possibly for target detection. This cannon is reportedly capable of firing programmable ammunition, possibly BAE Systems' 3P rounds. The variant presented at Partner 2023 showcased a broad weapons suite mounted on a manned turret. This included a jamming system, two man-portable air defence systems (MANPADS), including the locally-produced Strela-2M and the newly acquired Mistral 3 ER, and two extended-ranged Malyutka ATGMs for defence against ground targets.

Complementing this is the Harpas, a tracked SPAAGM unveiled at Partner 2023, developed on an M-84 MBT chassis. It serves as Serbia's attempt at a domestic analogue to the 2K22 Tunguska, providing a combined gun/missile air defence system with mobility suited for armoured brigades. The Harpas uses twin 40 mm Bofors cannons to deliver a higher rate of fire than the PASARS and incorporates up to four short-range missiles, notionally these would be Serbia's RLN-RF and RLN-TK missiles. The RLN-RF uses a thermal seeker, while the RLN-TK is guided by a semi-active radar homing (SARH) seeker, with both reportedly offering engagement ranges of up to 12 km – far exceeding the effective range of the onboard cannons. For target detection, the Harpas is equipped with the Thales GS-40, a modification of Weibel's Xenta-M X-band radar system. Whether this platform will progress beyond the prototype stage remains to be seen, but it reflects Serbia's ambition to develop a mobile, domestically produced SHORAD capability that can support its manoeuvre forces.

The Harpas tracked SPAAGM was unveiled at the Partner 2023 exhibition in Belgrade. In the example shown, the vehicle is equipped with two each of the RLN-RF and RLN-TK missiles. [Mark Cazalet]

Closing thoughts

Serbia's procurement efforts reflect a deliberate attempt to modernise its armed forces and build up a larger pool of domestic expertise and manufacturing capability, all while also having to navigate its relations between East and West. Though constrained by budgetary and geopolitical limits, Belgrade has revitalised domestic industrial capacity in several key sectors, particularly in wheeled armoured vehicles and artillery. Meanwhile, legacy Cold War-era equipment continues to be upgraded and retained where feasible. The result is an eclectic, but increasingly capable force structure designed to meet Serbia's unique security requirements in the immediate region, where many of its neighbouring states are often smaller in size and lack many of the capabilities the Serbian armed forces have built up since the collapse of Yugoslavia. As regional dynamics evolve, diplomatic pressures may test the sustainability and coherence of its procurement choices in the future.

The UK's Deep Recce Strike Brigade, old wine in new bottles?

Sam Cranny-Evans

The British Army's Deep Recce Strike Brigade Combat Team (DRS-BCT) is seen as a modern solution for deep fires and reconnaissance in future conflicts. Yet, many of its structures and roles mirror the artillery-centric force deployed during Operation Granby in 1991. While the DRS-BCT introduces updated platforms and digital targeting, questions remain about mass, doctrine, and munitions. This article examines whether the brigade represents innovation – or a repackaging of old ideas.

When British and US forces deployed to Saudi Arabia in 1990 ahead of their operation to free Kuwait from Iraqi forces, they took with them the multiple launch rocket system (MLRS), something of an oddity at that time. Launching 227 mm M26 rockets loaded with dual-purpose improved conventional munition (DPICM) submunitions, a type of cluster munition, the MLRS attained something of a legendary status in the US military for delivering "steel rain", a phrase used by a US artillery battery to describe themselves, rather than one used by Iraqi soldiersss, according to a 2020 article published by the *New York Times*. In any case, the MLRS is emblematic of the ground-based firepower brought to bear during that war, which included helicopters in a ground-attack role and masses of artillery all supported by forward observers.

A Challenger 1 of the Royal Scots Dragoon Guards moving through the desert. The tanks were significantly enabled by massed artillery, and coalition forces were under strict orders not to advance without artillery preparation. [US DoD/PHC Holmes, via Wikimedia Commons]

In the opening ground invasion phases of Operation Granby (the name given to the UK's military operations in Iraq during the 1991 First Gulf War), the indirect fire of the Royal Artillery, which had been designed and refined for use against Soviet forces, delivered devastating overmatch against Iraqi units despite being dug-in. The result was that the armoured engagements that followed were very successful; the 7th Armoured Brigade travelled 300 km, destroying 90 Iraqi tanks with only two casualties and 15 wounded while the 4th Armoured Brigade destroyed 60 Iraqi tanks and lost ten men, mostly to friendly fire. In one engagement, gunners from the 2nd Field Artillery regiment engaged an Iraqi company in support of a Canadian detachment. "Good shooting.... target annihilated... many enemy dead.....Out!" the Canadian who called for the fire mission is reported to have said. Op Granby reflected the quintessential purpose of artillery in combined arms operations; destroy or suppress the enemy to preserve combat power in the lead armoured formations.

Fast forward to 2022, the British MoD launched the Future Soldier progsramme, which formally announced the Deep Recce Strike Brigade Combat Team (DRS-BCT); a brigade-sized structure that would accommodate the bulk of the British Army's indirect fire capabilities, including its reconnaissance assets. It is expected to fight in the enemy's deep areas, degrading their centres of gravity and setting the conditions for success for the rest of the deployed force. Specifically, it "will focus on the Army's deep fight capabilities, combining deep fires with reconnaissance and the ability to integrate non-lethal effects. It will utilise enhanced fires systems to provide long-range persistent surveillance for the coordination of deep fires", the

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Army explains on its website. The structure and the ambition for the DRS-BCT sounds innovative, but is it that different from its Gulf War predecessors?

Operation Granby: British order of battle

At the outbreak of the Gulf War with Iraq's invasion of Kuwait in August 1990, the Royal Artillery was configured for a large war with the Soviet Union in continental Europe. This meant three different types of artillery regiment providing fire support. Three field artillery regiments were expected to accompany each of the UK's four armoured divisions and provide for their fire support needs; they were equipped with M109 self-propelled howitzers (SPHs) and FH70 towed guns, both in 155 mm, as well as the 105 mm Abbot SPH. There were also heavy regiments that were armed with the M110 203 mm (8 inch) heavy guns, which were nuclear-capable. The M270 Multiple Launch Rocket System (MLRS) – capable of being armed with either 227 mm rockets, or the 610 mm ATACMS tactical ballistic missile (TBM) – was also making its way into the heavy regiments, all of which were held in a central artillery brigade. Finally, there were nuclear regiments – by 1990 the British Army relied on the 50th Missile Regiment, armed

A convoy of US M110A2 203 mm howitzers belonging to 2nd Battalion, 142nd Field Artillery, conducts a movement during combat operations in support of Operation Desert Storm. The UK also deployed its heavy M110A2s during the operation. [US ANG/1SG Tony Rice, via Wikimedia Commons]

with the MGM-52 Lance nuclear tactical ballistic missile. The aforementioned were highly capable units that trained more or less exclusively for war with the Soviet Union, which meant that divisional fire missions (three regiments or 72 guns firing on a target) were commonplace.

At the same time, the writing was on the wall for the Soviet Union. The Berlin Wall had fallen in 1989, reunifying Germany one year later, and it became clear that the risks of conflict were subsiding. Technically, the Soviet Union would continue existing until December 1991, but that had not stopped the British Army from easing its levels of readiness and maintenance schedules. The result was that the Royal Artillery was forced to cannibalise vehicles and mix units in order to provide the forces necessary for Operation Granby. Six regiments were sent to Saudi Arabia to support the 1st Armoured Division, including:

- 2nd Field Regiment Royal Artillery (M109)
- 12th Air Defence Regiment RA (Rapier short-range air defence)
- 26th Field Regiment RA (M109)
- 32nd Heavy Regiment RA (M110)
- 39th Heavy Regiment RA (MLRS)
- 40th Field Regiment RA (M109)

There were also a range of reconnaissance elements integrated into the Divisional Artillery Group, including the 16th/5th Queens Royal Lancers (later amalgamated with 17th/21st Lancers to become The Queen's Royal Lancers in 1993) that are now also a part of the DRS-BCT since becoming part of the Royal Lancers (Queen Elizabeth's Own), in 2015. Those reconnaissance elements were primarily equipped with Scimitar tracked reconnaissance vehicles and their variants, and tasked with finding targets for the 32nd and 39th Heavy Regiments. It is also worth noting that the 4th Regiment of the Army's Air Corps also deployed with two squadrons of Lynx and Gazelle helicopters armed with TOW anti-tank guided missiles (ATGMs). They were expected to support the deep battle along with the heavy regiments and reconnaissance elements; however, poor weather reportedly prevented the helicopters from doing so.

The aforementioned is quite similar to the order of battle for the DRS-BCT, which includes the following formations:

- Household Cavalry Regiment, Armoured Cavalry with Ajax.
- 1st The Queen's Dragoon Guards, Light Cavalry with Jackal and Foxhound.
- The Royal Lancers (Queen Elizabeth's Own), Armoured Cavalry converting to Ajax.
- The Royal Yeomanry, Light Cavalry Reserves with Jackal.
- 1st Regiment Royal Horse Artillery, Armoured Fires, to be equipped with RCH155 SPH and a squadron of Ajax-equipped troops.
- 3rd Regiment Royal Horse Artillery, Deep Fires with M270 MLRS.
- 5th Regiment, Royal Artillery, Surveillance & Target Acquisition with Taipan artillery-locating radars.
- 19th Regiment Royal Artillery, Armoured Fires with Archer SPH.
- 26th Regiment Royal Artillery, Deep Fires with M270 MLRS. Converted from 26th Field Regiment, which served in 1991.
- 101st (Northumbrian) Regiment Royal Artillery, Deep Fires Reserve regiment, will provide a formed MLRS battery to each of 3 RHA and 26 Regt RA.
- 104th Regiment Royal Artillery, Armoured Fires Reserves, will provide reinforcements to 1 RHA and 19 Regt RA.
- 100th (Yeomanry) Regiment, Reserve regiment providing joint terminal attack controllers (JTAC).
- 6th Armoured Close Support Battalion, Royal Electrical and Mechanical Engineers.
- 206th (North West) Multi-Role Medical Regiment.

The DRS-BCT is also expected to synchronise deep effects including those from the UK's AH-64E Apache attack helicopter fleet, although the future of those aircraft is somewhat

An Apache AH-64E being refuelled on a blocked road during Exercise Talon Guardian in 2022. The DRS-BCT is expected to coordinate deep fire assets including the Apache. [Crown copyright 2022/Cpl Danny Houghton]

uncertain at present. Despite selection of the AGM-179 Joint Air-to-Ground Missile (JAGM) in 2021 to replace Hellfire, there has been little movement in terms of orders or further integration of the missiles into UK service.

Regardless, there are a number of similarities between the Divisional Artillery Group (DAG) from 1990–1991 and the DRS-BCT. The armoured artillery regiments will primarily support the close fight, offering fire support to the 12th and 20th Armoured Brigade Combat Teams, for example, much as the field artillery regiments did in the First Gulf War. Reconnaissance assets like The Royal Lancers will work with the 3rd and 26th Regiments Royal Artillery to find and strike targets at depth. The primary element that appears to set the DRS-BCT apart is that the 5th Regiment Royal Artillery, equipped with the Taipan artillery-locating radar, is included within its span of command. This adds to its organic target detection capabilities alongside the forward reconnaissance elements.

The Gulf War DAG did also include short-range air defence assets including the 12th Air Defence Regiment with Rapier and two air defence batteries that were tasked to support the two armoured brigades. It is likely that the 7th Air Defence Group would function in a similar way, providing an umbrella for the DRS-BCT and dedicated close support for the armoured brigade combat teams.

Overall, the structure of the DAG deployed by the British in Op Granby and the DRS-BCT is very similar, but what about the doctrine?

Artillery and the three battles

"A divisional artillery commander has three tasks, not two: Fight the Deep Battle, win the Counter Battery Battle, and resource the Close Battle. Because these are the three battles a Peer/Peer+ enemy will fight, these three tasks are set in stone. An artillery commander cannot opt out of any particular one…Forcing an artillery commander to choose which of the three not to fight, is as fatuous as forcing someone to choose between air, food and water."

This quote is taken from an article published in the *British Army Review* in 2020 by Lt Col Matt Wilks, a gunner serving in the Land Warfare Centre at the time. The quote itself was provided by Lt Col Andrew Gillespie, who served as a battery commander in the 2nd Field Artillery regiment during the Gulf War. Lt Col Wilks continues in some depth on the divisional deep battle during the Gulf War stating: "The Operation Granby divisional deep battle sought to fix and defeat, by physical attack, enemy forces that could threaten the assaults taking place on initial divisional objectives," he explains. The paper is set up to compare and contrast the previous approaches to deep battle with the contemporary edicts that focused on information manoeuvre.

"As such, it was fought relatively 'close'. It was barely distinct from the close battle, except for its purpose and the nature of its resourcing: a formation recce regiment with an immense allocation of artillery and airpower," Wilks continued. Indeed, the 1st

View through the face mask of two British soldiers wearing protective chemical weapons clothing holding rifles in a foxhole during the First Gulf War. Chemical weapons were a major threat during the war and elements believed to be associated with Iraqi capabilities in this area were targeted during some of the air strikes. [Crown Copyright 1991]

Armoured Division was bolstered by air power and a US artillery brigade, which in effect meant the division was supported by a corps of artillery. This brought hugely destructive levels of fire-power to the division's operations. For one objective, Objective Brass, British armour was supported by three regiments of M109s, a sub-unit of the US brigade's M110 and MLRS batteries, and two air sorties. All of this firepower was amassed and delivered onto a single objective, Gillespie wrote in his 2001 memoir.

The 1st Division fought its three battles in two stages; the deep battle was fought before the ground offensive began on 24 February 1991. It consisted of the well-known air strikes and what were known as 'gun raids'. Artillery batteries would push forwards, beyond the berms protecting coalition troops in Saudi Arabia to engage Iraqi targets and then withdraw. This stage of the battle also included the counter-battery battle, and served to isolate Iraq's frontline units. Just prior to the offensive, the coalition forces conducted a four-hour artillery bombardment against Iraqi positions, expending 90,000 rounds of ammunition. 24,000 of those rounds were fired by the 1st British Armoured Division. As the ground offensive got under way, the artillery switched to the close battle, eventually abandoning the deep battle altogether as there were no viable targets and the armoured offensive was moving too quickly. The two armoured brigades could initially only progress when properly supported with artillery to ensure minimal casualties, but were eventually delegated fire support and allowed to take greater initiative.

It is difficult to glean much about the doctrine that the DRS-BCT is expected to follow and how it will be deployed. This is partly because the formation only exercised for the first time in 2023, and has since been stripped of all of its AS90s, some of its M270s, and all of its original ARTHUR artillery locating radars, to equip Ukraine's armed forces. The concept of employment has likely been written and tested in simulated form, and some elements – such as 19th Regiment RA with its Archer howitzers – have been tested in real-world training scenarios.

At least conceptually, it appears to have been difficult for British officers to agree on a definition for 'the deep'. Ukraine's strikes against Russian ammunition depots are often held up as an example of deep fires, and yet others refer to the deep as 'anything beyond-line-of-sight weapons'. The DRS-BCT was originally expected to yield non-lethal effects, but it is unclear what is meant by that, or how it would happen. In theory, the DRS-BCT would likely support 3rd Armoured Division (3 Div) in much the same way that the DAG supported the 1st Armoured Division in Op Granby. The primary difference in a peer war is that the Royal Air Force would likely be extensively engaged in a strategic suppression/destruction of enemy air defence (SEAD/DEAD) campaign that would consume much of its resources and limit its ability to contribute to the deep or close battles of the land forces. This is an interesting tension within the UK's planned Digital Targeting Web that will see sensors and shooters connected in real time. While it may be possible to achieve, the likelihood is that resources will be so limited, that the individual services may end up fighting their own individual battles, without wider support for a portion of time.

