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Ukraine Back on the Offensive

Following a long wait, Ukraine has restarted offensive combat operations against Russia, starting in late-April, and gradually ramping up throughout May. The bulk of the offensive action around this time has been around the periphery of Bakhmut, where the Ukrainian Armed Forces have been attempting to push back Russian forces. While Ukrainian forces made incremental gains to both the North and South of Bakhmut in the first two weeks of May, since then, progress appears to have stalled. Looking at the area, the main effect of the offensive appears to have been forcing Russian forces backward to more defensible positions, to behind the Berkhivka Reservoir in the North, and to the other side of the water canal in the South.

On 20 May, Yevgeny Prigozhin, Head of the Wagner mercenary group, announced that Bakhmut had been fully captured by Wagner forces, thus ostensibly bringing to an end an eight-month long grinding battle of attrition. This claim was contested by President Volodymyr Zelensky, and Ukraine still claims to retain control of portions of the town, broadly understood to refer to Khromove in the North and a small neighbourhood in the southwest. These latter claims are somewhat tenuous. Realistically, the majority of Bakhmut hasn't been under Ukrainian control for some time, with Wagner in control of around 75-80% of the town since around mid-April. However, symbolism aside, it is unclear what has been gained by capturing the remaining 20-25%.

Elsewhere on 22 May, a raid was launched into Belgorod Oblast in Russia, ostensibly by two groups of pro-Ukrainian Russian paramilitaries – the Freedom of Russia Legion (LSR), and the far-right nationalist Russian Volunteer Corps (RDK). By 23 May, the Russian Ministry of Defence claimed to have pushed the groups back to the Ukrainian border, a claim assessed as "likely" by the Institute for the Study of War, following imagery analysis and geolocation of footage from Russian state media. Furthermore, both groups appear to be sponsored by Ukraine, given their use of western hardware including US M1151 HMMWVs, M1224 MaxxPro MRAPs, and Polish Dzik-2 protected patrol vehicles. Although the attack was repelled, it perhaps best served to embarrass Russia by demonstrating that its border with Ukraine is more porous than they would like.

Both sets of offensive actions – Bakhmut periphery and Belgorod – appear to be aimed at pushing Russia to divert forces and supplies away from the front lines, thereby leaving those areas of the line weaker for a breakthrough offensive by Ukraine's combat brigades. In the former case, Ukraine appears to be attempting to surround Bakhmut, thus potentially threatening Russian gains in what remains of the town proper. Similarly, Belgorod serves as a reminder that Russia does not have complete control over its border, and may be vulnerable to future efforts conducted by special forces groups or irregular saboteurs.

At the time of writing in late-May, it may be somewhat too early to tell what the impact of the Belgorod raid has been on Russian force concentrations. However, in Bakhmut, Prigozhin appears to be getting ready to move on, having announced that he would hand over control of the city to the Russian Army on 1 June. While it remains to be seen if this timetable will be kept to, it does open up the possibility of Wagner forces being freed up for redeployments to other areas. This could potentially include use of the group to shore up portions of the front lines where a breakthrough would most likely be attempted.

In terms of where that breakthrough would take place, the South still appears to be the most promising direction with respect to potential gains. In particular, securing Tokmak would allow Ukraine to threaten Melitopol' and exert pressure on all of Russia's forces on the East bank of the Dnipro, incentivising them to move back to more defensible positions closer to Crimea, and giving Ukraine's forces in Kherson the freedom to cross the Dnipro with much less risk. Indeed, the fact that Ukraine appears to be launching diversionary actions primarily in the North, would seem to suggest that they are keen to divert forces away from the South.

While it may still be some weeks before any major offensive is likely to start, Ukraine seems to be well aware that offensive action is needed – not just to recapture territory, but also to maintain pressure on the Russian armed forces, limiting their capability to regenerate. Indeed, Russia's strategy appears to have shifted to one of loss-avoidance while they regenerate lost capability. In this vein, the Russian MoD has continued to announce deliveries of new equipment, including T-90M MBTs, showing that the country still has the potential to re-equip its formations. If left unchecked, Russia could regain the capability to perform meaningful offensive action, posing serious problems for Ukraine going forward. Avoiding this is important for Ukraine, but engaging in large-scale offensive action against a dug-in opponent is risky, and leaves Ukraine little room for mistakes. All told, this coming summer may prove the decisive phase in the war, one way or another.

Mark Cazalet

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Cover Photo: A shot from underneath an I-HAWK launcher, on display at Gatow Airfield in December 2022.
Photo: Mark Cazalet

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More Weapons Pledged for Ukraine as Zelensky Tours Western Allies

(pf) Coinciding with a flying visit by Ukrainian President Volodymyr Zelensky to meet UK Prime Minister Rishi Sunak at his official country residence, Chequers in Buckinghamshire, on the morning of 15 May 2023, the UK government announced "the further UK provision of hundreds of air defence missiles and further unmanned aerial systems including hundreds of new long-range attack drones with a range of over 200 km.

"These will all be delivered over the coming months as Ukraine prepares to intensify its resistance to the ongoing Russian invasion," read a communiqué from the prime minister's office.

Photo: R Sunak/Twitter

While the provision of air defence missiles is likely to involve the Starstreak manportable air defence system already supplied to Ukraine, the mention of 200-km-range "long-range attack drones" does not match anything in the current UK armed forces inventory.

When ESD approached the UK Ministry of Defence (MoD) for further details, an MoD spokesperson replied, "I'm afraid we're not confirming anything further on the details beyond what's already in the press release."

The systems in question may well be loitering munitions (LMs) procured off the shelf from an ally. However, it is also possible that they are the result of an urgent operational requirement (UOR)-like UK development with provision to Ukraine specifically in mind.

UK defence research and development house QinetiQ, for example, is known to have been working on "a unique 3D-printed delta-wing 'suicide' drone" among various crash programmes designed to be ready in months rather than years for use by Ukraine.

The latest-announced UK munitions package for Ukraine follows UK Defence Secretary Ben Wallace announcing on 11 May that the UK would provide Ukraine with Storm Shadow air-launched deep strike cruise missiles. These weapons, which have a range in excess of 250 km, are likely to have been integrated onto the MiG-29s being donated to Ukraine by Poland and Slovakia. The UK is therefore at the forefront of providing Ukraine with long-range weapons that can reach behind the Russian front lines.

Prior to sweeping in and out of Chequers in a Royal Air Force Chinook helicopter, President Zelensky had visited President Emmanuel Jean-Michel Frédéric Macron in France on 14 May, where Macron pledged that France "will train and equip several battalions with dozens of armoured vehicles and light tanks, including AMX-10 RCs".

Previous French-supplied AMX-10 RC light tanks have already been deployed in Ukraine.

On 13 May, ahead of a visit by Zelensky to Berlin, the German MoD announced further arms deliveries to Ukraine worth EUR 2.7 Bn: its biggest package yet. According to the MoD, the package includes 20 more Marder infantry fighting vehicles, 30 Leopard 1 main battle tanks, four IRIS-T air defence systems, 15 Gepard anti-aircraft tanks, 200 reconnaissance unmanned aerial vehicles, anti-aircraft ammunition, additional artillery ammunition and more than 200 armoured combat and logistics vehicles.

Royal Navy Type 31 Frigates to be Fitted with Mk 41 VLS

(pf) The future Type 31 frigates to be operated by the UK Royal Navy (RN) will be equipped with the US-designed Mk 41 Vertical Launch System, RN-focused website Navylookout.com reported on 17 May 2023.

The website quoted RN First Sea Lord Admiral Sir Ben Key as saying at the First Sea Lord's Sea Power Conference in London on 17 May, "We also need to advance our ability to deliver lethal long-range offensive fires against our adversaries. Hence the decision to ensure the Mark 41 Vertical Launch Silo is fitted to the Type 26 and, I am delighted to say, we intend to fit it al-

Image: Babcock

so to our Type 31 frigates. This will enable potential use of a large variety of current and future anti-air, anti-surface, ballistic missile defence and strike missiles."

While the RN's future Type 26 frigates were always destined to have 24 Mk 41 'strike-length' VLS cells in addition to 48 vertical launch cells for SeaCeptor (CAMM) air-defence missiles, the Type 31 frigates were planned as lower-cost, general-purpose frigates that would conduct more lower-end RN operations compared with the more capable Type 26s. It was therefore stated by the then First Sea Lord, Admiral Sir Tony Radakin, in November 2021 that the Type 31s would be fitted 'for but not with' the Mk 41 VLS.

As well as air-defence and anti-submarine missiles, the Mk 41 VLS is capable of launching Tomahawk cruise missiles, giving ships hosting it a significant land-attack capability. In future the Mk 41 VLS will enable the potential use of a large variety of current and future anti-air, anti-surface, ballistic missile defence and strike missiles. These will include the Future Cruise/Anti-Ship Weapon currently being developed by MBDA, which will ultimately replace the Harpoon missile in RN service (an interim capability will be provided by the Kongsberg Naval Strike Missile).

How many Mk 41 VLS cells will be installed in the Type 31 frigates was not explicitly outlined, but navylookout.com noted that the ships were "built with the foundation structural seats for four eight-cell Mk 41 strike-length VLS modules".

When ESD approached the UK Ministry of Defence for comment on 18 May, an RN spokesperson said, "The Mk 41 Vertical Launching System will deliver surface-launched strike operations against a full spectrum of targets. Working closely with the US Navy, we have commenced an assessment phase to explore the options and costs associated with fitting T31 with Mk 41. It is too early to provide any further information whilst this commercially sensitive work is ongoing."

This assessment phase will determine configuration and installation options for the Type 31 fleet.

Babcock International was awarded a contract in November 2019 to build five Type 31 frigates. Construction of the first frigate, Venturer, began in May 2022 at Babcock's yard in Rosyth, Scotland.

German Tiger Combat Helicopters Will Not Be Modernised

(OH) The German government has decided not to participate in the Airbus Helicopters Tiger MkIII programme and to withdraw the Bundeswehr's Tiger combat helicopter from service in 2038, according to a report by the German Press Agency.

Thus, a decision that had been in the air for months now seems to have been made. German government opposition to the continued use of the Tiger had been in evident for some time. Meanwhile, no one from the German

Image: Airbus Helicopters

armed forces has publicly declared their support for the Tiger; there are apparently considerable doubts within the Bundeswehr as to whether the concept of a combat helicopter flying into territory defended by enemy forces still has a long-term future.

Moreover, in April the German government responded to a question from the CDU/CSU parliamentary group in the Bundestag by stating that it was not assumed that the possible modernisation of Germany's Tiger combat helicopters under a MkIII mid-life upgrade would significantly improve the material readiness of the fleet, although in its reply the government had stated that the decision had not yet been made. In addition, it emerged from the document that the Tiger's anti-tank capability was limited, in particular due to a lack of ammunition.

A lack of operational readiness

The Bundeswehr currently has 51 Tiger combat helicopters, for which the planned end-of-service date is set for 2038. For operation beyond this date the German government would have had to join the MkIII Midlife Upgrade Programme, under which the Spanish and French armed forces are planning to upgrade their Tigers.

However, the Bundeswehr has had considerable problems with its Tiger combat helicopter since their introduction and satisfactory availability rates could never be achieved. In May last year then defence minister Christine Lambrecht said that at that point only nine of the 51 helicopters were operational.

The latest report on the material readiness of the Bundeswehr, published by the Ministry of Defence in 2021, says of the Tiger, "The readiness of KH Tiger continued to be at an unsatisfactory level during the reporting period. The backlog of main inspections with a large number of aircraft due to a lack of docking capacities continues to affect the operational readiness of this system. The measures introduced to reduce the inspection backlog will not begin to take effect until the end of 2023 at the earliest. However, the complete elimination of the congestion is not expected before the end of 2026. ... The aim is to achieve a significant increase in material readiness at KH Tiger in annual steps up to 2026."

Light combat helicopter

Meanwhile, however, the German government has committed itself to providing NATO with 48 combat helicopters by the beginning of 2032. In order to compensate for the foreseeable capability deficits of the Tiger fleet and to relieve them, the German government is examining the introduction of a light combat helicopter.

Currently, the most likely option for such a light combat helicopter is the H145M from Airbus Helicopters. This type has already been introduced into Bundeswehr service as a light multi-purpose helicopter (the H145M LUH SOF) and is mainly used by the special forces.

The German government aims to have the procurement of light combat helicopters approved by parliament this year.

Turkey's Hürjet Advanced Jet Trainer Makes Maiden Flight

(pf) The Turkish Aerospace Hürjet advanced jet trainer, the country's first indigenously produced supersonic-capable jet aircraft, achieved its maiden flight on 25 April 2023.

Flying out of Turkish Aerospace's facility 20 km northwest of Ankara with Chief Test Pilot Ercan Çelik at the controls, the Hürjet was airborne for 26 minutes, during which it reached a speed of 250 kts (463 km/h) and attained an attitude of 14,000 ft.

As the aircraft landed and Çelik disembarked, he was embraced by Dr Ismail Demir, President of the Turkish Defence Industry Agency (SSB), in front of an applauding crowd.

With the first completed Hürjet prototype unveiled in Ankara in December 2022, Turkish Aerospace had originally planned to conduct the maiden flight of the Hürjet on 18 March, but the devastating earthquake that struck Turkey and Syria on 6 February inevitably delayed the programme. However, on 18 March the SSB did post a video taken that day of the Hürjet conducting taxiing trials.

Currently powered by a General Electric F404 turbofan, the Hürjet is designed to have a maximum speed of Mach 1.4, a service ceiling of 13,716 m (45,000 ft), a climb rate of 39,000 ft/minute, a range of 2,222 km and a payload capacity of 2,721 kg.

As well as being positioned as a platform that could replace older advanced jet trainers (AJTs) such as the Northrop T-38, Aero L-39 and BAE Systems Hawk with an aircraft that could train fifth-generation fighter pilots, the Hürjet is billed as a potent yet affordable light attack platform: potentially an attractive proposition for air forces that cannot afford to operate a full-on jet-powered strike aircraft fleet.