The equipment

This would perhaps be manageable if 3 Div and the DRS-BCT could put the same quantity of artillery into the field as the British division in 1991, but that is sadly not the case. As highlighted by Lt Col Wilks, the 1st Armoured Division had 60 155 mm guns and a regiment of MLRS at its disposal as well as masses of ammunition. The modern-day equivalent (assuming the regiments in question have guns) provides for 48 155 mm guns in two regiments, and two regiments of MLRS, potentially providing up to 54 MLRS in six batteries. The M270 as a platform is much the same as it was in 1991, albeit with some upgrades to improve their blast protection.

The primary difference is in the ammunition. The UK previously deployed with the US DPICM cluster munitions mentioned at the opening of this article, but decided to abandon their use after

A British Archer SPH, seen here deployed on Exercise Hedgehog in Estonia. Archer is the most technologically advanced howitzer to have ever served in the Royal Artillery. [Crown copyright 2025/AS1 Leah Jones]

M270 MLRS vehicles at Camp Bastion, Afghanistan, in 2008. The UK's deployments during the War on Terror led to a move away from area effects, turning the MLRS into a long-range precision strike system. [Crown Copyright 2008/Cpl Ian Houlding]

agreeing to dispose of the majority of its cluster munitions at the 22/23 February 2007 Oslo Conference on Cluster munitions, and later signing the Convention on Cluster Munitions in Dublin on 30 May 2008. Consequently, the UK's forces are now reliant on the more accurate M31 GMLRS rocket, which is guided, but carries a 90 kg unitary warhead. Providing that it hits the target, it will have an effect. However, the rocket is known for 'precisely missing', whereby an error in the entered data can lead to a strike that technically follows the right pattern, but is in the wrong place. In contrast, the M270s deployed in 1991 could deliver area effects, with thousands of submunitions delivered over a wide area in a matter of minutes. The effect of these munitions has been hotly debated since 1991, but their impact in Ukraine – especially against deployed batteries of air defence systems and missile launchers – indicates that they are still an effective weapon. Without those M26 rockets, and even with double the number of launchers, the DRS-BCT would struggle to provide the level of fire support and suppression that the DAG did.

There is scope for some form of cluster munition, and that is in the procurement of the BAE Systems BONUS 155 mm artillery round, which deploys two sensor-fuzed munitions with explosively-formed penetrator (EFP) warheads. These rounds are reportedly effective in Ukraine and are expected to be procured to enable the 14 Archers in service with the 19th Regiment RA. Presumably they will equip the RCH155 once it comes into service, too. At present, the Royal Artillery has no armoured howitzers to compare with the M109s of the DAG, but it is expected to receive the RCH155, an artillery system based on the Boxer 8×8 wheeled armoured vehicle "in this decade". The RCH155 will replace the AS90s donated to Ukraine and as a platform it appears to be a mixed blessing. On the one hand, the L52 155 mm gun offers greater range than the AS90, but on the other, it is based on a wheeled platform that is unlikely to match the AS90 in terms of off-road mobility. It also has a crew of two, which has raised concerns around the stress placed upon an artillery crew during

A Scimitar with the Household Cavalry in 2016 on exercise; it is set to be replaced by the Ajax reconnaissance vehicle, three times the size of the upgraded Scimitar Mk2. [Crown Copyright 2016/Cpl Tim Jones]

prolonged periods of combat. For comparison, the M109s deployed in Operation Granby had crews of 11.

The small and light Scimitar reconnaissance vehicles will give way to Ajax. At 38 tonnes, the Ajax is more than three times heavier than the upgraded Scimitar Mk 2, and five times heavier than the Scimitars that fought in 1991. However, its sights and potential for networked connectivity (assuming they can be equipped with high-capacity networked digital radios, which currently seems unlikely) offer significant advantages in that targets *could* be automatically logged and registered in FC-BISA, the Royal Artillery's fire control system. Ajax also offers much better protection and firepower than the Scimitar, which, given its size, it will presumably need if detected on reconnaissance missions.

One element of the equipment that will really differentiate the DRS-BCT from the DAG is the unmanned aerial vehicles (UAVs) that it should gain access to. At present, there are two key projects; Project TIQUILA, which is procuring tactical drones used by 32nd Regiment RA, and Project CORVUS, which will replace Watchkeeper in the Land Tactical Deep Find (locating hostile units at relevant battlefield depths) role for the 47th Regiment RA. These assets will, in theory, significantly extend the reconnaissance reach of the DRS-BCT, potentially out to 150 km, depending on the efficacy of the enemy's air defences. This would be critical to properly enabling the artillery's deep battle in any meaningful sense beyond the extension of the close battle, as described by Lt Col Wilks in his 1991 review.

One last thing

Overall, it is probably reasonable to say that the old wine of Operation Granby has been given a new bottle, although that bottle should be significantly better-enabled. One glaring difference however, is in how the DRS-BCT is likely to be resourced. The British Army is newly focused on attritable strike systems to generate its combat power, but artillery ammunition remains an important component of a combined arms operation, suppressing and destroying enemy positions and formations, much as it did in 1991. This requires considerable magazine depth, which in turn requires very deep pockets. Precision fires, as embodied by the M31, are valuable tools, but they are not a replacement for massed artillery bombardments when it comes to minimising casualties. This is somewhat evident in Ukraine; drones, which are relatively precise, are able to locate and destroy individual vehicles and positions, but are not able to suppress an enemy throughout their depth so that a breakthrough can be successful. Perhaps this should be one of the cardinal takeaways from Operation Granby for the British Army: It should equip itself to fight a war with mass artillery fires, mass expenditure of ammunition, and mass use of loitering munitions. Ultimately, a war with Russia would come down to the ability to whittle down the first and second echelons of Russian troops, allowing the UK's two armoured brigades to fight them in a much-depleted form, before squaring up to the third echelon (if it exists) in what is hoped to be an uneven fight. That will not happen without using a lot of ammunition, regardless of how smart and complex the concept of employment around the DRS-BCT might be.

Strategic shift: UK CSG deployment demonstrates switch in UK strategic focus

Dr Lee Willett

The UK's deployment of its carrier strike group (CSG) on the CSG25 deployment has demonstrated a subtle but significant shift in UK geostrategic emphasis. It has also underscored once more the wider utility of the UK's carrier strike capability in supporting UK geostrategic aims, however they may shift.

Arguments aimed at the UK's carrier programme throughout its development included that the capability was not needed, was too expensive, and was too lacking in outputs.

Yet the CSG25 deployment – which also incorporates the UK's carrier strike capability being certified as fully operational – has so far demonstrated significant effect on a global scale, from the Eastern Mediterranean to waters off north-eastern Australia. Moreover, the importance of investing in two carriers is being underscored. While HMS *Prince of Wales* is leading CSG25 around the world, HMS *Queen Elizabeth* is heading for dry dock for planned refit. If the UK operated only one carrier, any time period that carrier was in dry dock would see the UK having no carrier at sea – effectively having no carrier at all.

▲ The UK aircraft carrier HMS *Prince of Wales* (foreground) sails alongside the US carrier USS *George Washington* during Australia's 'Talisman Sabre' exercise in July 2025. The two carrier strike groups (CSGs), plus Australian Navy assets, conducted CSG integration activities. [Crown copyright 2025]

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With the Russo-Ukrainian War continuing today in the Euro-Atlantic theatre, with conflict ebbing and flowing across the Middle East, and with the UK needing to demonstrate interest and influence across the Indo-Pacific at a time of security concerns there, the continuous availability of a carrier gives the UK government a degree of choice regarding which of these strategically important commitments the UK will support. Indeed, across the length of the CSG25 deployment, the CSG may well support most or all of these commitments, and several others.

For CSG25, the HMS *Prince of Wales* CSG has included the UK Royal Navy (RN) Type 45 air-defence destroyer HMS *Dauntless* and Type 23 anti-submarine warfare (ASW) frigate HMS *Richmond*; the Royal Canadian Navy *Halifax* class frigate HMCS *Ville de Quebec*, Royal Norwegian Navy *Fridtjof Nansen* class frigate HNoMS *Roald Amundsen*, and Spanish Navy *Alvaro de Bazan* class frigate ESPS *Méndez Núñez*, with these ships all being multirole platforms; an RN *Astute* class nuclear-powered attack submarine (SSN); and three support ships (two UK, and one Norwegian).

The *Prince of Wales's* crewed airwing includes 24 F-35B Lightning II fighter aircraft, and 12 rotary-wing airframes (a mix of Wildcat and Merlin HC4 and HM2 helicopters, some of the latter bringing the Crowsnest airborne surveillance and control capability). Additional helicopters are also present across the CSG. A number of unmanned aerial vehicles (UAVs) are also being embarked for trials.

Sailors on watch aboard the Royal Navy (RN) Type 45 destroyer HMS *Dauntless* surveil the Red Sea as the CSG transits the region. The Red Sea passage helped reinforce the CSG's readiness for conducting high-end operations. [Crown copyright 2025]

Strategic focus

Like its predecessor global deployment CSG21, in which the HMS *Queen Elizabeth* CSG sailed from the North Atlantic to the North Pacific and back between May and December 2021, CSG25 is also focusing on the Indo-Pacific region. However, reflecting the strategic implications for international security of the Russo-Ukrainian war, CSG25 is balancing this Indo-Pacific focus with reinforcing UK commitment to NATO. It is also evident that the Indo-Pacific phase will focus as much on building partnerships for security as for trade.

CSG21 was heralded as a strategic-level 'soft power' opportunity for the UK to build partnerships with Indo-Pacific regional powers to boost UK trade and influence. However, the outbreak of the Russo-Ukrainian war in 2022 and the eruption of conflict across the Middle East since October 2023 have changed things on a global scale, and have prompted CSG25 to bring greater focus on building Indo-Pacific partnerships with a 'hard power' focus on security. It is also balancing this 'hard power' focus equally between the Euro-Atlantic and Indo-Pacific. For example, the CSG's first major activities took place in the Eastern Mediterranean in early May 2025, where it participated in both the US Navy (USN)/NATO-led 'Neptune Strike' regional enhanced vigilance activity and the Italian Navy (ITN)-led 'Med Strike' carrier integration exercise also in May. By mid-July, the CSG was off the coast of Australia, working with Australian and US forces on Australia's major 'Talisman Sabre' force integration exercise.

En route between the two, the CSG sailed through the Red Sea, cooperating with USN assets as it navigated safely both the narrow choke point of the Bal-al-Mandeb straits and the Iran-backed, Yemen-based Ansar Allah (Houthi) rebel attacks on commercial and naval shipping that are continuing along the Red Sea/Bab-al-Mandeb/Gulf of Aden corridor.

"Working closely with partners from across the globe, Operation 'Highmast' [the CSG25 deployment] will demonstrate credible deterrence and our support to NATO and the rules-

based international order," Commodore James Blackmore, the RN's Commander UK Strike Group (COMUKCSG) said, in an RN statement released when the CSG sailed in April. "This will reaffirm that the UK is secure at home and strong abroad, and will reinforce the UK's commitment to the Indo-Pacific."

The statement noted that Op 'Highmast' has three aims: to declare the ***Queen Elizabeth*** class carriers, with all their constituent parts, fully operational; to reaffirm UK commitment to NATO; and to maintain international security and prosperity. Generating on operations during CSG25 an airwing including 24 fixed-wing aircraft is a key last step in certifying the UK's carrier capability as fully operational.

In the Royal United Services Institute's (RUSI's) annual Gallipoli memorial lecture on 24 June 2025, Vice Admiral Andrew Burns – the RN's Fleet Commander – underlined the mix of hard and soft power at the core of the CSG25 deployment.

"In support of the UK's national strategy, the RN will continue to play its part in the application of defence levers where it can have greatest effect … supported by global presence and periodic deployments beyond the Euro-Atlantic region." In terms of greatest effects, Vice Adm Burns highlighted defence exports, as well as defence capability partnerships like the Australia/UK/US AUKUS strategic accord designed to deliver nuclear-powered submarines and other high-end technologies for the three partners.

"Naval power serves as a geoeconomic lever through power projection and diplomacy," Vice Adm Burns continued, "The multinational task group at sea today, being led by ***Prince of Wales***, is doing just that, enabling the UK to project influence globally, reassuring allies, and deterring adversaries." "The passage of the task group through the southern Red Sea signals our determination to uphold the international system upon which our economic prosperity depends," Vice Adm Burns added, "The naval diplomacy facilitated by port visits that will stimulate engagement, and the multinational exercises with allies in the Indo-Pacific, not only establish trust and interoperability but also strengthen economic relationships and our regional influence."

Indeed, the CSG's passage through the Red Sea – along with the anti-air warfare operations conducted in that region by the Type 45 destroyer HMS ***Diamond***, plus ***Richmond*** and her Type 23 sister ship HMS ***Lancaster*** in late 2023 and early 2024, when the Red Sea crisis first erupted – demonstrated the RN's readiness to operate effectively in more testing environments. Availability of enough ships is the first step in building presence for deterrence: being ready for the more challenging tasks including warfighting is the next.

Compare and contrast

This higher-end operational focus is perhaps the small, subtle, but significant shift between the two CSG deployments.

"In many ways, the strategic intent behind the CSG21 and CSG25 deployments is similar. They are about underscoring the UK's stake in regional stability in the Indo-Pacific, including economically; its ambition to play a role in upholding international norms globally; and [its intent] to support allies and partners in the region," Nick Childs, Senior Research Fellow for Naval Forces and Maritime Security at the International Institute for Strategic Studies (IISS), told ESD in an interview on 14 July 2025. Childs noted, "What has changed is the strategic context, which has got darker in both the Euro-Atlantic and the Indo-Pacific regions, with heightened concern about security in Europe but also increased fear of regional confrontation in the Indo-Pacific."

"There was much fanfare for CSG21 because it was a double roll-out both of the re-generated carrier capability and its

A core part of CSG25 is certifying full operational capability for the UK's CSG, with the embarkation of up to 24 F-35B aircraft on board for an operational deployment. [Crown copyright 2025]

operational debut, plus the initiation of the 'Global Britain' and 'Indo-Pacific tilt' agenda of the then-Conservative government," said Childs, noting, "Since then, the UK's defence ambitions in the Indo-Pacific have been tempered and reoriented somewhat. Most particularly, the new Labour government is espousing a 'NATO-first but not NATO-only' defence policy."

"So, the messaging behind CSG25 is more about the connections between the security concerns in both Europe and the Pacific and how the operational lessons and training from the deployment will benefit the UK's contribution to NATO," Childs explained. As is being demonstrated on CSG25, carriers are playing a crucial role in burden sharing between NATO allies across both the Euro-Atlantic and Indo-Pacific theatres. Like the UK and France have done, Italy has deployed its aircraft carrier (ITS *Cavour*) to the Indo-Pacific region previously. "[CSG25 is occurring] much more in the context of a coordinated approach including other European deployments of carriers by France and Italy to the Indo-Pacific region, but also coordinating what's left in the NATO area when one of these deployments takes place," said Childs. "There is also more of a focus on the role the UK can play as a convening power with a carrier capability as the centrepiece of a more multinational and interoperable task group," Childs continued.

Moreover, CSG25 is taking place in the context of defence deployments being part of a broader approach by the UK government towards Indo-Pacific security, including more emphasis on defence industrial collaboration through the constructs such as AUKUS and the Global Combat Air Programme (GCAP) next-generation fighter aircraft project – established between the UK, Italy, and Japan – plus greater emphasis on diplomacy, Childs added.

"A key outstanding question is the extent to which such deployments are chiefly all about defence diplomacy and deterrence, or whether they carry the implication they could translate into real defence commitment if the 'balloon goes up' in the Indo-Pacific somewhere, for example over Taiwan," said Childs. "That is less clear, not least because there is growing concern that such an eventually might occur in the context of multiple regional crises including in Europe, where the UK would necessarily put its focus and with forces that are even more thinly stretched now than they were a few years ago", Childs cautioned.

"There is also the likelihood that, even if a UK government decided to commit resources to any confrontation scenario in the Indo-Pacific, it would be less likely perhaps to be a carrier deployment, and more likely to be through niche capabilities like submarine deployments, strategic intelligence, surveillance, and reconnaissance (ISR), or special forces," Childs continued, noting, "Nevertheless, periodic deployments like the CSGs help facilitate those options too, through practising interoperability with regional allies and partners, and could be justified on those grounds as well."

Strategic defence

The shift in strategic emphasis from Indo-Pacific to Euro-Atlantic and from 'soft power' to 'hard power' for the RN and its CSG was reflected in the UK's latest Strategic Defence Review (SDR), published in June 2025.

Across these two theatres, the SDR highlighted the need for the RN, and the UK more widely, to strengthen further-still its relations with key strategic partners, including (amongst others) Italy and Norway in the Euro-Atlantic, along with Australia and Japan in the Indo-Pacific. In the case of Italy, it highlighted not only GCAP, but also the deepening interoperability between the two countries' CGSs. The latter includes commonality in F-35B capability.

One of the core roles set out for the UK armed forces in the SDR is to deliver deterrence and defence in the Euro-Atlantic

An Italian Navy F-35B fighter aircraft prepares for launch from HMS *Prince of Wales* during Exercise 'Med Strike' in May 2025. The carrier integration exercise was designed to demonstrate support for NATO interests in the Mediterranean Sea. [Crown copyright 2025]

CSG assets including the Spanish Navy F-100 frigate ESPS *Méndez Núñez* (left) and the RN Type 23 frigate HMS *Richmond* work together in the Mediterranean. The CSG25 deployment is designed to demonstrate the UK's reinforced commitment to NATO needs. [Crown copyright 2025]

theatre, including in support of NATO. The SDR stressed the role of advanced, fifth-generation combat aircraft within carrier airwings and wider carrier strike capability in supporting NATO regional plans.

Italy's and the UK's ability to conduct integrated F-35B operations across their respective CSGs was demonstrated in 'Med Strike'. As regards Norway, amongst other interactions in the Euro-Atlantic theatre the two partners are operating together on NATO's 'Baltic Sentry' maritime presence, surveillance, and deterrence activity designed to secure regional critical undersea infrastructure (CUI). Norway of course has two ships deployed on CSG25.

In the Indo-Pacific context, the UK and Australia are building a new submarine together under AUKUS. Japan is a GCAP partner, and CSG25 may see cooperative activities at sea involving UK and Japanese F-35Bs.

In each of these four contexts, the CSG25 deployment is demonstrating increased cooperation in terms of delivering capability to generate high-end 'hard power' designed to build warfighting capacity and deterrence against state-based threats.

Illustrating also the SDR's requirement for the UK's CSG airwing to evolve into a hybrid construct mixing crewed and uncrewed airframes plus conventional strike missile capabilities, CSG25 will see the RN continue testing UAV concepts and capabilities: several UAVs are embarked aboard Prince of Wales.

Multinational by design

To date, 'Neptune Strike' and 'Med Strike' in the Euro-Atlantic and 'Talisman Sabre' in the Indo-Pacific have bookended CSG25, with each exercise focused on building high-end operational capability.

In 'Neptune Strike', the CSG operated under NATO command in an enhanced vigilance activity designed to build deterrence, including against threats to freedom of navigation.

In 'Med Strike', the CSG teamed up with the ITN's CSG – centred around Cavour – for a week-long activity designed to integrate all elements of a CSG capability, conduct offensive carrier operations, and train together in ASW tasks. Alongside the already-multinational *Prince of Wales* CSG France, Portugal, Türkiye, Spain, and the United States participated.

"Working at the heart of a powerful NATO force sends a strong message and shows clearly the phenomenal capabilities that not only the UK, but the alliance as a whole, possesses," Cdre Blackmore said, in an RN statement.

Following ports calls in Singapore and Jakarta, Indonesia, in mid-July 2025 the CSG arrived off Australia for two weeks of exercising on 'Talisman Sabre', as perhaps the centrepiece of CSG25. Underlining too the centrality of CSG integration across the exercises undertaken during CSG25, one of the first serials of 'Talisman Sabre' saw the *Prince of Wales* CSG integrate with the USN's USS George Washington CSG and the Royal Australian Navy's Hobart class guided-missile destroyer HMAS Sydney for dual carrier operations in the Timor Sea. In a statement, the RN referred to this activity as "a powerful demonstration of naval power," demonstrating "commitment to the collective security of the Indo-Asia-Pacific region".

Overall, these exercises reflect a fundamental principle of the UK CSG's operational construct – that it is international by design, integrating international assets into the group and conducting operations in support of international interests. The CSG25 deployment is also demonstrating that such an international construct can deliver a range of effects in the strategic theatre of the UK's choosing and requirement.

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Hybrid navies: Integrating uncrewed capability into carrier strike

Dr Lee Willett

A carrier strike group (CSG) is by definition a multi-domain construct. Its airwing seeks to generate effect at sea and ashore while securing the aircraft carrier itself. The carrier is also protected by surface ships in the air and surface domains, and by submarines in the underwater and surface environments. These CSG assets can also generate offensive effects both at sea and ashore. A CSG provides significant mass for deterrence and defence. However, in contemporary naval operations, even something as large as a CSG needs more mass. Here, NATO navies are assessing options for integrating maritime uncrewed systems (MUS) like uncrewed surface vessels (USVs) in CSG capabilities and operations to add more mass, particularly (but not only) for lower-end tasking to allow the CSG's crewed assets to focus on core high-end warfighting requirements.

CSGs are complex beasts, integrating at an operational level the highest-end conventional warfighting capabilities both onboard the carriers themselves and across the strike group. The capabilities a CSG brings and the effects it generates mean that, at a politico-strategic level, it is one of the most prized assets for defence and diplomacy a country can possess. This in turn, however, means very few countries possess such a capability. Amongst NATO's navies for example – with the exception of the US Navy (USN) – the Alliance's carrier-operating navies possess these ships in only small numbers (although even the USN's 10-carrier fleet could be seen as a relatively limited number compared to its commitments). In today's returning era of state-based naval power and competition at sea, CSGs are continuing to retain a prominent defence and diplomacy role. However, to expand their outputs while allowing their traditional carrier strike capabilities to be focused ever-more sharply on high-end deterrence and defence requirements, NATO's carrier navies are looking to integrate MUS into their CSGs to meet certain operational requirements.

▲ The US Navy (USN) carrier USS *John C Stennis* (left), the French Navy carrier FS *Charles de Gaulle*, and elements of their strike groups are pictured sailing together in US Fifth Fleet's area of operations. The US, French, and UK navies are all developing 'hybrid' crewed/uncrewed mixes for their carrier airwing capability. [US Navy]

AUTHOR

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MUS capabilities can be used by a CSG to support a range of operational needs. Unmanned aerial vehicles (UAVs) demonstrate this range of options. They can be employed to conduct carrier onboard delivery tasks at short distance around the CSG or at longer distance from shore. They can provide sustained surveillance, either close in to the CSG or as its outer ring acting as a long-range picket. Working with the airwing itself, they can be used for air-to-air refuelling support, or as 'loyal wingmen' alongside crewed fast jets, adding to the sensing and strike capability of the individual aircraft.

Uncrewed surface vessels (USVs) – especially larger models – can also provide forward-deployed picketing capability, running out ahead of the CSG to add advanced sensing capacity as well as the ability to conduct strike operations at sea and ashore.

Uncrewed underwater vehicles (UUVs) are perhaps the one capability that is not as straightforward to integrate into a CSG to provide direct support, primarily because a CSG is a constantly moving beast and communications across the underwater domain continue to be challenging. However, where UUVs potentially can play a core role is in providing indirect support, for example if deployed from a nuclear-powered attack submarine (SSN) operating as part of the CSG, or being deployed in numbers well ahead of a CSG to provide sensing barriers or sanitisation of an area of potential strike operations or of any maritime choke points that exist in a planned transit route.

Across the scope of MUS developments, NATO's carrier-operating navies are conducting trials to test capabilities and concepts of operation (CONOPS) for these systems to see how they can support and enhance CSG activities.

Naval plan

Of NATO's carrier navies, the USN has been experimenting with MUS for the longest time period. However, as the world's most powerful navy, and with a spine of crewed frontline platforms larger than any other navy apart from China's, the USN may have different requirements for uncrewed capabilities and may see MUS as shaping its future in different ways to other navies.

The USN has completed integration of a torpedo tube launch-and-recovery UUV capability for its *Virginia* class SSNs. The capability is currently deployed on board USS *Delaware* (pictured). [US Navy]

The USN's initial focus fell on using UAVs in air support activities, such as on-station tanking, before it explored air-based concepts that included developing strike capabilities for UAVs (under unmanned combat air vehicle (UCAV), programmes). On the surface, large USVs will offer the navy options to deploy these platforms within CSGs but pushed forward to their outer defensive ring to provide offensive surveillance and strike in order to clear transit routes or conduct strikes ashore to reduce threats.

Despite the communications issues in the underwater domain, the USN does have an active UUV programme for its SSN force. After successfully developing a torpedo-tube launch-and-recovery (TTL&R) concept and system, the capability – in the form of an HII Yellow Moray (REMUS 600) UUV – is now operational onboard the Virginia-class SSN USS ***Delaware***. The boat has forward-deployed to the European theatre, taking this capability with it. Across its SSN fleet, the navy intends to have this capability permanently available on at least one boat.

With the USN having standing requirements to improve surge capacity and lethality at scale, as well as decision advantage, uncrewed platforms can support such requirements and add operational and strategic value for the navy. A lesson it has learned from Ukrainian operations in the Black Sea in the Russo-Ukrainian war, is how off-the-shelf robotic and autonomous systems offer a rapid and proven solution for building sea denial capability.

Certainly, the USN's most recent 'Navigation Plan' ('Nav Plan'), published in late 2024 and focused on building USN warfighting capability – to provide readiness to enhance the navy's long-term capability and operational output, but also to prepare for the possibility of war with China by 2027 – underlined clear development lines for USN MUS capability. Under what is termed 'Project 33' – a concept designed "[to] get more ready players on the field by 2027" – the USN is aiming, as one of seven projects, to scale robotic and autonomous systems integration with more platforms at greater speed. Such capabilities will be at the core of the navy's 'future hybrid fleet', augmenting multi-mission conventional forces through expanding reach, resilience, and lethality via manned/unmanned teaming (M/UMT) concepts.

The 'Nav Plan' noted that: "*By 2027, we will integrate proven robotic and autonomous systems for routine use by the commanders who will employ them. We will integrate mature capabilities into all deploying carrier and expeditionary strike group certifications to refine our approach to command and control of [M/UMT] at sea.*" In this context, the 'Nav Plan' added that the next phase in innovating MUS capability will be to prioritise key operational problems across critical mission areas including surveillance, fires, networking, logistics, and deception.

Enhanced capability

Since 2021, the UK Royal Navy (RN) has been conducting a series of trials from its ***Queen Elizabeth*** class carriers using UAVs, not only to add operational capability to the ships and their carrier strike groups (CSGs) but to keep the CSG concept at the cutting edge of technology development.

This development work is continuing with the RN's latest CSG activity, the CSG25 deployment to the Indo-Pacific theatre being delivered on Operation 'Highmast'. The deployment is demonstrating how autonomous capabilities can be blended into a conventional carrier airwing to meet different requirements, including adding mass.

CSG25 also reflects the RN's pathway towards deploying and integrating MUS into its current and future force structures: this pathway leads towards what was set out in the UK's latest Strategic Defence Review (SDR), published in June 2025, which directed the RN along a heading of developing a 'hybrid navy'. This means developing crewed and uncrewed capabilities in tandem. The CSG25 deployment reflects just this, with UAVs being operated onboard, while the deployment of 24 F-35B Lightning II fighter aircraft takes the UK's carrier capability past its full operational capability development milestone. Personnel from 700X Naval Air Squadron – the RN's MUS centre of expertise – are embarked on the carrier HMS *Prince of Wales* for CSG25 to trial, for example, the Malloy Aeronautics T150 UAV, to transport equipment.

ESD also understands that the RN plans to conduct USV trials with the CSG. The SDR also headlined both the RN's direction in developing MUS capability, including for CSGs, and the impact this could have both for the UK and NATO. "We will provide leadership in NATO, by transforming our aircraft carriers to become the first European hybrid airwings – with fast jets, long-range weapons, and drones," according to the SDR.

A Malloy Aeronautics T150 UAV is pictured operating from the flight deck of the Royal Navy (RN) aircraft carrier HMS *Prince of Wales*. During its CSG25 deployment, the RN has been testing UAV capabilities. [Crown copyright 2025]

"The RN must continue to move towards a more powerful but cheaper and simpler fleet, developing a 'high-low' mix of equipment and weapons that exploits autonomy and digital integration," the SDR continued. *"Carrier strike is already at the cutting edge of NATO capability, but much more rapid progress is needed in its evolution into 'hybrid' carrier airwings, whereby crewed combat aircraft (F-35Bs) are complemented by autonomous collaborative platforms in the air, and expendable, single-use drones."*

Such a 'hybrid' carrier airwing will be central to how the RN transforms its skills, equipment, and ways of operating to be part of an integrated force in the maritime domain, the SDR noted. Underlining the integrated, joint nature of any carrier airwing and the role of MUS therein, the review added that the UK Royal Air Force (RAF) must develop autonomous collaborative platforms that can operate with fourth-, fifth-, and future-generation aircraft, and from UK carrier decks.

NATO's carrier navies are developing concepts for conducting integrated operations between crewed and uncrewed aviation, as manned/unmanned teaming. [Crown copyright 2025]

Broadly, the RN's plans for developing MUS are based around progressing as fast as possible in generating MUS capability and maintaining flexibility to adjust direction without becoming set on a single path, while ensuring that key tasks that need crews remain crewed – such as high-end anti-submarine warfare (ASW), which still requires an SSN – all aided by overcoming and even lowering barriers to system integration. Delivering a hybrid navy will, after all, increase integration requirements and challenges.

ASW is an early focus area for the RN in developing and integrating uncrewed capability with a view to developing intelligence, surveillance, and reconnaissance (ISR) mass and presence. Under 'Project Cabot', a two-phased approach is underway, developing: 'Atlantic Net' around a contractor-owned, contractor-operated, naval oversight (COCONO) model to bringing commercial UUVs into operations to provide a networked sensing 'net' in the North Atlantic; and then 'Atlantic Bastion', with the RN transitioning to a navy-owned and -operated MUS fleet and with a particular focus on UUVs and USVs to provide the persistent mass and presence, integrated with crewed platforms.

For the UUV capability, one key area of development is the Navy's Excalibur extra-large UUV (XLUUV) operational demonstrator. Known originally as 'Project Cetus' and developed under the RN's ASW Spearhead project, the XLUUV was first launched in February 2025. The RN is also interested in TTL&R UUVs.