Photo: Turkish Aerospace

Turkish Aerospace has already secured orders from the Turkish government for four Hürjet Block 0 prototypes and 12 initial Block 1 AJT-configured aircraft as replacements for the Turkish Air Force's T-38 Talon AJTs.

Putin Oversees Much Subdued Victory Day Parade in Moscow

(pf) The Victory Day parade held in Moscow's Red Square on 9 May 2023 was not the one envisaged by Russian President Vladimir Putin when he launched the invasion of Ukraine on 24 February 2022.


Image: BBC videograb

Russia's 9 May Victory Day parades, which commemorate the defeat of Nazi Germany in the Great Patriotic War (Second World War), have historically been spectacles of pomp and ceremony. This year, however, amid the failing and costly 'military security operation' in Ukraine, many victory parades around Russia were cancelled and the main one in Moscow significantly pared down and closed to the public.

While the Moscow parade would typically have involved around 200 military vehicles (although there were only 131 last year), around 11,000 troops and featured a flypast by the Russian Aerospace Forces, this year's event involved just 51 vehicles, around 8,000 troops and had no military flypast. The parade also featured no modern main battle tanks or tracked infantry fighting vehicles (IFVs); it was led by a lone, Second World War-vintage T-34/85 – and even that, one observer pointed out on Twitter, was a post-war example manufactured by Českomoravská Kolben-Daněk (ČKD) in Prague.

Russia's latest main battle tank, the T-14 Armata, which has featured in the Moscow parade since 2015 but which has not thus far turned up on the battlefield in Ukraine, was this year absent entirely from either location.

Also absent on 9 May was any contingent from Russia's Airborne Forces (Vozdushno-

desantnye voyska Rossii – VDV), which took a mauling early on in the invasion of Ukraine.
The total complement of military vehicles in this year's Moscow Victory Day parade was as follows: one vintage T-34/85 medium tank, 13 Tigr-M 4×4 armoured personnel carriers (APCs), six VPK-Ural 4×4 protected utility vehicles, 10 Z-STS Akhmat mine-resistant ambush-protected vehicles, three BTR-82A 8×8 APCs, six 9P78-1 Iskander tactical ballistic missile transporter-erector-launcher (TEL) vehicles, six S-400 mobile air defence system TELs, three RS-24 Yars intercontinental ballistic missile TELs, and three VPK-7829 Bumerang 8×8 wheeled APCs.
Beyond the ongoing war in Ukraine, one ostensible reason for the scaled-back 9 May parade in Moscow was an attack on the Kremlin by a pair of small unmanned aerial vehicles (UAVs) in the early hours of 3 May. Claiming that this was an assassination attempt on Putin, Russia blamed Ukraine for the attack, which Ukrainian President Volodymr Zelensky immediately refuted, saying, "We don't attack Putin or Moscow. We fight on our territory."
The notion that this was a serious assassination attempt on Putin by Ukraine seems unlikely. A UAV seen being destroyed in CCTV footage (either being exploded deliberately or downed by local air defences) seemed too small to do significant damage, or to travel the roughly 460 km to Moscow from the Ukrainian border, and the Kremlin is not Putin's main residence anyway.
The attack could have been launched closer to Moscow by Russian dissidents, perhaps with a view to simply embarrassing the Kremlin, given that two freight trains were derailed in the Bryansk region between Moscow and the Ukrainian border on 1 and 2 May.
However, it is also plausible that this was a 'black flag' operation launched by Moscow to provide a valid excuse for a pared-down Moscow parade on security grounds.
Meanwhile, Russia's national Immortal Regiment events, in which since 2011 hundreds of thousands of Russians around the country march with the portraits of relatives killed in the Second World War, have been cancelled amid concerns that relatives would parade portraits of Russian troops killed in Ukraine.
"There is a fear that people will carry portraits of people who have been killed in Ukraine and the real casualty figures – not the ones presented by the Defence Ministry – will be visible," historian Ivan Kurilla told Radio Free Europe/Radio Liberty's (RFE/RL) Siberia.Realities programme prior to Victory Day. RFE/RL also noted in an article on 2 May that, of the 125 people detained for anti-war protests on Victory Day in 2022, many were arrested at Immortal Regiment events.
Moscow has continually sought to play down Russian casualties in Ukraine, but since the invasion was initiated analysis by BBC News Russian and Mediazone estimates Russia has suffered at least 58,600 troops killed and more than 205,000 wounded. Leaked US classified documents that began circulating in April 2023 put Russian casualties at somewhere between 189,500 and 223,000, including as many as 43,000 dead.
In the wake of a barrage of cruise missiles targeted at Ukrainian cities earlier in the day, Putin's Victory Day speech accused the West of "unleashing war against Russia" and "creating a new cult of Nazism".
There is a certain irony in Putin labelling Ukraine and its allies as Nazis during his May parade speech this year in an attempt to hark back to the honour of the Soviet Union. In 1941 Soviet leader Joseph Stalin invited the actual Nazis – senior officers from the Wehrmacht – to the Moscow military parade that took place on 1 May that year following the Molotov-Ribbentrop non-aggression pact signed by Nazi Germany and the Soviet Union in 1939. Stalin's interest in signing that pact was the German promise to cede eastern Poland and the Baltic states to Russia after invading Poland itself. As it turned out the deal meant nothing; Operation Barbarossa, Nazi Germany's invasion of the Soviet Union, began on 22 June 1941.

Bundeswehr Orders 50 More Puma IFVs

(pf) Germany's two top military vehicle makers, Krauss-Maffei Wegmann (KMW) and Rheinmetall, have been awarded an order to build a further 50 Puma infantry fighting vehicles (IFVs), the companies announced on 15 May 2023.
A contract worth EUR 1.087 Bn for the IFVs was issued by Germany's Federal Office for Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw) to Projekt System & Management GmbH (PSM) a joint venture of KMW and Rheinmetall Landsysteme. Of the contract total, EUR 574 M will go to KMW and EUR 501 M to Rheinmetall.
A framework agreement was also signed that will enable a subsequent call-off of further Puma IFVs.


Photo: KMW/Rheinmetall

In addition to the 50 Puma IFVs, the order also includes eight flight-phase simulators for the MELLS (Spike-LR) multi-role missiles that arm them as well as spare part packages and special tool sets. Furthermore, an option exists for additional driver training vehicles and the integration of a turret-independent secondary weapon system (TSWA). Deliveries are set to start in December 2025 and be complete by the beginning of 2027.
The Bundeswehr already has 350 Puma IFVs in its inventory and was set to order more when, during trials in 2022, the vehicles suffered extensive breakdowns. This latest Puma order is thus a resumption of plans to further build out the Puma fleet, with the vehicle's revealed defects apparently resolved.
The Puma IFV is the principal weapon system of the German Army's mechanised infantry units. It can carry nine personnel: a crew consisting of the vehicle commander, gunner and driver, plus a six-strong infantry section.
The vehicle has a basic Class A level of armour that can withstand 14.5 mm rounds and allows it to be airlifted in an A400M transport aircraft, while an add-on Class C armour package, which up-armours the sides and roof adds around 9 tonnes to the vehicle original gross vehicle weight of 31.5 tonnes. The vehicle is protected against mine charges of up to 10 kg, while the Pumas in German service also have a soft-kill Multifunctional Self Protection System (Multifunktionales Selbstschutz-System – MUSS).
The Puma is armed primarily with a Rheinmetall 30 mm MK 30-2/ABM (air-bust munition) autocannon, but also has a coaxially mounted 5.56 mm HK MG4 machine gun as well as a MELLS launcher mounted on the turret.
In February 2023 the BAAINBw ordered the comprehensive modernisation of 143 Puma IFVs in the Bundeswehr inventory that had not yet been upgraded to the latest S1 standard. The upgrade, to be complete in 2029, includes the integration of high-resolution day- and night-capable camera systems, the MELLS missile system and the integration of digital radio equipment.
The 50 newly ordered Pumas will also be built to the S1 standard.