As regards USVs, while the RN is still in the early stages of understanding how best to operate them, it is focused on developing greater range, endurance, and levels of concurrency for these vehicles, and is looking at concepts to enable them to be operated in twos or threes, carrying different payloads and moving data around between them.

Alongside advancing 'Atlantic Bastion', a key priority for the RN in the next four years is casting the 'Atlantic Net' out, including getting technology demonstrators into the water within that timeframe, or much sooner. 'Atlantic Net' is seen as a key tool for the RN to help learn what it needs in terms of MUS capability. One element of this learning process is to understand the MUS role in the phase that exists between peacetime and wartime, including in relation to 'grey zone', hybrid threats. In the hybrid context, with NATO activities like 'Baltic Sentry' and projects like Task Force X Baltic being designed to develop surveillance, presence, and deterrence capability to counter threats to critical underwater infrastructure, USVs in particular can provide presence and rapid response outputs.

With the RN currently starting out on a 'crawl, walk, run' process for delivering MUS capability, such projects are designed to help the RN develop its understanding of what it needs and what it wants to do, including retaining the flexibility to adjust and adapt as needed. The navy is aware too that platforms procured to meet a particular requirement, role, and task are often found in due course to be suitable for others.

Alongside developing platforms, the RN is focused on the command-and-control (C2) and integration software and architecture that will link these platforms together, as well as harnessing and disseminating the data they gather. Of course, the value in MUS capability is their data output, as opposed to the platforms themselves.

Future carrier

For the French Navy, its focus on generating uncrewed capabilities to operate alongside its carrier capability is falling on development plans for its next-generation carrier, which is being delivered under the Porte-Avions de Nouvelle génération (PA-Ng) programme. Delivery and commissioning of the future carrier are scheduled for 2027 and 2028, respectively.

Like the RN and USN, France's new carrier is being designed and developed to carry a 'hybrid' airwing of crewed and uncrewed assets, with the ship's design tailored to embark a crewed/uncrewed mix of 30 aircraft (with the uncrewed systems being both UAVs and UCAVs). The ship's catapult launching concepts will be able to accommodate the different launching requirements for both crewed and uncrewed air vehicles. UCAV capability is anticipated to be available from 2040.

Like the USN, the Marine Nationale sees UAVs as providing both support and combat functions for a carrier. Janes reported from the Paris Air Show 2025 that the French armed forces ministry displayed a UAV designed to operate as a 'loyal wingman'.

'Loyal wingman' concepts often include the uncrewed aircraft supporting the crewed aircraft, for example, in the suppression/destruction of enemy air defence (SEAD/DEAD) roles, thus prospectively allowing the crewed aircraft to approach its targets ashore with reduced risk. For the French Navy, its amphibious vessels will also continue to be used as 'drone ships'.

With the RN's focus on developing a 'hybrid' airwing, the navy's carriers are central to its transformation into a 'hybrid' navy, integrating crewed and uncrewed systems in all domains. [Crown copyright 2025]

Serve to lead

Dr Trevor Nash

Sandhurst is a globally known brand that is charged with training officers for service in the British Army. This reputation has resulted in many of the world's armed forces sending cadets to train alongside their British colleagues. The training on offer at Sandhurst does not stand still as it must reflect the British Army's experiences, traditions and current tactics, techniques and procedures (TTPs). This process is best summed up by the Sandhurst motto, 'Serve to Lead'.

Officer Cadets march past the Old College building during their commissioning ceremony, known as Sovereign's Parade. [Crown Copyright 2013]

The Royal Military Academy Sandhurst (RMAS) is responsible for training all officers for service in the British Army as well as a number of overseas students from allied and partner countries. There are three intakes each year, in January, May and September, and each course lasts for 44 weeks that are split over three terms. These terms are referred to as Junior, Intermediate and Senior. Although numbers vary per intake, the latest cohort comprises 194 officer cadets and provides a typical average indicator of numbers.

AUTHOR

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

History and tradition play a large part in the culture of the British Army and so it is worth briefly placing the development of RMAS into context. Despite only being created in 1947, RMAS can trace its history back to the Royal Academy, part of the Royal Arsenal in Woolwich that was created in 1716. That organisation started formally training artillery officers in 1741. It became the Royal Military Academy (RMA) in 1764 and moved to a new home adjacent to Woolwich ranges that was known as 'The Shop'. During that time, the RMA trained officer cadets for both the artillery and engineers. It is interesting to compare the syllabus at 'The Shop' during this period with the current didactic emphasis on STEM (Science, Technology, Engineering & Mathematics).

Subjects taught in the 18th century included mathematics, mechanics, physics, chemistry and technical drawing – STEM by any other name! While artillery and engineer cadets benefitted from this technical training, infantry and cavalry officers relied on commissions being bought and sold. According to the military historian Alan Shepperd, this "often produced twelve-year-old ensigns who…could become colonels at twenty." This situation was only ended in 1871 with the Cardwell Reforms that banned the purchase and sale of commissions.

Officer training for these infantry and cavalry 'gentlemen cadets' started in Great Marlow in Buckinghamshire in 1802 before moving to the newly-built Royal Military College (RMC) at Sandhurst in 1812. Located on the Berkshire-Surrey border, Sandhurst provided an ideal training site being adjacent to Barossa Common and at the time, the sparsely populated villages of Sandhurst, Blackwater, Bagshot and Yately.

Shepperd quotes the driving force and first Governor General of RMC, Maj Gen John Le Marchant as saying the reason for selecting the site at Sandhurst was dictated, "as to avoid a neighbourhood injurious to the morals of the cadets and which allow for military movements and the construction of military works without interruption."

So with the amalgamation of RMA and RMC in 1947, the following decades saw all Army Officer education and training based at RMAS with the transfer of the Mons Officer Training school for Short Service Commission Officers from Aldershot in 1972. In October 1981 the Woman's Royal Army Corps (WRAC) College, Camberley relocated to RMAS. After a period of transition, WRAC Course 6 became the first to be fully resident and trained at RMAS in September 1984. Since 1992, all those being commissioned into the Regular Army – regardless of age, educational background or military experience have undertaken the 44-week regular commissioning course.

Other courses delivered at RMAS include those for Army Reserve Officers who complete a modular eight-week course alongside regular Professionally Qualified Officers (doctors,

A platoon from CC252 on arrival at RMAS are given a tour of the establishment. [Sandhurst Trust]

Around 50% of those attending the two-day Briefing phase move on to the more demanding Main Board. On Main Board day one and following an introductory talk, potential officer cadets are subject to a battery of psychometric tests that are designed to assess cognitive capabilities and personality traits. Attendees also write a short, timed essay on current affairs and complete a Multi-Stage Fitness Test.

nurses, dentists, padres, lawyers and veterinary surgeons) with reservist Professionally Qualified Officers only being required to complete the last four weeks of the eight-week course.

Selection: AOSB

For individuals that want to become officers in the British Army, they need to meet a defined educational standard with A levels or ALIS (A-Level Information System) equivalent scores. If successful, the potential officer cadet will undergo an interview with a 'local recruiter' before attending the Army Officer Selection Board (AOSB) at Leighton House, Westbury in Wiltshire.

AOSB is divided into two phases; a two-day Briefing stage and a four-day 'Main Board' period. The former is really a chance for the Army to assess the individual and for the individual to prepare to move on to Main Board if they pass the Briefing phase. The selection team is looking to gauge the individual's development potential, understand a little about what role/regiment/corps the individual aspires to join, and glean an understanding of the individual's knowledge of current affairs and ability to 'easily meet the fitness standards required' that are demanded on Main Board.

As well as an interview, Briefing Day One also sees attendees undertake psychometric testing, take part in group discussions following a two-minute introduction by each candidate and conduct a planning exercise. On Day Two, candidates complete a range of physical tests and take part in both leader directed and leaderless tasks, where they are assessed by Westbury's staff.

In its advice to potential officer cadets, the AOSB says of the Briefing period, "you'll be taught how to prepare for your next visit, the Main Board, and assessed during physical and practical exercises.

"The AOSB Briefing is where you can start showing who you are: so be sure to arrive well-rested and well-prepared. However, don't be worried by the tests; they're designed to help us understand your development needs before you attend the Main Board. If your performance at Briefing shows that you're ready for the Main Board you'll be put forward for a place."

Sandhurst trains a significant number of overseas students. Pictured here is the first female officer from Nigeria to be commissioned through RMAS, Officer Cadet Princess Owowoh, being congratulated by Maj Gen Ochai, the Commandant of the Nigerian Defence Academy. [Crown Copyright 2024]

Day two includes group exercises in practical problem solving, an interview where the potential officer cadet is asked about his or her, "experiences and interests, and why [they] are applying to be an Army officer." The day culminates with a tutorial and a revision period in preparation for day three's planning exercise.

Day three is perhaps the most challenging aspect of the Main Board that the potential officer cadet has to face. Following a five-minute lecture with a Q&A session, the planning exercises follows and is described by the AOSB as, "a test of conceptual problem solving. This exercise involves a solo written assessment followed by a group discussion." The written submission includes a focused and map-based briefing on the planning exercise and a series of open answer sheet questions where the individual has to justify their plan. The day concludes with an Individual Task course where the aim is to compete as many solo tasks as possible and then compete in group command tasks where individuals are placed in command roles for different phases or tasks. The final half-day is spent carrying out a number of competitive group command tasks.

Since 2021, AOSB for Late Entry (LE) Officers that have been selected for commissioning after normally reaching the rank of Warrant Officer, have been held at RMAS. If successful, these candidates undertake a four-week short course at Sandhurst.

Syllabus

As highlighted earlier, RMAS trains a number of different students and this diversity can be seen in Commissioning Course 252 (CC 252) that started training in 2025. Of the 194 Officer

Cadets in Inkerman and Blenheim Companies, 16% are female whilst 69% are graduates. Twenty of the 194 are international cadets from 16 nations around the world.

The number of overseas cadets vary with CC 251, the previous intake, having 28 out of a total cadet cohort of 196. These 28 overseas cadets came from 17 countries including Armenia, Bosnia & Herzegovina, Cambodia, Cote d'Ivoire and Paraguay.

The British Army has had a long relationship with many nations around the world that have trained officers at Sandhurst. The major ones include Bahrain, Malaysia, Nigeria, and The United Arab Emirates to name but a few. In all, over 5,500 international students from 132 different countries have been trained at RMAS since 1947. Students are selected by their own armed forces and applications to attend are made to the UK Ministry of Defence through the respective nation's Defence Attaché.

RMAS is commanded by a Major General, the current incumbent being Maj Gen Nick Cowley OBE. In February 2025 the British Army adopted a new training structure that saw the Commandant RMAS also become the General officer commanding (GOC) Army Individual Training Command. This entails taking on responsibility for soldier Phase One training at Catterick, Harrogate, Pirbright and Winchester.

According to the Sandhurst Trust, "Brigadier Nick Wight-Boycott OBE will command the Academy day-to-day as one of a trio of Brigadiers reporting to the General, responsible for Sandhurst, Soldier Training and the newly created Leadership Development Group (LEDG)."

RMAS comprises two colleges: Old and New, with each being commanded by a Lt Col. Companies making up the colleges are commanded by Majors whilst platoons are commanded by Captains. Cadets spend their Junior Term in Old College, then their Intermediate and Senior Terms in New College. A third College, Victory College, is generally used to house Army Reserve Officers and Professionally Qualified Officers.

The current Common Commissioning Course, the backbone of the current syllabus, was first written in 1992 although it has been significantly modified over the years, most notably in 2015 through the adoption of Project McNamara that focused on command, leadership and management. Many of the changes generated by McNamara were driven by the British Army's experiences in Iraq and Afghanistan and drawn together in a guidance document, *RMAS Group Strategy to 2030* that was published in November 2023.

The latest modification to the syllabus occurred in 2024 with the adoption of Project ADAIR. "One change in the first two weeks is that the cadets now learn what it is to be an officer and the acceptable values and standards," the Sandhurst Trust stated in a newsletter. "This has always been part of the course but was traditionally covered much later. The new syllabus sets the standards right from the start while still emphasising basic skills and the transition from civilian to soldier."

More time is now spent in the field on military training, while the Adventure Training courses that officer cadets undertook during the breaks at the end of terms one and two have been scrapped. The aforementioned military field training takes place locally on Barossa, and in the Black Mountains and Sennybridge; both in Wales. These exercises start by covering section drills before moving on to platoon operations and then platoon operations in a company context. The final exercise, Dynamic Victory, is conducted in Germany on the US ranges at Grafenwöhr and Hohenfels that are managed by 7 US Army Training Command. This major exercise concentrates on stabilisation operations in a coalition environment.

Another significant exercise is Templar's Triumph that takes place at Longmoor Camp in Hampshire. This exercise focuses on peace stabilisation and COIN and features OPFOR, personnel playing civilians and press as well as including a representative from the International Committee of the Red Cross.

Officer Cadets undertake riot control drills on Exercise Templar's Triumph. [Crown Copyright 2021]

Officer cadets are given what are referred to as Command Appointments during these field training exercises to allow the RMAS Directing Staff to evaluate their skills, knowledge, planning capacity, their delivery of orders and leadership.

As discussed earlier, the adoption of Project ADAIR resulted in an increased emphasis on field training and some of the extra time required to conduct this has come from a reduction in foot drill. That said, the Sovereign's Parade that sees students complete their training prior to leaving as commissioned officers to conduct 'special to arms training', demands an extremely high standard of individual and collective drill.

Since the first parade in 1948, Sovereigns and their representatives have included HRH King George VI, HRH Queen Elizabeth II, King Abdullah of Jordan, HRH The Prince of Wales and in April 2023, King Charles III.

Although RMAS is steeped in tradition and British Army history, it embraces and welcomes new technology. An example is the Academy Drone Club that teaches officer cadets and staff the skills of flying, operating and maintaining UAVs. The club is part-funded by a charitable donation from the Sandhurst Trust who said, "with UAVs becoming increasingly prevalent on the battlefield we are helping to train the next generation of officers in this vital skill. As an indication of the emphasis of this new skill the Academy is hosting an international drone competition in September 2025."

Possible changes?

The most recent 2 June 2025 Strategic Defence Review (SDR) highlighted a number of changes, that if implemented, may result in future changes to the RMAS curriculum. Although early days, the SDR talks of reforming training to increase the number of commercial providers and a continuation of the Army's policy of a more fluid structure that brings together resources and units that are tailored for a particular operational requirement.

Another stated aim of the SDR was to "breakdown single-service silos" and this perhaps implies officer cadets being exposed to joint operations much earlier in their careers than hitherto. More widely, the potential for soldiers to take gap years or pursue "zig-zag careers" where the individual might spend time in industry before returning to service have all been mooted.

Whatever the future brings, RMAS is a world-leading centre for officer training and will cope well with change as its graduates are honed to 'Serve to Lead'.

Over the past 18 months, the focus on field training exercises has increased as drill and some academic periods have reduced. Shown here are officer cadets at Grafenwöhr, Germany, on Exercise Dynamic Victory. [US Army/Spc Adrian Greenwood]

Mapping the expansion of Russia's defence industry

Sam Cranny-Evans

Russia's defence industry has seen a dramatic transformation since the 2008 'New Look Reforms' and especially since Moscow's full-scale invasion of Ukraine in early 2022. Once dependent on foreign machine tools and regular state orders, it is now operating under wartime conditions, massively expanding its missile, drone, and ammunition production. This article looks at how Russia has rebuilt its industrial base to sustain prolonged high-intensity warfare, and what that means for NATO and its allies.

▲ Two-piece 152 mm ammunition for a 2A65 Msta-B towed howitzer arranged for firing in a 2019 Russian exercise. Russia's defence industry has had to expand significantly to even partly resource the country's use of this ammunition. [Russian MoD]

In the wake of the Cold War, Russia's defence industry contracted, as the country's arms exports fell. The Soviet Union had accounted for 40% of the world's conventional arms exports in the 1980s, and this had fallen to just 10% for Russia by 1996. At the same time, 65% of Russia's defence production was exported, with the federation's own forces decidedly deprioritised amidst the pressures of the country's economic collapse. Factories were left to decay and their staff released, no longer supported by state orders. The limited resources available to the Russian government were focused on those things that guaranteed security – the nuclear stockpile.

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The Russian armed forces appeared to follow the trajectory of the country's defence industry, struggling to deploy capable forces to Chechnya in 1994, and later succeeding in Georgia in 2008, but with many flaws that made clear the need for transformation. While the Russian forces were successful in Georgia, their organisation and readiness were sluggish. None of the services had integrated with each other, instead fighting their own battles simultaneously. Reconnaissance, communications, and airpower had all proven less effective than imagined and it was clear that change was needed. The 'New Look Reforms' were initiated in October 2008, just two months after the war in Georgia had ended. They set out to revamp Russia's equipment and restructure its forces, improving real-time reconnaissance and modernising the Soviet-era equipment to meet the conditions that dominated modern warfare.

In essence, the Russian forces were primarily expected to be capable of dealing with disruption at Russia's borders and in the former Soviet Union. It was expected that brigade-sized formations would be sufficient for this task, especially if they could carry most of the required equipment. This led to the first boost in investment for the Russian defence industry for domestic orders since the early 1990s. Some growth in export had helped stabilise the Russian defence industry's spiral, but was not enough of a demand to drive expansion. By 2008, the country exported USD 8 billion worth of conventional weapons, around four times the exports from 1996 and 23% of the global arms exports, placing Russia second behind the US.

The year 2008 is noteworthy for another reason beyond the start of the New Look Reforms, and that is because it was essentially the last year of war for the Russian Federation until 2014. Previously, the country's armed forces had been involved in at least one conflict every year since 1992, and the conclusion of counter-insurgency operations in Chechnya in March 2009 would bring that spell to an end. In order, Russian forces had fought in:

- 1991 to 1993: Georgian Civil War
- 1991 to 1992: South Ossetian War (creating the conditions for the 2008 war)
- 1992 to 1993: War in Abkhazia
- 1992: Transnistrian War
- 1992 to 1997: Tajikistani Civil War
- 1994 to 1996: First Chechen War
- 1996 onwards: Peacekeeping deployment in Serbia.
- 1999: Peacekeeping deployment in Kosovo
- 1999: War in Dagestan (which led to the Second Chechen War)
- 1999 to 2009: Second Chechen War
- 2008: Russo-Georgian War

A Chechen fighter stands near the government palace building during a short lull in fighting in Grozny, Chechnya, 1995. Russian forces deployed to Chechnya and fought that war mostly from existing stocks. [Mikhail Evstafiev, via Wikimedia Commons; CC BY-SA 3.0]

So, 2009 would bring relative calm and time to focus on modernisation. Most importantly for the Russian defence industry, it brought funding and the return of state orders for equipment. However, there were not enough funds to warrant any dramatic expansion and, to some extent, you could argue expansion was not needed. Russian forces had been involved in at least eight conflicts and had eventually muddled their way through them. There had been some painful setbacks and there was definitely a need for modernisation – especially where deterring NATO was concerned – but the timelines for modernisation under the New Look Reforms and the 2011–2020 State Armaments Programme were eminently achievable within the existing industrial footprint. Modernisation was essential, with the Russian government estimating in 2013 that the defence industry would need at least USD 3 billion worth of computer numerical control (CNC) machine tools every year until 2017.

The Russian defence industry went to Europe, the US, and Japan to meet its modernisation needs, buying between 35 and 60% of its CNC machine tools from those states between 2009 and 2017. Many plants were able to modernise their production methodologies, such as the Serov Mechanical Plant, which produces shell bodies for artillery and mortars. Some plants, like the Votkinsk and Almaz-Antey plants were almost entirely re-equipped with western CNCs, enabling the much more precise and accurate milling and machining of missile components. Some factories, like Stankomash, which produces a range of products from artillery ammunition to propellers for large ships, were almost completely built by European companies. A large number of Italian CNC providers, for instance, appear to have supplied machinery to the Konar company, essentially building a factory from scratch.

This modernisation revived the Russian defence industry, and came with further partnerships to upgrade and improve Russian equipment. Thales was selected in 2007 to supply its Catherine series thermal imagers for Russian tanks, that would go on to equip most of Russia's modernised armoured vehicles, with some form of domestic production also undertaken. The defence industry continued in this way, modernising its own equipment and processes, and delivering at a modest pace to the Russian armed forces. Between 2005 and 2015, the increases in Russia's defence budget outstripped its increases in GDP, with an average of 7.9% for the former, and 3.4% for the latter. That is, until the 2022 invasion of Ukraine.

A war economy

If Russia's operations in the opening phases of the operation had gone as planned, and if Western states had not provided the equipment that they did, it is likely that Russia would have succeeded with many of its original goals. For instance, if the airborne VDV that initially seized Hostomel Airport (25 km north-west of Kyiv) had linked up with armoured units driving around the capital, they may have successfully held the airport for reinforcements to be delivered. Without Western ammunition, Ukraine's defenders would have run out of their own reserves sooner or later, and the fight would have become even more one-sided than it was in terms of firepower until mid-2023. This is an important caveat to bear in mind; Russia was confident that its so-called 'special military operation', led by its intelligence services, would succeed relatively quickly. There would be intense fighting and that was expected, but it was not expected to last too long, and if it did, Russia's strategic reserves of ammunition and vehicles would cover the military's needs.

The then-Minister of Defence Sergei Shoigu, visiting a unit in Russia's Western Military District and inspecting what appears to be freshly-produced 30 mm ammunition in June 2023. [Russian MoD]

However, it seems that the consumption of both was far greater than imagined and consumption rapidly outstripped production of the Russian ammunition and missile industry in particular. Gradually, Russia transitioned to a wartime economy, albeit in a quiet way. The order to fully mobilise the defence industry was given in 2022, creating the legal framework for the shift to a wartime economy, according to a 2025 RUSI paper. This allowed the Kremlin to access the Federal reserves of strategic materials, mandate companies to go into contracts with the State for defence production, adjustments to labour regulations that meant factory workers would be expected to work for 12-hour shifts, six days per week, and state regulation of prices within the defence industry.

The Kremlin poured money into the defence industry and armed forces in a move that could be described as 'military Keynesianism'; an economic policy that advocates increased government spending on the military to stimulate economic growth and maintain full employment. Military Keynesianism is a specific application of the broader Keynesian economic principles that government spending can boost aggregate demand, especially during economic downturns.

Although, it is worth noting that Putin already saw defence as a driver of domestic growth and said as much publicly in 2012. Defence spending averaged USD 53 billion per year between 2011 and 2021, rising to USD 79 billion in 2022 and USD 94 billion in 2023, then USD 140 billion in 2024 and a projected USD 143 billion in 2025, according to a research paper from CSIS. Rostec, the state-owned conglomerate, was given control over several ammunition plants and others within the ammunition supply chain to modernise their production, and other elements of the defence industry were further rationalised. By the end of 2024, Rostec had invested USD 8.7 billion in expanding and modernising its factories in order to meet the state defence orders. The company's total revenue in 2024 reached approximately USD 39 billion, Rostec CEO Sergey Chemezov told Putin in June 2025. This was more than Italy's defence budget for that year. The expansion is now becoming clear, through satellite imagery, which some open-source outlets have analysed. Other reports point to the dramatic expansion in procurement of CNC machines from China, which now appears to supply most of Russia's machine tooling needs.

Missiles

Russia had a varied collection of missiles when it invaded Ukraine, and was widely expected to make extensive use of them, from the tactical level to the strategic. This is largely how the war panned out, even after the first Iranian Shahed-136 one-way attack (OWA) drone was launched at Ukraine in September 2022. Russia's missile strikes occurred on a regular basis and included dozens of cruise and ballistic missiles. The balance of the strike packages was eventually altered to include more and more Shaheds, and in increasing numbers, Gerans (Russia's domestic version of Shahed, which includes various modifications and upgrades) manufactured in Russia. The night of 28 June 2025 saw the use of massive waves of Gerans, including decoys, and a mixture of missiles including ground-launched 9M723 Iskander ballistic missiles, 3M-54 Kalibr cruise missiles launched from the Black Sea, air-launched Kh-101 cruise missiles, and Kh-47M2 Kinzhal aeroballistic missiles. In total, Russia deployed 537 weapons (including decoys) in a wave of attacks lasting nearly 12 hours. Just 60 of the weapons used were missiles, the remainder were OWA drones.

Regardless of the ratios used, Russia has expended an enormous quantity of missiles in Ukraine. Between September 2022 and 2024, Russia launched 11,466 missiles and OWA drones at Ukraine, according to data collected by Ukrainian Data Scientist Petro Ivaniuk. Russia's attacks reached a total of 4,000 OWA drones launched in May 2025 alone, compared to just 1,100 between May and June 2023. A massive wave of 728 drones was launched against Ukraine on 9 July 2025, with many striking Kyiv. So, the Russian defence industry has clearly expanded to meet this need, and satellite imagery helps track their progress.

Missile propellant

Analysis from the International Institute of Strategic Studies (IISS) published in November 2024 shows that expansions are underway at five sites related to the production of solid propellant used in Russian missiles, and may be underway at a raw materials producer:

- New buildings have been observed at the Morozov plant, which is reported to produce components for the 9M723 Iskander short-range ballistic missile (SRBM) and the Topol-M intercontinental ballistic missile (ICBM).
- The Perm solid propellant site has been refurbished and a significant area at the site cleared. It is involved in the production of most of Russia's ICBMs.
- The Federal State Unitary Enterprise 'Federal Centre for Dual Technologies Soyuz' also shows signs of refurbishment and clearances to make way for new buildings. It is involved in most of Russia's ballistic missiles as well as tactical systems like the BM-30 Smerch 300 mm multiple rocket launcher (MRL).
- The Kamensky Plant, was undergoing one of the most significant expansions according to the IISS analysis. The analysis showed a significant expansion to the plant's facilities and a number of new buildings. The site is associated with the production of motors for the Topol-M ICBM
- The Joint Stock Company 'Federal Scientific Production Centre Altai' in Biysk appears to be undergoing a similar mix of expansion and refurbishment. The site also supports strategic missiles, including Topol and the Bulava submarine-launched ballistic missile (SLBM).
- Anozit, thought to be Russia's only manufacturer of the ammonium perchlorate needed for solid missile propellant, reported plans to expand its production of the chemical in 2022.

The continued use of missiles of all classes against Ukraine is the greatest reflection of Russia's increased missile production. Without it, Russia would not have been able to sustain its strikes at the scale and pace that it has.

A Tu-95MS loaded down with Kh-101 cruise missiles. Russia has launched extensive and massive cruise missile strikes against Ukraine, necessitating increased production of missile propellant. [Dmitry Terekhov from Odintsovo, Russian Federation, via Wikimedia Commons; CC BY-SA 2.0]

This image shows an American worker at Orbital ATK shaping uncured ammonium perchlorate before it is shaped and cured into a missile booster. Russia is thought to have a single plant producing this, Anozit. [NASA's Marshall Space Flight Center, via Wikimedia Commons]

Drones and loitering munitions

Expanded production of drones and loitering munitions has followed an interesting trajectory in that there appears to be a tendency to forcibly acquire shopping malls, evict the existing tenants, and turn the mall into a production facility. The expanded production of drones has become key for Russia as its forces rely on them for most reconnaissance and often also for command and control.

TABLE 1

Growth in Lancet loitering munition use since 2022

Year	Total uses	Average per month
2022	100*	25
2023	778	64
2024	1,889	157
2025	690	98**

Notes:
*Lancet use appears to have started in August 2022.
**Data until mid-July 2025.
Data sourced from: lostarmour.info

Some of these conversions appear to have been quite successful, with the use of Lancet family loitering munitions being a strong indicator of the expanded production.

Thus far, 2024 was a peak year for Lancet use, with several exceptional months including May 2024, which saw more than 300 of the strike drones deployed in support of Russia's offensive operations in Kharkiv and elsewhere.

Overall, Russia's wider drone and loitering munition production has seen a truly staggering increase in production quantities since 2022. Select examples of key manufacturer expansion efforts are detailed below:

Alabuga
Location: Alabuga Special Economic Zone, Tatarstan
Products: Shahed/Geran series OWA drones
Description: The production site in the Alabuga Special Economic Zone responsible for producing Shaheds and Gerans has been variously reported on since 2024 when details of the site became public – but thought to have been established the previous year. It has produced thousands of Geran-2s for Russia's airstrikes against Ukraine, and has continued working despite several successful Ukrainian strikes hitting the factory. Some reports from early 2025 found that African women were working in the factory, often exposed to dangerous chemicals and overall dire working conditions. They had been promised high wages and a good standard of living in recruiting campaigns likely supported by Russia's intelligence agencies. Then, in June 2025, it emerged that there were plans to send 25,000 North Korean workers to the factory and satellite imagery from the same month appears to show extensive construction of additional accommodation, supporting those reports. Speaking to the BBC, also in June 2025, Artem Dehtiarenko, spokesman for Ukraine's security service, said that 25,000 Shahed and Geran drones had been produced at the site, with another 20,000 assembled from kits.

▼ The Alabuga carbon fibre factory under construction in 2013. Today, it is believed to support the production of Geran drones. [Aydar Murtazin, via Wikimedia Commons; CC BY-SA 3.0]

NPO IzhBS
Location: Izhevsk
Products: Granat 4 reconnaissance UAV and others.
Description: In 2024, the Scientific and Production Association Izhevsk Unmanned Systems (NPO IzhBS), part of the Kalashnikov Concern, was reportedly in the process of increasing its production of drones by a factor of ten. It had commissioned a new production facility with an area of 5,800 m2, and it later emerged that IzhBS had purchased a shopping mall in Novyi Dom in September 2023. The company plans to add to that production figure by 50% in 2025.

Supercam
Location: Ryazan'
Products: Supercam S350 reconnaissance drone
Description: Supercam (part of a group of companies formally known as Unmanned Systems) reportedly took control of the Solnechny shopping centre in Ryazan in January 2025. Eviction notices were served to existing tenants of the facility, which is reported to have a total area of 17,250 m2. Another company within the group known as Finco LLC appears to represent Supercam internationally and with the Russian MoD, according to Ukrainian investigative group, Molfar. Supercam's headquarters is in Izhevsk, which is also home to Zala Aero and Izhevsk Unmanned Systems (IzhBS).

▲ A Supercam S350 drone ready to launch in 2019. The duration of the War in Ukraine, and need for more drones for reconnaissance as well as command and control, led to the rapid expansion of drone types used by Russian forces. [Supercamaero, via Wikimedia Commons; CC BY-SA 4.0]

Zala Aero/Aeroscan
Location: Italmas
Products: Lancet loitering munition, possibly Z-16 reconnaissance drones.

Description: Zala Aero led the way for Russian drone manufacturers it seems, in commandeering shopping malls for production facilities. Alexander Zakarov, the company's chief designer was shown touring the Italmas mall in July 2023, using a Segway to travel the length of the facility that had been established there. The mall was reportedly abandoned because of the COVID pandemic, and subsequently turned into a production facility for Russia's Lancet loitering munitions.