Leonardo Delivers First ECRS Mk2 Radar to BAE Systems

(pf) Leonardo has delivered the first prototype European Common Radar System Mk2 (ECRS Mk2), which the company claims is the world's most capable active electronically scanned-array (AESA) fighter radar, to BAE Systems for integration onto the Eurofighter Typhoon, the

Photo: Leonardo

UK Ministry of Defence's Defence Equipment & Support (DE&S) organisation announced on 21 April 2023.

The prototype arrived at BAE's flight-testing facility at Warton in Lancashire on 31 March from Edinburgh, where it was developed and manufactured by Leonardo UK, DE&S noted. It will now undergo integration work and ground-based testing in preparation for first flights on a Typhoon in 2024.

The development of the ECRS Mk2 radar is taking place under a GBP 2.35 Bn (EUR 2.65 Bn) investment that integrates the new radar onto Royal Air Force (RAF) Typhoons via a Phased 4 Enhancement programme being taken forward with Germany, Italy and Spain.

The ECRS Mk2 features an innovative multi-functional array (MFA) that can perform both traditional radar functions such as search and targeting, as well as electronic warfare (EW) tasks. It is understood to feature greater sensitivity than other AESA fighter radars, giving unparalleled passive detection at a very long range and allowing the Typhoon to detect and attack enemy aircraft while remaining outside their engagement range.

The ECRS Mk2's EW capability, meanwhile, will allow it to locate and deny the use of an adversary's radar with a powerful electronic jamming attack while staying beyond the reach of threats.

"This delivery marks the next major step towards securing Typhoon's place in the future battlespace, ensuring that the UK retains the freedom to deliver air power wherever and whenever it is needed," Mark Stead, senior vice president for radar and advanced targeting at Leonardo UK, was quoted by the company as saying.

"The ECRS Mk2 will equip RAF pilots with the ability to locate, identify and suppress enemy air defences: a powerful combination of capabilities that will increase the Eurofighter Typhoon's lethality and survivability, and the survivability of other friendly forces."

Group Captain Mat D'Aubyn, the RAF's Air Capability Typhoon Programme Director, was quoted by DE&S as saying: "The new radar is eagerly anticipated as it will further enhance the superb capabilities of Typhoon and keep it at the leading edge of combat air for years to come."

With a view to the Italian Air Force's potential future adoption of the ECRS Mk2, Leonardo in Italy is also contributing to the radar's development, with engineers from Leonardo's Nerviano, Milan-based radar site having joined the team in Edinburgh. This collaboration, Leonardo explained, will enable acquiring system design capabilities that will ensure that the Italian Ministry of Defence has sovereign control over the new radar system at every stage of its operational life.

Technology from the ECRS Mk2 will also feed into the Global Combat Air Programme (GCAP) to develop a sixth-generation fighter, in which the UK and Italy are partners along with Japan.

Romania Retires its Last MiG-21 LanceRs

(pf) The Romanian Air Force (RoAF) officially marked the retirement of its fleet of MiG-21 LanceR fighters on 15 May 2023.

Ceremonies were held simultaneously at the 71st Air Base 'General Emanoil Ionescu', located in Câmpia Turzii, and the 86th Air Base 'Lieutenant Aviator Gheorghe Mociorniță', located in Borcea, which concluded with the take-off of the last three MiG-21 LanceR aircraft in operation at each of those bases. Those six MiGs then flew to the 95th Air Base 'Erou Căpitan aviator Alexandru Şerbănescu', located in Bacău, where the LanceR fleet was officially retired from service.

Several MiG-21 LanceRs had already been flown to Bacău over the last five months as their remaining flight hours expired.

Romania's National Defense Supreme Council made the decision to retire the RoAF's LanceR fleet on 18 May 2022, accelerating the RoAF's transition to the Lockheed Martin F-16. The RoAF currently 17 refurbished ex-Portuguese F-16AM/BMs (14 single-seat AMs and three twin-seat BMs), which were acquired between October 2016 and March 2021. An initial operational capability with the first 12 of these aircraft was declared in March 2019. The RoAF stated in December 2021 that it planned to acquire 32 ex-Norwegian F-16s to add to its current fleet. A EUR 388 M contract for these was signed on 4 November 2022, with first deliveries planned for late 2023.

Photo: RoAF

The RoAF first began operating Mikoyan MiG-21s in the 1960s, upgrading around 110 of these under an expensive contract with Israel's Elbit Systems between 1993 and 2002. In recent years around 16-18 single-seat MiG-21 LanceR C fighters and up to 12 MiG-21 Lancer B twin-seat conversion trainer variants remained of this fleet. However, these aircraft were only used for air policing missions and were grounded multiple times (most recently in April 2022) due to their high accident rate (one crashed on 7 July 2018, for example, and another on 2 March 2022, although the latter may have been mistakenly shot down by Ukrainian air defences).

The last European operator of the MiG-21 is now the Croatian Air Force, which still has 12 MiG-21BisD/UMD aircraft in service. These will be retired in 2024 and replaced by 12 ex-French Dassault Rafale F3Rs.

Rest of German Puma IFV Fleet to be Upgraded to S1 standard

(pf) Germany's Federal Office for Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw) has awarded Projekt System & Management GmbH (PSM), a joint venture of Krauss-Maffei Wegmann (KMW) and Rheinmetall, a contract to retrofit a further 143 Puma infantry fighting vehicles (IFVs), the companies announced on 19 April 2023.

Photo: KMW

In doing so, the German government is exercising two options contained in the original contract for retrofitting original Puma IFVs to the new S1 design standard. That contract, worth EUR1.04 Bn, was signed in June 2021 and covered 154 Pumas.

The value of the latest contract is in the region of EUR 770 M.

This upgrade contract will see the key capabilities of firepower and command and control of all 143 Puma IFVs brought up to the S1 standard by 2029.

"Exercising these options assures that every Puma in the Bundeswehr inventory will conform to the uniform S1 design status," Rheinmetall stated in a press release. "Among other things, the retrofit includes integration of high-resolution day- and night-capable camera systems, the MELLS multirole lightweight missile system (the German designation for the Israeli Rafael Spike LR), digital radio equipment, and the IdZ-ES expanded future soldier system.

The Bundeswehr has a total fleet of around 350 Puma IFVs, which began to enter service in June 2015. With 40 Pumas initially upgraded to S1 standard to serve with NATO's Very High Readiness Joint Task Force (VJTF) under a July 2019 contract and then 154 IFVs covered under the June 2021 deal, this latest contract to upgrade 143 IFVs means that all Pumas apart from 13 driver training vehicles will have been upgraded to the S1 standard by 2029.

Public Accounts Committee gives UK MoD's Equipment Plan a Mauling

(pf) The UK Ministry of Defence (MoD) Equipment Plan for 2022-2032 "has failed to adapt to a more volatile world", frequently suffers from major programmes being delivered "many years late and significantly over budget", and is overly optimistic in claiming to be affordable, according to a report by the UK House of Commons Committee of Public Accounts published on 19 April 2023.

Photo: Crown Copyright

Noting that the UK must once more consider the possibility of fighting a land war in Europe, and that the MoD had emphasised that UK membership of NATO was central to its defence strategy, the Committee noted that the MoD "acknowledged there is significant risk that the UK could not fulfil its commitment to provide NATO with an operational Army division to fight such a war. Indeed, at the moment the UK must rely on its NATO allies to fill gaps in defence capabilities, such as the lack of long-range airborne early warning radar."

The Committee also pointed out that the 2022 to 2032 Equipment Plan, based on financial data as at 31 March 2022 and published in November 2022, was already out of date and did not reflect lessons learned from Ukraine, such as the need for hard-edged, conventional warfighting deterrence and larger munitions stockpiles. Other strategic developments have also not been taken account of, the Committee asserted, such as the UK's combat air partnership with Japan and Italy under the Global Combat Air Programme (GCAP), announced in December 2022, and the September 2021 AUKUS strategic partnership with the United States and Australia.

While acknowledging that the British Army's much-delayed Ajax AFV programme had finally completed its user validation trials after mitigating issues with noise and vibration, the Committee stated, "Even when Ajax is finally introduced, it will not operate to its full potential without the Morpheus communications system. … However, Morpheus has also been delayed, having originally been due by the end of 2021. As a consequence, Ajax will be fitted initially with Morpheus's predecessor, Bowman, which does not have the same integration capabilities. The Department [MoD] was unable to tell us when Morpheus would enter service, but the military planning assumption is that this will be towards the end of the decade."

Regarding the MoD's budget assumptions, the Committee asserted that the Equipment Plan's affordability still relies on over-optimistic assumptions about the cost of programmes and the efficiencies and cost reductions that can be achieved.

"Although the Department assesses that the Equipment Plan is affordable over ten years, this obscures significant financial pressure. There is a deficit of GBP2.6 billion over the first seven years of the Plan and the ten-year plans of four of the six Top Level Budgets are in deficit. Most notably the Army's forecast costs are £2 billion more than its budget," the Committee warned.

"Overall affordability is based on potentially over-optimistic assessments of project costs, with the Department's Cost Assurance and Analysis Service estimating that costs could be at least GBP5 billion higher than forecast," it added. "The Plan's affordability also relies on the Department achieving a GBP5.2 billion surplus in the final three years of the Plan, and on the Department achieving all cost reductions and efficiency savings included in the Plan. This includes GBP2.1 billion in the next three years which Top Level Budgets do not yet have plans to achieve. We doubt that the Department can achieve all these savings, but its contingency to cover any shortfall during this period is just GBP0.5 billion." Further to these concerns, the Committee noted that the Equipment Plan's affordability also relies on some projects being delayed, with the MoD having reduced project cost forecasts by GBP13.2 billion to reflect this, and that the UK's worsening economic environment had simply been ignored.

"The Department has not included external cost pressures, including inflation and foreign exchange movements, in its central assessment of the Plan's affordability," sated the Committee. "This is despite identifying when it produced the Plan that inflation could increase project costs by up to GBP2.1 billion over ten years. It did not include this inflationary pressure in its affordability analysis despite it being more than 80% of the Plan's forecast surplus of GBP2.6 billion. Inflation has since risen higher than the March 2022 forecast, and the Department accepts it will struggle to manage affordability as a result.

"Further, the pound to dollar exchange rate has remained below the Plan's worst-case scenario for several months, increasing the cost of several major Plan programmes," the Committee pointed out. "In the worsening economic environment, there is an increased possibility that some of the GBP25 billion of risks that the Department deemed unlikely – and has not included in cost forecasts – may occur, further increasing pressure on the Plan. Cost of living increases caused by rising inflation also mean that the Department might struggle to attract and retain staff with the skills it requires to deliver equipment programmes. We do not think that the Department has sufficiently taken these factors into account when considering the affordability of the plans."

In response to the Committee's report, an MoD spokesperson stated, "The Public Account Committee's assessment that our Equipment Plan does not align with the lessons learnt from the Ukraine conflict is unsubstantiated. The lessons we have seen from Ukraine have largely confirmed our 2019 warfighting analysis, which underpinned our subsequent investment decisions – meaning we have not needed to substantially reform our equipment pipeline. "Nor do we recognise the broken procurement system painted by this report. The Department routinely assesses time, cost and risk factors on all projects, and delivers the vast majority on time and in budget, and we have made numerous changes to improve procurement practices where projects have fallen short. Some of these projects are decades long, and many of our reforms will take time to deliver results." On 13 March 2023 the UK government announced that it had committed to an additional GBP 5 Bn in defence funding over the next two years "to meet the challenges of an increasingly volatile and complex world". Inflation, however, will inevitably take its toll in this uplift. According to UK Treasury accounting UK defence spending was GBP 71.4 Bn in 2021/22, so, with UK inflation currently running at 10.1% (March 2023), the UK defence budget would need to be GBP 78.6 Bn for the year just to keep pace with it – and a GBP5 Bn rise over two years does not reach that figure. UK Defence Secretary Ben Wallace had argued for a GBP 10 Bn spending boost. Thus, unless inflation can be tamed, the announced additional GBP 5 Bn will see no increase in defence spending in real terms.

Photo: Rheinmetall

Rheinmetall and Ukroboronprom to Co-operate

(pf) Germany's Rheinmetall and Ukrainian state-owned arms manufacturer Ukroboronprom have entered into a strategic co-operation agreement, Rheinmetall announced on 13 May 2023.

Co-operation between the two organisations is intended to strengthen the Ukrainian defence industry and ultimately its national security through the step-by-step creation of joint defence technology capabilities that will be resident in Ukraine.

"Under this agreement Ukraine will benefit from a comprehensive transfer of technology, the creation of additional defence technology capacities in Ukraine, additional local valued added, and the short-term delivery of military equipment from Germany," Rheinmetall noted in a press release. "To begin with – subject to official approval – a joint venture will be set up to serve as a bridge between Rheinmetall and Ukraine's existing state-owned defence sector. Closing is scheduled for the end of June 2023, and the joint venture is expected to be operational from mid-July 2023."