Regarding the latter case, Zakarov appears to have suggested the mall's conversion in August 2022, in a presentation that managed to combine imagery of the Soviet past, with a justifiable blow against Western brands, *"As a person born and working in a city of gunsmiths, it was bitter for me to see how powerful factories built in Soviet times were being turned into shopping malls one after another...We have developed a concept for converting shopping malls, which before the start of the SVO mainly sold goods of Western brands, into factories for the production of three types of domestic drones," he was reported to have said. Zakarov later told Russia 1 TV that Lancet production was "organised in the building of a former shopping centre."*

The Italmas mall has since been renamed the 'Italmas Research and Development Center' (Научно-исследовательский центр 'Италмас'). Aeroscan reportedly purchased another shopping mall in Izhevsk called the Stolitsa shopping mall in September 2023, ordering the occupants to vacate the premises by October of that year.

Ammunition

Ammunition, especially artillery ammunition, is central to Russia's way of war, and its defence industry struggled to meet the immense needs generated by fighting in Ukraine. Analysis based on modelling and publicly reported figures indicates that North Korea was called in to supply in excess of five million rounds of artillery ammunition to resource Russia's war. This is an enormous amount of ammunition, and comprises roughly 40% of Russia's 14 million rounds estimated to have been used between August 2023 and April 2025. Russia had strategic reserves and old ammunition to refurbish, combined with new production; it was estimated to be capable of producing between two and four million rounds in 2024. This is also a lot of ammunition, but nothing compared to the potential usage, so expansion became critical.

Biysk Oleum Plant
Location: Biysk
Products: RDX
Description: The Biysk Oleum Plant is located in Siberia and has been reportedly undergoing an expansion since May 2023, with wooded areas at the site cleared and new buildings evident by September 2024. It has since emerged that the site is the subject of a USD 189 million expansion that would deliver a new production line estimated to be capable of producing 6,000 t of RDX per year, which is enough for around 1.2 million 152 mm artillery rounds.

Plastmass Plant
Location: Kpoeysk
Products: Artillery ammunition and unguided rockets
Description: Plastmass is a large ammunition facility producing a variety of different munitions for the Russian armed forces. It was expected to start a modernisation and refurbishment process in 2021 that would add 4,000 m2 to its production capacity, but it was unclear if this had progressed by October 2024. However, Rostec did report a five-fold increase in the plant's production in June 2024 with another 20% expected to follow the year after. It also has extensive recruitment requirements and appears to be working either with or towards three-shift schedules to maximise its output.

Tambov Powder Plant
Location: Kotovsk
Products: Propellent for 122 mm and 152 mm artillery rounds as well as explosives.
Description: Tambov is a Soviet legacy plant producing pyroxylin powders for various ammunition types. It had hired 500 additional staff by the end of 2022, and in 2023 was transferred to Rostec's ownership in 2023 to facilitate improved production and the site's expansion. Subsequently, the company planned to hire 3,000 more staff by 2025. It was also undergoing refurbishment and modernisation, including expansion of its facilities through a contractor called Gidroavtomatika. Tambov has been targeted with Ukrainian drone strikes, the outcome of which remains unclear.

Looking ahead

The above provides a small insight into Russia's defence industry, which is estimated to include at least 1,400 entities. Nevertheless, it does provide an indication of the expansion underway and what is happening to increase the country's production. However, Russia's defence exports have collapsed since 2022 as the state-mandated support for the War in Ukraine and interest rates on domestically-available capital made Russia unattractive to foreign militaries, and unprofitable for the defence industry itself.

There is also the element of the social impact of all this spending and government approach, which has militarised Russian society. Many Russians now work in the defence industry, an estimated 4.5 million in 2024 according to RUSI, although it is worth noting that Putin gave a figure of 3.5 million in February 2024. Either way, Russia is militarising, with even school children now being taught to build and fly FPV drones, others to dig trenches and fire assault rifles. A raft of policies is aimed at increasing birth rates, with rewards offered to young Russian women that fall pregnant and give birth, all of this enmeshed in a wrapper of patriotism.

This all matters because these are policies that will be hard to reverse. Moreover, these policies will leave an indelible mark on Russia, its economy, and its people. It potentially sets the stage for decades of further confrontation and potentially conflict with NATO. Whereas the Russian defence industry of 2021 probably could not have supported a prolonged conflict with NATO, the one that looks likely to emerge in 2027 or 2028 almost certainly could.

A 2S19M1 Msta-S self-propelled howitzer shown during a 2017 demonstration. Despite the rise of small drones, expanding the supply of artillery ammunition remains critical to Russia's war effort. [RecoMonkey]

The British naval construction sector: Status report

Conrad Waters

The United Kingdom's naval construction sector has been undergoing a significant revival in recent years. Multiple procurement programmes are currently underway to support a much-needed modernisation of the British Royal Navy (RN). The recently revealed results of the 2025 Strategic Defence Review (SDR 2025) herald a further expansion of the sector, with the submarine segment likely to be a significant beneficiary. However, detailed prospects for naval construction will gain more clarity after the expected publication of a detailed Defence Investment Plan, as well as of a long-awaited Defence Industrial Strategy, before the year's end.

Construction of SSN-AUKUS submarines will support the UK's submarine industrial base for decades ahead. [Crown Copyright 2024]

Overview

The United Kingdom retains one of the world's largest naval construction sectors, maintaining the ability to design and build a full spectrum of vessels. In contrast to many of its European peers, its activities are particularly heavily weighted towards national naval requirements, meaning relatively few ships have been built for export in recent years. The industry has, however, achieved success in selling designs for overseas construction under transfer of technology agreements. It also remains an important supplier of naval equipment.

Domestic demand for warships has grown substantially over the last decade. The block obsolescence of the RN's Cold War-era ships has driven the need for increased procurement and this has been supported by a modest yet steady uptick in defence spending. Recent government announcements to accelerate defence spending to reach an initial 2.5% of gross domestic product, with an ambition to go further thereafter, suggest that this trend will continue. The recent SDR 2025 is also supportive of additional naval investment. However, it makes few tangible commitments beyond setting a target for the acquisition of SSN-AUKUS (SSN-A) nuclear powered attack submarines under the so-called Pillar I of the tripartite security agreement. As discussed later in this article, many detailed decisions have still to be revealed.

The importance of the British shipbuilding sector is reflected in the publication of a National Shipbuilding Strategy (NSS) in 2017, which was subsequently refreshed in 2022. Both documents were aimed at revitalising and expanding the overall indigenous maritime industrial base. Their scope also extended to shipbuilding and equipment for commercial requirements but not submarines. These have typically been considered as a discrete segment by virtue of being part of the UK's wider nuclear enterprise. The 2022 NSS set out a 30-year pipeline of planned government shipping procurement to help inform industry of future demand. However, whilst acquisition of complex warships has essentially been restricted to British shipbuilders, policy is notably more flexible than that adopted by many countries with respect to the origin of other ships. At present, it is not clear to what extent the current British government will maintain the existing NSS approach.

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Following reversal of a previous policy of consolidation, British warship construction is currently split between three major suppliers. The largest of these is BAE Systems. Its facility in Barrow-in-Furness is the only British site capable of building submarines, whilst its integrated shipyards at Govan and Yarrow in Glasgow comprise the UK's largest builder of major surface vessels. Babcock International Group, who recently upgraded their shipyard at Rosyth near Edinburgh, is also involved in surface warship construction following its award of the contract for the Type 31 frigate programme. These two British-owned companies have recently been joined by the UK arm of Navantia, following the Spanish group's acquisition of the former Harland & Wolff business in January 2025. Its main facility is the famous Harland & Wolff yard in Belfast. However, the purchase has also brought the Appledore shipyard in Devon and two smaller Scottish facilities focused on the commercial sector under its wing.

In addition to their shipbuilding sites, both BAE Systems (at Portsmouth) and Babcock (at Devonport and Faslane) maintain important maintenance and refitting facilities. Also of note are the shipyards of APCL Group. These maintain the naval support vessels of the Royal Fleet Auxiliary (RFA) and, alongside Ferguson Marine in Glasgow, are supplying block assemblies for BAE Systems' warship construction. The activities of the prime shipbuilding contractors also support a very extensive ecosystem of suppliers. Amongst these, the various naval propulsion businesses of Rolls-Royce Group and the UK operations of Atlas Elektronik, MBDA and Thales are particularly prominent. Many British contractors have gained strong niche positions within their areas of expertise; BMT (ship design), David Brown Santasalo (gearboxes), MacTaggart Scott (lifts and handling equipment), MST Group (high-speed boats) and Ultra Maritime (sonar) are just a few examples in this regard.

Submarines

The British naval construction sector is dominated by submarine building. This forms part of the wider Defence Nuclear Enterprise, which is focused on the maintenance of the UK's strategic Continuous At-Sea Deterrence (CASD) capability but also includes conventionally-armed, nuclear-powered attack submarines (SSNs). The overall enterprise cost GBP 10.9 billion in the 2024/25 financial year, approaching 20% of the British Ministry of Defence's entire equipment budget. Total spending is expected to increase over the years ahead, amounting to around GBP 130 billion during the next decade.

As mentioned previously, construction of all British submarines takes place at BAE Systems' shipyard in Barrow-in-Furness. This activity is supported by the production of nuclear reactors at Rolls-Royce's factory at Raynesway in Derby, specialised structures manufactured at the government-owned Sheffield Forgemasters, and the provision of weapons handling and ongoing maintenance by Babcock. Whilst the Trident ballistic missiles carried aboard British strategic submarines are sourced from the United States, their nuclear warheads are manufactured by the Atomic Weapons Establishment at Aldermaston. All these facilities are receiving substantial investment as part of an expansion in capacity. Notably, employment at Barrow-in Furness has grown from approximately 11,000 in 2023 to 13,500 in 2025, and is expected to grow to 16,500 by 2027. In a notable initiative, GBP 20 million a year over the next ten years is being invested to support housing, transport and social infrastructure in the town to encourage the recruitment of the required workforce.

BAE Systems is currently involved with the design and production of three classes of nuclear-powered submarines at various stages of programme maturity. The oldest is that for seven

BAE Systems is Britain's sole submarine manufacturer. This photograph shows HMS *Agamemnon*, the sixth *Astute* class SSN, at the time of her launch in October 2024. [BAE Systems]

Astute class SSNs, the first three of which were ordered as long ago as March 1997. The project has been marked by the delays and attrition of relevant skills that marked the immediate post-war era. Concerningly, there has been little if any increase in the slow pace of construction between the earlier and later submarines in the class. At present, BAE Systems is close to delivering the sixth boat, HMS *Agamemnon*, which was launched in October 2024. Later that month, a fire broke out in the Devonshire Dock Hall where submarine assembly takes place. It has been speculated that this may delay delivery of the seventh and final member of the class, HMS *Achilles* (formerly HMS *Agincourt*), which remains under construction.

Part of the reason for the slow pace of progress with later members of the *Astute* class may be the strain on resources caused by the transition to the construction of the four *Dreadnought* class strategic submarines that will replace the existing *Vanguard* class boats in providing CASD. As of May 2025, the programme remained within its GBP 41 billion – including a GBP 10 billion contingency – budget, with a total of GBP 17.4 billion having been spent to March 2024. The first steel was cut for the lead boat in October 2016, and was followed by a formal keel laying ceremony in March 2025. Dreadnought reportedly remains on track to enter service in the early 2030s. Work has also started on the second (*Valiant*) and third (*Warspite*) submarines, with long-lead items and other materials procured for the fourth (*King George VI*) and final member of the class.

Barrow's longer-term future will be secured by construction of the planned SSN-A submarines that will be acquired jointly with Australia as part of the AUKUS agreement. Whilst the Royal Australian Navy submarines will be assembled locally at a new Submarine Construction Yard at Osborne in South Australia, the nuclear reactors to propel all the class will be built at Rolls-Royce's Raynesway plant. Accordingly, Australia is investing GBP 2.4 billion in helping expand Rolls-Royce infrastructure and pay its share of the submarines' development costs. The programme entered a Detailed Design and Long Lead (D2L2) phase in March 2023 that encompasses the design, prototyping and purchase of main long lead components for the first British submarines. Contracts worth GBP 4 billion to support completion of this work were subsequently announced in October that year. Deliveries of the first British SSN-As are expected towards the end of the 2030s.

In one of the major developments to emerge from SDSR 2025, the UK MoD has decided to build "up to 12" Royal Navy SSN-As, almost double the number of the planned *Astute* class flotilla. This will be achieved by leveraging the investment made in the submarine industrial base to achieve a construction drumbeat to one submarine every 18 months. Whilst remaining lower than the production rate achieved during the Cold War, this seems to be an ambitious target given the delays that have impacted recent production, but reflects the importance attached to securing the underwater domain given ongoing Russian investment in modernising its own submarine arm.

Surface warships

The extent of British investment in submarine capabilities has inevitably given rise to questions about the resources that will be available post SDR 2025 to fund the previously planned expansion of the Royal Navy's surface fleet. At present, procurement has been authorised for two classes of frigate intended to maintain the 2010 target of 19 major surface combatants. However, whether aspirations to further increase this number to up to 24 major warships will be achieved is a matter of some conjecture.

The flagship surface warship construction programme is for eight 'high-end' Type 26 anti-submarine warfare frigates. Three of these ships were ordered from BAE Systems at a cost of GBP 3.7 billion in 2017. A GBP 4.2 billion contract for the remaining five followed in 2022. Fabrication of the lead ship, named *Glasgow*, commenced in July 2017 and, as of mid-2025, work on five of the frigates was underway. In a similar but rather less ambitious fashion to the submarine business, their construction is being supported by a major programme of investment in BAE Systems' Clyde shipyards, which is reported to amount to GBP 300 million overall. Its centrepiece is the new covered Janet Harvey Hall at the Govan yard in Glasgow that allows the simultaneous assembly of two Type 26 frigates in a controlled, weather-tight environment. The facility was officially opened in June 2025 and is being used for the assembly of all the Type 26 frigates from the third vessel onwards.

A formal keel-laying ceremony for the lead *Dreadnought* class strategic submarine was held in BAE Systems' Devonshire Dock Hall at Barrow-in-Furness in March 2025. [BAE Systems]

Updating ESD in July 2025, BAE Systems noted that the aft block of *Belfast*, the third Type 26, had entered the Janet Harvey Hall earlier that month. It was expected to be joined by the ship's bow in the weeks ahead. After completion of structural integration, the frigate will be floated off by means of semi-submersible barge and transported to the Scotstoun site,

The Janet Harvey Hall has been built at BAE Systems' Govan shipyard to support construction of the Type 26 frigate class. [BAE Systems]

where outfitting of the first two members of the class is currently underway. The statement noted that work on the fourth and fifth ships was also currently in progress and that a first steel cutting ceremony for the sixth Type 26, HMS ***Newcastle***, was expected later in 2025. The current expectation is that the eight ships of the class will be commissioned between 2028 and 2035.

The Type 26's 'Global Combat Ship' export iteration has already formed the basis of similar warship construction programmes in the shape of Australia's ***Hunter*** class frigates and Canada's 'River' class destroyers under transfer of technology arrangements. Firm orders for three of each type had been placed by mid-2025 as part of larger projected programmes. Whilst construction of all these ships will take place overseas, the design's selection will result in substantial orders for the British Type 26 supply chain. The Type 26 is also one of four contenders alongside proposals from France, Germany and the United States for Norway's programme to import at least five new frigates. Selection of the preferred supplier for a hotly contested order was believed to be imminent at the time of writing.