"Meeting Ukraine's urgent needs in its fight for freedom and democracy as quickly as possible [following the Russian invasion of February 2022] is a matter of central importance to us at Rheinmetall," the company's chief executive, Armin Papperger, was quoted as saying. "Thanks to its expertise and capabilities, Rheinmetall has what it takes to be a valuable and powerful partner to Ukraine, both in the short term and in the long run. We are pleased to have Ukroboronprom, led by Yuriy Husyev, as a very capable and trustworthy partner at our side.

"We are proud that Germany is doing everything it can to help the people of Ukraine – be it in the form of humanitarian aid, financial support or military equipment," Papperger continued. "Here, Rheinmetall works closely with the German government, assuring that help reaches Ukraine as quickly and efficiently as possible. In times of change, we take responsibility by doing our part to secure peace in Europe."

Yuriy Husyev, the General Director of Ukroboronprom, was quoted as saying, "I am honoured to set up the joint venture between one of the world's leading manufacturers in the defence industry, Rheinmetall, and the leading, full-scale operating, Ukrainian defence producer, which [has] increased the production of military equipment and armoured vehicles despite of numerous Russian missiles attacks: the State Concern Ukroboronprom. Already working 24/7 for the victory, Ukroboronprom can do even more while having such a partner as Rheinmetall. We are thankful to Rheinmetall for their willingness to help us defeat Russia. We will do all our best to make this co-operation useful to defence forces of Ukraine as soon as possible."

As a first step, the maintenance and repair of vehicles transferred to Ukraine under the German government's multilateral 'Ringtausch' equipment exchange projects, as well as those directly supplied to Ukraine, will form the foundation of initial co-operative measures. In later phases, based on a comprehensive transfer of technology, the co-operation partners intend to jointly produce selected Rheinmetall products in Ukraine.

Further ahead, co-operation between Rheinmetall and Ukroboronprom could also involve the joint development of military systems by teams of Ukrainian and German specialists, including for subsequent export from Ukraine, Rheinmetall noted.

Embraer signs MoU with Portuguese Aerospace Firms

(pf) Brazilian aerospace manufacturer Embraer announced on 24 April 2023 that it had signed a memorandum of understanding (MoU) with a number of Portuguese aerospace companies.

The signing of the MoU took place during a visit to Portugal by Brazilian President Luiz Inácio Lula da Silva at an event also attended by Portuguese Prime Minister António Costa.

The Portuguese signatories to the MoU were Centro de Engenharia e Desenvolvimento de Produto (CEiiA), Empordef Tecnologias de Informação (ETI), GMVIS Skysoft (GMV) and OGMA.

"I'm very pleased to celebrate a new phase in the relationship between Embraer and the Portuguese State through the defence industry of Portugal, which is a reference for us in co-operation in aerospace and defence projects," Embraer quoted its President and CEO, Francisco Gomes Neto, as saying in a press release. "The results of the C-390 Millennium [airlifter] strategic partnership have shown the potential that companies and governments of the two countries, working together, can achieve," he added.

The main goal of the MoU is the development of the technological and defence-industrial base of Portugal, reinforcing its capacity to develop engineering, research, and development activities and Embraer's role in making that happen.

A key aspect covered by the MoU is the potential strategic relationship for the development and systems integration of Embraer's recently launched A-29N version of the Super Tucano turboprop trainer/light attack aircraft, which is intended to address the needs of NATO member states.

Photo: Embraer

This includes research, technological development, and innovation, with the aim being to expand and increase long-term commercial relations between companies during the development, production, and operation/support phases of the A-29N programme.

"Today, with the signing of this memorandum, we take another important step in the continuous development of technologies related to the A-29 Super Tucano," Bosco da Costa Junior, President and CEO of Embraer Defense & Security, was quoted as saying. "The interest of NATO countries in this aircraft led Embraer to announce recently the launch of a new version, the A-29N, which we are sure will achieve great success in the international market."

The State of Autonomy, AI & Robotics for Russia's Ground Vehicles

Samuel Bendett

The war in Ukraine has thrust the issue of autonomy and artificial intelligence (AI) literally to the frontline, with both belligerents aiming for, and actually utilising various degrees of AI and autonomous operations. At the time this chapter was written (spring 2023) the Russian military has displayed a limited range of ground weapons and systems considered 'autonomous'. Likewise, Russia's supposed application of AI for the military has been either very limited, or not utilised on the scale of their Ukrainian opponents, owning to a number of economic, industrial and military factors.

In this war, the autonomy in ground vehicles is so far limited to mostly remote-controlled systems, owing first and foremost to the Russian military's approach and capacity to develop such technology, along with a very complicated Ukrainian battlespace teeming with countermeasures. By May 2023, there was yet to be an example of an actual ground autonomous system used in direct combat, although some open-source data suggests that certain types of uncrewed ground vehicles (UGVs) may already be utilised. This chapter will review Russian concepts and approaches to utilising UGVs as a military asset, with an eye towards deployment in Ukraine. Given the ongoing hostilities, it is likely that some information contained therein may be outdated by the time this chapter is in print, in which case this manuscript should be treated as part of a body of analytical literature examining the state and nature of Russian military autonomy and AI research, development, testing and evaluation.

Credit: RIA Novosti

Front view of the tracked version of the Marker UGV.

Russian Military AI and Autonomy for Ground Systems

This chapter will concentrate on the most recent developments that impact how the Russian military conceptualises UGV applications in combat. This effort is facilitated and aided by a number of Russian government departments, offices and initiatives, launched over decades to guide the military's thoughts and developments in autonomy and robotics. One of the most impactful developments so far is the Ministry of Defence's (MOD's) launch of the Main Department for Artificial Intelligence in August 2022. Its responsibilities point to its role as the main AI node in the military's research and development ecosystem, with authority on AI use and implementation across the force, roughly equivalent to the US Department of Defense's JAIC (Joint Artificial Intelligence Center). While multiple autonomy and AI efforts are already taking place across the MOD institutions, this AI Department is likely to manage technologies, efforts and lessons learned by the Russian military to date, along with the funding to invest in ready systems, products and weapons.

In fact, the Russian state media confirmed that this Department is using the experience gained in Ukraine to increase the effectiveness of its weapons, albeit without going into additional details on how that's accomplished. The Department's newly appointed director, Vasily Yelistratov, confirmed that AI technologies are used in Russian high-precision weapons as a cross-cutting technology in ground-, air-, and sea-based systems. In what has become an official byline in the MOD's high-tech research community, Yelistratov notes that wars of the future will be wars of machines, emphasising the human-out-of-the-loop goal to eventually minimise human losses. With such sentiment common across the

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Russian military, the MOD so far does not spell out publicly how it intends to graduate from a human-intensive combat of today to the environment where humans have a lessening, and eventually, a disappearing, role in combat.

Another recent official development that sheds light on the MOD's envisioned autonomy is the "Concept of the Russian Armed Forces activity in the development and use of weapons and systems using artificial intelligence technologies" (AI Concept), first unveiled in July 2022, and then in March 2023 at the United Nations. This public document effectively enshrines a human-in-the-loop as the current guiding authority, such as the need to maintain human control over a military machine to uphold compliance with the existing norms of international law. This document maintains that such control should be exercised by means of limitations on types of targets, duration of operation, geographic scope and scale of use; admitting persons who have successfully mastered the procedures of responsible use of AI-enabled weapons to management and control roles; and ensures human control over the production process of separate military elements and products. The document notes that responsibility for using weapons systems with AI technologies lies with the official who assigns a task to such weapons and gives the order to use them. The Concept also directs that a human should remain responsible for decisions to develop and use AI-enabled weapons throughout their life cycle, as well as in accordance with applicable norms of international law, including by ensuring operation of such systems within a responsible command and control (C2) chain.