The other component of British surface warship construction comprises five general purpose frigates being built by Babcock at Rosyth. Intended to be a disruptive programme designed to increase competition in the supply of Royal Navy warships, the acquisition was carried out under a fixed-price contract with a reported value of around GBP 1.25 billion (exclusive of certain government furnished equipment). This arrangement has already proved costly to Babcock. It has had to take provisions totalling GBP 190 million on the agreement due to the impact of the COVID-19 pandemic and higher-than-expected cost inflation. On the plus side, the 'Arrowhead 140' design – itself based on Denmark's ***Iver Huitfeldt*** class – has already gained important transfer of technology contracts for the construction of two ships in Indonesia and three in Poland.

Work on HMS ***Venturer***, the lead Type 31, commenced in September 2021. Construction is taking place in another new ship hall, the Venturer Building, which is broadly similar to but slightly smaller than BAE Systems' equivalent facility at Govan. Three of the five ships were under construction as of mid-2025 and all are expected to be delivered by the end of the

The lead Type 31 frigate *Venturer* seen exiting Babcock's Venturer Building at Rosyth in May 2025. [Conrad Waters]

▲ A computer-generated image of BMT's fleet support ship design for the Navantia-led Team Resolute. BMT is one of numerous specialist companies supporting the British naval construction sector. [Team Resolute]

decade. In line with this schedule, HMS *Venturer* was rolled out of the Venturer Building at the end of May 2025 prior to being launched by semi-submersible barge the following month. Speaking to *ESD* at the roll-out event, Babcock's Chief Executive Marine, Sir Nick Hine, stressed the importance of delivering on customer expectations with respect to the existing domestic and overseas contracts as part of his ambition to expand orders for the Type 31 design to "31 by 2031".

Other naval construction

The other major naval British construction programme currently underway encompasses three fleet solid support ships (FSSs). Designed by BMT, these auxiliary vessels are intended to provide non-liquid replenishment for carrier strike groups and other warships. A GBP 1.6 billion contract for the ships' construction was awarded to the Navantia-led Team Resolute in January 2023. The agreement envisaged assembly of the FSSs at the Harland and Wolff shipyard in Belfast from blocks fabricated by Harland and Wolff group's Appledore and Belfast facilities, as well as by Navantia's own yard at Puerto Real near Cádiz. It involved significant investment to modernise the Belfast site, which had not completed a new-build ship for 20 years. At the time the contract was signed, it was envisaged that all three ships would be operational by 2032. Implementation of the contract was subsequently disrupted by the financial insolvency of Harland and Wolff, ultimately leading to the group's acquisition by Navantia in January 2025. The Spanish group has now resumed modernisation of the former Harland & Wolff shipyards.

TABLE 1

Current British Royal Navy warship construction programmes

Class	Type	Displacement	First ordered	Total requirement	Completed	In construction
Submarines						
Astute	Nuclear-powered attack submarine (SSN)	c. 7,500 tonnes	1997	7	5	2
Dreadnought	Nuclear-powered strategic submarine (SSBN)	c. 17,000 tonnes	2016	4	0	3
SSN-AUKUS	Nuclear-powered attack submarine (SSN)	n.k.	Tbd	Up to 12	0	0
Surface Vessels						
Type 26 'City'	Frigate (FFG)	c. 7,000 tonnes	2017	8	0	5
Type 31 'Inspiration'	Frigate (FF)	c. 6,000 tonnes	2019	5	0	5
Auxiliaries						
Solid Support Ship	Replenishment ship (FSS)	c. 40,000 tonnes	2021	3	0	0

Note: SSN-AUKUS has had design and initial long-lead items ordered.

XV *Patrick Blackett* is being used to explore prototype technologies for a new generation of uncrewed surface vessels designated the Type 92. Such uncrewed vessels are likely to form an increasingly significant part of future Royal Navy construction programmes. [Crown Copyright 2024]

Speaking to ESD, Donato Martínez, Chief Executive Officer of Navantia UK said, "We are investing GBP 115 million across our four UK sites – Appledore, Arnish, Methil and Harland & Wolff Belfast – to modernise and create state-of-the art capabilities, fit for UK defence demands". He noted that work is now well underway at the iconic Belfast shipyard, stating this included "the installation of cutting-edge equipment such as robotic plasma cutters, a fully mechanised flat panel line, and automated quality control systems". He added, *"Upgrades to delivery systems, stockyard management, and digital integration are also in progress, ensuring we can deliver the FSS vessels with speed and precision. Investments are also underway in Appledore shipyard, where facilities and processes are being prepared to host the first cutting of steel for the lead FSS ship before the end of 2025. Construction works in other sites will follow in 2026".*

Looking to the future, Martínez anticipated that Navantia UK would continue to support government programmes, including through component manufacturing and specialist capabilities. He explained, "Our GBP 115 million investment programme reflects that vision, ensuring all four sites are equipped to contribute to the UK's long-term sovereign defence and industrial objectives".

The way ahead

The longer-term future for the British naval sector is inevitably subject to securing orders for new construction. The submarine segment has most security in this regard, with the SSN-A programme providing visibility for decades into the future. The picture with respect to surface ship construction is far less clear, as important elements of the 30-year pipeline of requirements outlined in the 2022 NSS have already been overtaken by subsequent developments. The imminently expected Defence Investment Plan that will follow on from SDR 2025 should do much to provide the desired clarity, and according to UK Secretary of State for Defence John Healey, promises "line-by-line" detail of future equipment required. If this ambition is delivered, the plan will be of much greater utility than previous recent British defence documents. These have tended to lack considerable detail as to planned force structures and intended procurement.

On the face of it, the expanded funding envelope should be sufficient to provide enough work for the surface yards and supporting sub-contractors. The 2022 NSS encompassed requirements for an undefined number of anti-air warfare ships – now commonly referred to as the Type 83 destroyer – and "up to five" follow-on Type 32 general purpose frigates. These were supplemented by plans for what are now known as multi-role strike ships (MRSSs) and various smaller vessels and support shipping. SDR 2025 explicitly endorses only some of these requirements – the anti-air warfare "air dominance system" being a notable example – and paints a vision where there is significant use of autonomous systems to bulk out crewed platforms and provide additional mass. It is known that the Royal Navy are already developing Type 92 uncrewed sloop and Type 93 uncrewed underwater vehicle concepts to work alongside the Type 26 frigates and other platforms to secure maritime dominance in what is referred to as the 'Atlantic Bastion'. Equally, a fleet of Type 91 missile 'barges' is envisaged to supplement the magazine capacity of the Type 83 destroyers. Implementing these concepts would have a significant impact on the shape of the future shipbuilding programme and the nature of shipyard capacity required.

Another open question is the extent to which the investment in modernising British naval shipbuilding can be leveraged to improve the sector's export performance to levels achieved in other European countries. Recent successes in exporting the SSN-A, Type 26 and 'Arrowhead 140' designs under transfer of technology arrangements are evidence of progress towards attaining this ambition. However, it is many years since a major warship was built and exported from a British shipyard. Securing this goal would be tangible evidence of the British naval construction industry's return to playing a leading role in a highly competitive market.

Market overview: Longevity and innovation in the machine gun sector

David Saw

Century-old machine gun designs continue proving their worth in modern warfare, from the battlefields of Ukraine to NATO training exercises. Yet questions surrounding the US Army's Next Generation Squad Weapon (NSGW) programme highlight the ongoing tension between battlefield reliability and the pursuit of enhanced performance through the adoption of new cartridges and technologies.

The L7A2 General Purpose Machine Gun (GPMG) in action during a counter-ambush in Afghanistan by British troops. The L7A2 is the British version of the FN MAG, arguably the most successful Western GPMG. [Crown Copyright]

The machine gun first became a practical proposition in the mid-1880s, before going on to transform modern warfare. One of the issues that needs to be addressed when evaluating the machine gun sector is the classification of different machine gun types. In the beginning it was very simple – there was just the machine gun, then along came the Light Machine Gun (LMG), both of which used standard rifle calibre ammunition. Then at the start of the 1920s came the arrival of the Heavy Machine Gun (HMG), with the John Moses Browning designed M1921 in 12.7 × 99 mm (.50 BMG) calibre, which eventually evolved into the M2HB in use today.

That might sound rather straightforward in terms of classifications, but unfortunately it is not. In Germany in the 1930s the MG34 in 7.92 × 57 mm Mauser used the standard rifle cartridge, but this was something very different since it was the first of what was later described as the universal machine gun. With its bipod it could be used as a light machine gun, or in a sustained fire role it could be mounted on the Lafette tripod.

The MG34 was succeeded by the MG42 as the standard universal machine gun. The MG42 later formed the basis for the MG3, chambered in 7.62 × 51 mm NATO, which was adopted by the Bundeswehr in the late 1950s. Beginning in 2015, the MG3 began to be replaced by the Heckler & Koch (HK) MG5, also in 7.62×51 mm. It should be noted that the MG42 was incredibly influential in post-1945 machine gun design internationally and also the MG3 still remains in widespread service globally. it is also worth noting that another classification is used for the universal machine gun – the General Purpose Machine Gun (GPMG).

To round off the subject of machine gun classifications, a more recent evolution appeared as a result of the 5.56 × 45 mm NATO round becoming a standard infantry cartridge. Since more firepower was needed at the squad level, this led to the development of the Squad Automatic Weapon (SAW), essentially a lighter LMG in 5.56 × 45 mm. Finally, to conclude, we have the emergence of another machine gun classification in the form of the Medium Machine Gun (MMG), which is effectively a GPMG/universal machine gun type weapon in a sustained fire role. However, looking to the future, the GPMG/MMG is likely to find itself with expanded performance parameters, fulfilling HMG-type roles in a much lighter package and more manageable format.

Starting points

When it comes to machine guns, it all began with the Maxim gun, developed by Hiram Maxim in the 1880By the 1890s, Maxim's company and the rights to his machine gun had been purchased by Vickers, one of the most important defence manufacturers of the era. Vickers would go on to develop an evolved version of the Maxim design, known as the Vickers Gun in 7.7 × 56 mmR (.303), which would be adopted by the British Army in 1912 and remain

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in service until 1968. The Vickers was incredibly reliable. As long as you had ample supplies of belted ammunition, water for cooling the gun and spare barrels – changed every 10,000 rounds – the Vickers could fire more than 100,000 rounds in a day without issue.

Among the European nations that acquired the Maxim gun and later produced it domestically were Germany and Russia. The Imperial Russian Army acquired a number of early Maxim guns using an 11 mm black powder round. However, in 1910 they adopted a locally-produced Maxim variant in their standard 7.62 × 54 mmR cartridge as the PM M1910 – this was placed on the Sokolov wheeled mount which also featured a gun shield. The weapon continued in service with the Soviet Army, as a modernised M1910/30 variant with a different Vladimirov mount that allowed for anti-aircraft engagements introduced from 1930 onwards. Production of the M1910/30 continued through to 1945. Post-1945, the M1910/30 would be supplied to Soviet client states such as North Korea and North Vietnam amongst others, but large numbers of weapons were put into store in the Soviet Union.

The M1910/30 not only outlasted Imperial Russia, it went on to outlast the Soviet Union and one might have expected that these weapons would fade into obscurity – not so! As war broke out in the Donbas, eastern Ukraine in 2014, Russian surrogate separatists raided weapon storage sites and fielded M1910/30 machine guns. To make up for their own equipment deficiencies, Ukrainian forces also deployed these old guns. Following the full-scale Russian invasion in February 2022, substantial numbers of M1910/30 guns were withdrawn from storage and fielded by the Ukrainian military.

The fact that a weapon that has a design basis in the 1880s and ceased production in 1945 is still in service in a combat zone is extraordinary! These days, the M1910/30 would be classified as an MMG and its ability to provide highly-reliable sustained fire is tremendously useful in repelling Russian assaults on Ukrainian fixed positions. Of course some might point to the fact that such a 'mature' system remaining in service and performing successfully indicates a lack of innovation in the machine gun sector. This would be an unfair analysis – the fact that a weapon with such a heritage is still in combat service and still performing illustrates the excellence of Hiram Maxim's original design.

A possible future?

The 1980s saw the start of the Squad Automatic Weapon (SAW) era in terms of infantry weapons and the weapon that epitomised this was the FN Minimi (in 5.56 × 45 mm). The Minimi was adopted by Belgium, the US and 20 other NATO countries, as well as achieving a broader global customer base. Over the years the weapon has evolved, with different configurations fielded. Demands for extended range and more hitting power from a SAW class weapon saw FN further develop the weapon with a version in 7.62 × 51 mm. The current version of the Minimi, the Minimi MK3 is available in both 5.56 × 45 mm and 7.62 × 51 mm.

The US military was an early adopter of the Minimi, with their version having modifications and receiving the M249 classification. US M249s have gone through a Product Improvement Programme (PIP), with US Special Forces adopting their own modified versions of the M249. Based on combat experience from Iraq and Afghanistan, the US military has been looking at a number of programmes to acquire a next generation of infantry weapons. As part of this process, despite the failure of a number of new small arms

An 82nd Airborne Division squad moves forward with the M249 Squad Automatic Weapon (SAW) during Exercise Swift Response 25 in Bardufoss, northern Norway, on 12 May 2025. The M249 is the US version of the FN Minimi, in service with 22 NATO countries. [US Army]

initiatives, the US Army embarked on an effort known as the Next Generation Squad Weapon (NGSW) programme.

The NGSW programme consists of two primary elements – the Next Generation Squad Weapon-Rifle (NGSW-R) programme to replace the M4 carbine and the Next Generation Squad Weapon-Automatic Rifle (NGSW-AR), a replacement programme for the M249 SAW. These weapons will be fielded in the new 6.8 × 51 mm Common Cartridge. SIG Sauer won the contract to supply the new weapons, the XM7 for NGSW-R and the XM250 for NGSW-AR, as well as the new round in 2022. The weapons will also be fitted with a SIG Sauer SLX suppressor and a Vortex optic/fire control system.

If the US Army adopts new generation weapons and a new round, that will obviously challenge the conventional wisdom as regards future small arms in NATO. The XM7 and the XM250 were sent for trials with US Army and National Guard formations, with the industrial infrastructure to support the new weapons and the associated ammunition family being established. It seemed that the XM7/XM250 trials programme was going well and the US Army seemed totally committed to the new weapons and envisaged substantial purchases in the coming years.

However, rumours started to emerge that all was actually not well with the XM7/XM250 and the new round. Matters came into the open when US Army Captain Braden Trent published a monograph while at the Expeditionary Warfare School, United States Marine Corps University, Quantico, Virginia titled 'Maintaining Lethality Dominance: The Future of Small Arms and the Joint Force'. Based on considerable research, the monograph was a critique of both NGSW weapons, the fire control system, suppressor and the new common cartridge.

The Trent monograph added to the rumours of problems surrounding the new weapons, even calling into to question the absolute utility of the NGSW solution and the new ammunition. Both the US Army and the manufacturer, SIG Sauer, have disagreed with the assertions on weapon performance in Trent's monograph. The official version is that the test programme for the new weapons and ammunition is progressing well and no major problems have been encountered. Even so, the negative comments from the user community about the NGSW are not going away and this might yet prove difficult and potentially derail the programme.

Wah – A powerhouse from Pakistan

At the recent IDEF exhibition in Istanbul, Usman Bhatti, Managing Director & CEO of Wah Industries Limited (WIL), met with Stephen Barnard, Publisher of ESD, to discuss the company's transformation, diversification, and future vision.

[WIL]

ESD: Wah Industries Limited (WIL) has a long history encompassing explosives and other defence materiel. What's new?
Bhatti: WIL is owned by Pakistan Ordnance Factories (POF), the country's premier defence production complex. With the full support of the POF Board, we have redefined our role from being a primarily defence-focused organisation to becoming POF's outward-facing, commercially driven arm. This strategic realignment has allowed us to compete with agility in both domestic and international markets, broadening our horizons well beyond our traditional core.

We are now seeing unprecedented growth, with revenues reaching new heights and our outlook set on crossing major international milestones. This transformation is not just about business—it's about contributing to Pakistan's economy through a diversified portfolio that spans multiple sectors.

ESD: What does WIL's portfolio look like today?
Bhatti: Our activities cover a wide spectrum. In energy and commodities, we import coal for Pakistan's power sector under long-term contracts and have entered MOGAS trading under a structured model that ensures sustainable operations.

In infrastructure, we undertake major civil works, including dams, canal networks, and other critical projects through our wholly owned subsidiary, Wah Construction Limited (WCL). In mobility, we have secured large-scale contracts for electric buses, positioning WIL as a leader in sustainable transport. In the power sector, we are engaged in acquiring and dismantling redundant government power plants and competing to supply new ones to recycle assets and create new value.

In defence manufacturing, we are establishing a major artillery production facility with advanced technology partners, as well as a new ammunition plant with potential expansion into multiple calibres. We also have exclusive partnerships with international OEMs for technology transfer, local manufacturing, and market development—strengthening both our national capability and our export potential.

ESD: What about next-generation warfare capabilities?
Bhatti: This is one of our most promising areas. We are working with leading global OEMs on UAVs, loitering munitions, tactical drones, and other next-generation systems. These partnerships are aimed at integrating advanced capabilities into Pakistan's defence ecosystem while creating products for regional and international markets.

WIL has adopted a modern governance framework to support such initiatives—transitioning from public-sector procurement constraints to SECP-aligned (Security & Exchange Commission of Pakistan), corporate governance that enables faster decision-making and greater operational agility. We have strengthened our leadership at the C-level and established a dedicated Technical Advancement Division to drive innovation and explore emerging technologies.

ESD: That's quite a departure from WIL's traditional model.
Bhatti: It is a deliberate shift, supported at every step by the POF Board. We are combining financial discipline, transparency, and strong project structuring to ensure long-term sustainability. Our focus is on strategic partnerships, technology acquisition, and value creation for Pakistan—both in defence and in diverse civilian sectors.

Internationally, we maintain a strong presence at leading exhibitions such as IDEF, DSEi, and IDEAS—not just as exhibitors but as active dealmakers. These platforms allow us to secure joint ventures, technology collaborations, and long-term supply agreements that shape our future direction.

WIL today is a transformed organisation—competitive, diversified, and globally relevant—delivering growth at home while contributing to Pakistan's standing in the international industrial and defence community.

ESD: Mr Bhatti, thank you.

The XM250 was selected as the Next Generation Squad Weapon-Automatic Rifle (NGSW-AR), a replacement programme for the M249 Squad Automatic Weapon (SAW), seen here on display at Lake City Ammunition Plant to mark the start of work on a new 6.8 × 51 mm ammunition production line. [US Army Reserve]

Other options

Ongoing doubts about the NGSW could pose future challenges for M249 users, particularly those operating early Minimi models now approaching the end of their service life. One obvious solution, adopted by Minimi users of older system variants, is to acquire the current MK3 version of the Minimi in either 5.56 × 45 mm or 7.62 × 51 mm. Elsewhere in Europe, Germany procured a domestic system in this category in the shape of the HK MG4 in 5.56 × 45 mm. IWI in Israel has gained success with its Negev SAW in 5.56 × 45 mm. This is available in a standard version, plus two versions with shorter barrels for special forces applications. The more recent Negev NG-7 is a 7.62 × 51 mm variant and, like the original Negev, is available in three different variants.

Looking at the SAW category in a broader international context, it is plain how influential the Minimi has been. Developments in China are a case in point. As a part of an ambitious new generation small arms programme, China has fielded the QJB-201 SAW in the Chinese 5.8 × 42 mm calibre, and the QJS-161 variant featuring a shorter barrel and reduced weight for special forces.

In recent years, there has been growing concern over the weight burden carried by the individual soldier. One means of lightening the load is to reduce the weight of an individual weapon, while not compromising performance. This challenge led FN to develop the Evolys, which they describe as an ultralight machine gun, available in both 5.56 × 45 mm (with a maximum range of 800 m), and 7.62 × 51 mm, (with a maximum range of 1,000 m). According to FN, the Evolys 5.56 weighs in at 5.5 kg, in comparison the Minimi MK3 in 5.56 mm weighing 8 kg. The Evolys 7.62 weighs 6.3 kg, whereas the Minimi MK3 in 7.62 weighs 8.8 kg. Evolys has been acquired by French Special Forces and is being evaluated by numerous other countries.

Meanwhile in Russia

In terms of small arms, the Russian military has not found it easy to move beyond legacy Soviet systems. In many cases, this is no real hardship as these legacy systems, including machine guns, are high-quality. A case in point is the PK machine gun family, developed in the 1950s by a team led by Mikhail Kalashnikov. It was intended to replace the Soviet Army's ageing World War II-era machine guns with a versatile GPMG, inspired by the German MG34 and MG42 systems. Although the Soviet Army had standardised on the 7.62 × 39 mm intermediate round, it was decided that the PK would use the old 7.62 × 54 mmR round, due to its superior range and power.

The PK acts as the SAW in Russian service, with the PKS variant acting as an MMG with a tripod mount. Other variants include the PKT variant for armoured vehicles, used in coaxial and pintle-mounted versions. Subsequently, the PKM modernised variant was developed and eventually followed by the PKP Pecheneg designed for SAW/LMG/GPMG roles. A shortened and lighter version of the PKM/PKP, known as the PKZ has recently been developed, although its current status is unknown.

The Ohio Ordnance REAPR-338 uses the 8.6 × 63 mm (.338) Norma Magnum round to achieve extended ranges and increased on-target effects. US Special Forces are looking into acquiring weapons in this category. [Ohio Ordnance]

The Russian Ministry of Internal Affairs (MVD) reportedly had a requirement for an SAW in 5.45 × 39 mm, which saw the development of the Kord Tokar 2. Separately, the Kalashnikov Concern had developed their own SAW in 5.45 × 39 mm as the RPL-20, again geared towards the Ministry of Internal Affairs (MVD) requirement and also for the national guard, Rosgvardiya. Kalashnikov Concern has reportedly suggested that the Russian Army might be interested in the RPL-20 to supplement the PKM/PKP at the squad level. For the present, the Russian Army appears to prefer the longer-range and higher power of the PKM/PKP as its SAW.

New direction

In an ideal world, the future machine gun would offer more range and power than current systems, but without the penalty of increased weight from the weapon and its ammunition load. A move in this direction comes from SIG Sauer with their MG338 system that uses the 8.6 × 63 mm (.338) Norma Magnum round to achieve impressive results. Elsewhere, Ohio Ordnance has developed their REAPR-338 weapon, again using the Norma Magnum round, in response to a US Special Forces requirement known as LMG-M. This requires a weapon with a weight profile similar to the M240 GPMG, but capable of delivering greater range and enhanced on-target effects using a cartridge such as the Norma Magnum

Perhaps the successful fielding of a new weapon and round to meet the LMG-M requirement could change the state of play in the machine gun sector; perhaps it will be the XM250 and the 6.8 × 51 mm round that will be the catalyst for change? Or perhaps the majority of users will prefer to remain with the proven performance and reliability of weapons such as the FN MAG (known as the M240 in its US incarnation) or the PKM/PKP to meet their machine gun needs.

Serbia's Defence Industry: Achievements, Future Prospects, and Lessons Learned from the War in Ukraine

Dr Nenad Miloradović

Dr Nenad Miloradović, Serbia's Assistant Minister of Defence for Materiel Resources. [Serbian MoD]

In recent years, the war in Ukraine has dominated global geopolitical and security discourse. At the time of writing, a major diplomatic initiative – spearheaded by the world's leading powers – offers a potential pathway toward resolution. Yet, should diplomacy fail, the risk remains that the conflict could devolve into a protracted stalemate or escalate into something even more catastrophic. However imperfect or controversial, a diplomatic settlement would be vastly preferable – for the belligerents, their backers, and the broader international community. While future crises stemming from unresolved or "frozen" conflicts – so familiar to the Balkans – are always a possibility, they pale in comparison to the existential danger posed by unchecked escalation.

Regardless of how the Ukrainian conflict ultimately concludes, its repercussions are already shaping global defence postures. Across Europe and beyond, surging defence budgets, expanded production capacities, and continent-wide rearmament are now underway. The objective is clear: to achieve full readiness for a potential peer-to-peer conflict in Europe by the end of the decade.

Serbia's Defence Industry Strategy

Serbia is a militarily neutral country. Consequently, the capabilities of the Serbian Armed Forces (SAF) must be developed to align with the evolving European battlespace, to the maximum extent possible, ensuring the nation's independence and territorial integrity in what promises to be an unpredictable and unstable period ahead.

Historically, a strong defence-industrial base has underpinned Serbia's independence and neutrality, serving as a cornerstone of its defence strategy for nearly two centuries. For this reason, Serbia has invested in its defence industry almost continuously over the same period. The Serbian Ministry of Defence (S-MoD) plans and executes activities related to the industry's development. Its primary tools for achieving SAF capabilities and strategic goals include seven military technical institutions embedded within the S-MoD/SAF structure. At the forefront is the Military Technical Institute (MTI), Serbia's spearhead for defence R&D; Yugoimport SDPR, the country's most prominent producer of Armaments and Military Equipment (AME); and the Serbian Defence Industry Group (SDIG), a consortium of 17 state-owned factories.

The ongoing Defence Industrial Growth Plan (DIGP) aims to upgrade and modernise production lines in key defence technologies across these government-owned entities, while also enhancing the capacity of smaller, privately owned licensed AME producers (around 60 companies). In parallel, it fosters a growing ecosystem of SMEs, techno-parks, and university laboratories. The DIGP further emphasises partnerships with global defence companies for joint AME development and production in Serbia. Several collaborations with major European defence technology firms are already in motion, with more expected to follow.

Key Areas of Serbian AME Development and Production: Status and Prospects

Ammunition

Serbia's defence industry boasts a long tradition of ammunition production across all calibres and standards, both NATO and Soviet. This includes small arms, medium calibre rounds, artillery shells, tank ammunition, rockets, mortar bombs, grenades, guided anti-tank and air defence missiles, as well as guided and unguided airborne munitions. Increasingly, ammunition is also being designed for drones and unmanned aerial systems.

NORA B-52 NG SPH. [Yugoimport]

The industry is supported by Serbian manufacturers of energetic and pyrotechnic materials, which produce explosives, propellants, and rocket fuels renowned worldwide for their quality and competitiveness. Alongside these, Serbia produces the full spectrum of mechanical and electronic components – fuses, guidance blocks, seekers, and both metal and composite parts – enabling the development of new generations of "smart munitions" with enhanced precision, range, and lethality.

Artillery (Long-Range Precision Strike)
The SDI has developed a comprehensive portfolio of conventional and rocket artillery systems. Foremost among these is the NORA B-52, a 155mm wheeled self-propelled howitzer (SPH) with a range exceeding 40 km. Already in SAF service and exported to partners in Europe, Africa, and Asia, the latest M21 version features increased automation, improved accuracy, and extended range. Versions with ranges beyond 70 km are currently under development.

Rocket artillery programmes include three classes of modular multi-tube launchers – Morava, Oganj M18/24, and Tamnava – mounted on Serbian-built cross-country trucks (4×4, 6×6, 8×8). Highly mobile and digitised, these systems integrate modern fire-control architecture supported by mobile or UAV-based ISTAR assets. Capable of firing a full range of legacy rockets as well as modern guided munitions (122mm, 128mm, 262mm) with ranges of 40–70 km, they offer exceptional survivability and lethality on the modern battlefield.

Armoured Vehicles and Protected Mobility Systems
The SDI currently produces five types of wheeled armoured vehicles in multiple variants, with improved models in development. Two are based on monocoque steel armoured hulls with the latest Western suspensions, engines, and transmissions: the LAZAR L3/M 8×8 fighting vehicle, armed with a 30mm RCWS, and the MILOS/M 4×4 APC with 12.7mm/20mm RCWS.

Three additional vehicle types – M21 MRAP 6×6, BOV 4×4, and NTV/Hajduk 4×4 – serve in reconnaissance, command, and heavy-weapon carrier roles. All meet the latest standards of ballistic and mine protection while providing high mobility across rugged terrain.

Mechanised Forces Equipment
Two major upgrade programmes are underway: the M-84 AS-2 main battle tank and the M-80 AB1/2 IFV. Both platforms have been enhanced with next-generation armour (passive and reactive), battle management systems (BMS), counter-drone jammers, and, in future, active protection systems (APS). Their mobility has been significantly boosted with upgraded powerpacks and suspensions. Firepower has also been modernised with thermal imagers, advanced fire-control systems, and new-generation AP and smart munitions.

Soldier Systems
To meet SAF's requirement of increasing infantry firepower by 30%, the SDI has introduced a new generation of weaponry, night vision, communication systems, protective gear, and camouflage equipment.

The backbone is the MAP M-16 modular rifle family (rifle, carbine, LMG, sniper variant), capable of firing both 6.5mm Grendel and 7.62mm rounds. It integrates Serbian-made optics such as the NT35 thermal sight and ON4x32 day sight. Infantry squads are quipped with RBG grenade launchers (40x46mm and 40x51mm, range up to 800m). Sniper teams now field the M07 rifle (338 Lapua Magnum) and the DP12 anti-materiel rifle (12.7mm). Plans are in place to replace the M-84 GPMG with a new model chambered in .338 Norma Magnum.

Short-Range Air Defence and Counter-Drone Systems
The SAF's primary counter-drone and SHORAD platform is the PASARS M16, a hybrid self-propelled gun-missile system. The latest V4 version integrates a 40mm automatic cannon firing air-burst munitions, SHORAD missiles (MISTRAL, S2MA, RLN-IC), an AESA radar, a counter-drone jammer, an optoelectronic fire-control system, and full integration into higher-echelon air-defence networks – all mounted on a modern wheeled armoured platform.

Drones and Unmanned Systems
Serbia has developed two generations of Mali Milos tracked unmanned combat vehicles, as well as a logistic support vehicle. These are in service with SAF special and reconnaissance units, offering high mobility, strong protection, and silent movement thanks to electric propulsion.

In the aerial domain, Serbia has fielded three ISTAR/combat UAVs: VRABAC (40 km), SENKA (60 km), and Pegasus MALE (200 km), each capable of carrying reconnaissance payloads and launching guided or unguided munitions.

Loitering munitions under development include OSICA (25 km/2.5 kg warhead), STRŠLJEN (40 km/5 kg warhead), and GAVRAN (100 km/10 kg warhead). Additionally, SAF infantry and special forces are increasingly equipped with KOMARAC FPV attack drones (1-3 variants), including fibre-optic guided versions.

Conclusion

What is already clear is that Europe – and much of the world – is rearming at speed, moving toward new generations of weaponry, from unmanned systems to modernised legacy platforms, while dramatically expanding industrial capacity. This momentum is likely to accelerate through the end of this decade and beyond. In this process, Serbia cannot – and must not – fall behind.

MILOS 2 4×4 armoured tactical vehicle. [Yugoimport]

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