These two official developments point to an evolving concept that builds on the MOD's "Creation of Prospective Military Robotics through 2025" classified target programme launched in 2014 as the main roadmap for the development of aerial, ground and maritime robotics. To augment this process, the MOD has also developed a concept for the military robotics use through 2030. A major consideration and backdrop for the above-mentioned initiatives are Russia's significant human, material and technical expenditures in its Ukraine invasion that place an emphasis on developing and using weapons and systems operated by humans, in a direct or remote-controlled fashion. Yet the MOD's deliberations on AI and autonomy often include debates on the degree of such technology's evolution as either an eventual, unavoidable or a limited human substitute.

Credit: Russian Foundation for Advanced Research Projects in the Defence Industry

Nerekhta UGV during winter tests in Russia.

Credit: Russian MoD

Uran-9 UGV on display in Russia.

One such recent discussion in an MOD-run Voennaya Mysl' (Military Thought) publication, which aims its content at the active and retired military/security professionals, points out that AI as a computer phenomenon does not have the intellectual abilities of a person. The article specifically points out that the main difference between intellectualisation (human-like AI performance) and automation (limited set of pre-assigned tasks) is the computer's ability to make decisions in conditions of significant uncertainty, based on heterogeneous and incomplete information, frequently changing situations, including those outside the programmed algorithms.

This particular discussion notes that if AI has the ability to make decisions in a variety of, and in rapidly changing situations in a similar manner to a human, then the key point should be the system's independence to analyse data, make decisions and implement them without agreeing with a human, whether it be an operator, owner or a programmer. A military system endowed with such AI should theoretically be more independent than just a simple automated technical device, with the ability to draw conclusions and make decisions depending on the ongoing information analysis.

More specific to the UGV concept, some Russian military academics think that increasing the degree of intellectualisation as a result of autonomy in the vehicle's C2 should be carried out gradually. Such a campaign will progressively reduce the

Credit: RIA Novosti

Marker wheeled version during testing.

role of the operator in managing the UGV to authorising various actions, such as the procedure for using weapons or a route to a designated point. This would eventually exclude a person from direct participation by reducing operator role to task setting and controlling a robotics group on a given mission. Considering the psychological, mental and other limitations of human decision-makers' abilities, as well as the currently modest role of automation in decision-making, Russian MOD researchers think there is a growing need to use 'intelligent' systems for planning and managing daily and combat activities to transform unstructured data into knowledge ready for immediate use. In their deliberations, goal-setting is currently only the prerogative of humans, but since AI systems could be more and more scalable, the volume of 'human' functions transferred to them could also increase.

This and similar Russian military debates point to AI's potential for self-learning and adaptation, changing its algorithms to achieve a desired result via external conditions or stimuli. The potential concern is that such a military system could independently change and improve the software originally embedded in it via self-programming, therefore solving problems that were not foreseen during the initial creation of this particular system. It is likely that the MOD's AI Concept was finally unveiled to address such concerns, by assigning human responsibility to as yet an unknown set of AI military developments.

Russian military academics and experts are also trying to understand how AI can simulate human commanders' decision-making in combat. According to some in the MOD, neural network training is carried out on a sample limited by the knowledge of experts, as well as by the amount of information in official documents and manuals, leading to the conclusion that AI would not be able to copy actual human thinking. This current level of training can lead to the AI adopting solutions that do not go beyond the boundaries of the training sample itself. At the same time, ingenious, resourceful, creative and high-risk solutions usually associated with human thinking in critical and stressful situations would be ignored or simply go unlearned.

This means that there could be situations on the battlefield in which the AI, unlike the human commander, would not be able to make an actual 'intelligent' decision. To the MOD, the human, as a 'biological prototype' of an artificial neural network, arrives at knowledge throughout their life under the continuous influence of internal and external factors. It is this large volume of specified conditions and actions – that is, an entire lifetime of experience – that "does not fit into any computer program in principle". In 'practical UGV terms,' this implies:

- recognising different levels of incoming threats;
- quickly identifying the battlefield environment and terrain for subsequent action;
- determining and understanding the nature and extent of physical obstacles;
- coordinating with different ground and air-based assets for battlefield management;
- considering different levels of uncertain and unpredictable factors as a result of planned or accidental conditions on the battlefield;

Added to these will be many other criteria associated with modern combat like the one taking place in Ukraine. Some of these issues can be mitigated by constant training and updated data sets via an increasingly sophisticated AI learning modules, but the full extent of a UGV mimicking intuitive human behaviour is probably uncertain and unlikely.

Therefore, if human experience is a factor that any advanced intellectual systems cannot replicate, then AI would remain limited in its capability, even if it could offer quick and precise calculations and conclusions. This concept of an AI as a decision-making tool that aids humans is a key principle articulated across the Russian MOD today, despite engaging in discussions on the more futuristic capacity across the nation's military forces. Going forward, the MOD's priorities include introducing AI elements into drone control systems, swarm development, man-unmanned teaming (MUM-T), and integrating these systems in a common operating environment with manned aircraft. AI tests to enable multiple ground robotic systems are supposedly taking place across the Russian military industry and services. It is not clear to what extent the Ukraine war has affected such priorities, but for now there is no indication that the MOD is deviating from such long-term plans.

Credit: TV Zvezda

Kungas UGV family during tests in Russia.

Russian Military UGVs in Practice

As of 2023, Russian military developers have created multiple combat and support UGV systems, including Platforma-M, Nerehta, Soratnik, Kungas, Vihr, Shturm, Marker, Uran-6, Uran-9, Prokhod, Scarab, and Scorpion, to name a few. By May 2023, some of these were already used in Ukraine as remote-controlled systems, with the operator in firm control and relative proximity to the UGV itself. In July 2022, the Russian military tested the 'Prohod-1' demining UGV in Ukraine's Donbas region to clear mines and unexploded ordnance (UXO). The Russian MOD also noted that Prohod-1 was tested in Syria alongside Uran-6. Russian military sappers used the 'Kobra-1600' UGV in Ukraine for ISR and detecting unexploded mines, missile fragments and improvised explosive devices. The Russian military is also using Uran-6 demining vehicles to clear large areas of UXO across Donbass and southern Ukraine.

In April 2022, Russia pledged to begin live-fire tests of the Shturm heavy strike robot designed primarily for urban combat, which is being created on the basis of the T-72. It's not clear if the tests that involved firing at targets from a 125 mm gun were actually carried out, given a lack of subsequent media coverage. The same can be said about most of the UGV projects named above – after initial testing of Kungas, Vihr, Nerehta and Soratnik UGVs, they were either designated as test platforms for subsequent designs, or the Russian media went quiet on their continued development. For now, the biggest questions arising from Russia's pre-Ukraine invasion development of combat UGVs is their absence from frontline combat in the current war.

This absence is most likely defined by the 2018 Uran-9 UGV stress tests that took place in Syria. After a comprehensive analysis of Uran-9 failures, the Russian MOD indicated that for the next 10-15 years, one-time and preferably stationary UGV use is likely the most viable approach to employing them. Examples include 'one-off' or 'kamikaze' attacks against adversary hard points and immobile targets. The current UGV generation's ultimate combat mission is to be expendable as a complement to other systems, forces and units. The logistical and human-intensive difficulty of trying to retrieve damaged or destroyed UGVs should outweigh their production and development costs. Therefore, post-Uran-9 MOD directives proposed that such combat vehicles should be used with other military formations and never on their own, since their breakdown would negatively impact the speed and effectiveness of a military mission. In 2019-2020, the Russian military took delivery of a limited number of Uran-9 UGVs, presumably for testing and evaluation, but this was likely delayed due to the human and material resource allocation for the Ukraine war.

Credit: RIA Novosti

Uran-9 UGVs prior to 9 May 2019 parade in Moscow

Credit: RIA Novosti

Wheeled Marker UGV during tests with a small quadcopter

The Russian MOD's wish list for combat UGVs includes autonomy for faster decision-making, especially in the rapidly-changing urban combat environment. Some Russia-based military experts think that fully autonomous combat systems capable of seeking targets on their own could appear in several decades, based on the current evolution of AI technologies. The key characteristics for uncrewed and autonomous ground combat should include maximum unification, modularity, multifunctionality, compatibility with different systems, and the ability to integrate into existing and future military formations. Such platforms should enable information exchange between UGVs when part of a mixed group or a swarm of different ground and aerial vehicles, including with crewed systems, and be resistant to countermeasures.

Practical Combat UGV Application

In February 2023, Russia's Dmitry Rogozin, a former director of Roscosmos who now operates in the Ukraine's Donbas region, announced that he had taken delivery of several 'Marker' UGVs. He promised to start uploading target images and combat algorithms to the vehicle's C2 modules, and to install anti-tank weapons to possibly confront Western-provided M1 Abrams and Leopard 2 tanks. This marked the first appearance of a combat UGV in Ukraine, although ques-

Credit: RIA Novosti

Marker wheeled version during winter testing in Russia.

tions remain why Rogozin – who is now a private citizen – and not the actual MOD was tasked with this testing and evaluation.
Russia's Marker UGV was developed jointly by the Advanced Research Foundation (ARF, Russia's DARPA-like organisation) and Android Technologies, one of Russia's major robotics developers. Marker is a testbed for autonomous, robotic and AI technologies such as computer vision, communications, navigation, autonomous movement, and group control. By early 2023, there were several tracked and wheeled versions, including a reconnaissance UGV with a tethered unmanned aerial vehicle (UAV) drone for better intelligence, surveillance, and reconnaissance (ISR). Additionally, there is a combat version which can be armed with anti-tank guided missiles (ATGMs), automatic grenade launchers (AGLs), machine guns and/or pods capable of carrying UAVs or loitering munitions.
The Marker guard version is equipped with day and infrared cameras. The Marker was tested as a counter-UAV platform prior to the February 2022 invasion, as a defence against small drones that have become so prevalent in Ukraine war. There is also a Marker logistics version for cargo transport and medical evacuation. Rogozin's plans include testing the combat version with anti-tank missiles, and to test Marker's tethered drone as a reconnaissance platform, with the UGV hidden from potential Ukrainian countermeasures.
One of Marker's key roles is the coordinated autonomous action in an uncertain environment to perform tasks independently at a great distance from the operator, via deep neural networks to assist the vehicle's decision-making. The ARF also envisions Marker learning human voice commands, after it tested voice control technology for MUM-T. Marker's technical solutions such as AI, machine vision, and group control can be potentially scaled to the level of a large tank or other uncrewed ground vehicles, hinting at the possible future plans if this UGV passes the envisioned tests in Ukraine.
In 2021, Marker's developers conducted an experiment with several UGVs that travelled across forested terrain on their own to a pre-selected destination. Rogozin's test plans include Marker supposedly distinguishing adversary vehicles in battle via datasets. It's not clear whether such datasets will come from the ARF and/or Android Technologies, or Rogozin's organisation can acquire them elsewhere. There are Russian companies working on similar image recognition mechanisms for military UAVs' AI-enabled C2. This claim concerns neural network learning algorithms to identify NATO military equipment in a wide variety of environmental conditions, including short exposure times. This data could potentially aid in Marker tests, assuming Rogozin can acquire such datasets.
It's unclear whether Rogozin's experiment will involve:

- a fully remote-controlled Marker version to mitigate against Ukraine's battlefield complexity and uncertainty;
- a human-in-the-loop approach, with Marker travelling autonomously and an operator making the final target selection and termination decision, or;
- a human-on-the-loop approach, with Marker selecting and deciding which targets to strike on its own, with the operator making the final approval.

It's likely that the Marker ISR version can be best applicable to Ukraine. This will involve the UGV launching a tethered drone that runs on a power cable to a height of 150 m while its positioned behind cover to avoid detection, allowing the vehicle to 'see' up to 15- 20 km as part of a solution to provide key battlefield observation and situational awareness. If both claimed tests are unsuccessful, the UGV can be used as dug-in stationary gun platform, a plausible tactic indicated by the Russian MOD's review of Uran-9 performance in Syria.

Credit: Rusandroid, via Wikimedia Commons

Tracked Marker UGV during tests in Russia

Riding forward with UGVs?

Following the Russian military's disastrous performance in Ukraine, some Russian military commentators put forth ideas for potentially improving

tank and ground warfare operations. In June 2022, Victor Murakhovsky, editor-in-chief of the highly-respected Russian Arsenal Otechestva (Arsenal of the Fatherland) magazine, proposed that the main area for improving tank performance is in situational awareness and C2. Murakhovsky proposed equipping a tank with micro-drones that will operate within line-of-sight, up to 4-5 km, at range where adversary ground forces tend to concentrate, to more accurately guide tank shells to target and avoid detection. Likely influenced by significant losses among Russian tank crews in the opening months of the invasion, Murakhovsky noted the gradual automation and robotisation of combat processes inside the tank and reduction of the crew as another prospective development for tank warfare. Murakhovsky deliberated that in the near future, mixed formations made up of crewed tanks and uncrewed vehicles could take to the battlefield. In this scenario, remotely controlled robotic tanks could be the front offensive echelon to conduct reconnaissance, provide security, and perform other tasks in place of today's manned tanks.

Credit: Russian MoD

Uran-9 UGV during tests in Russia.

While in Syria the Uran-9 failed in the roles Murakhovsky prescribed to the future combat machine, the Marker can once again try to prove whether such roles are in fact technically feasible in the first place, given the complexity of the Ukrainian battlefield, and presence of numerous countermeasures that include plentiful commercial drones for target spotting and reconnaissance. Other

Credit: Sputnik

Udar UGV in testing.

Russian MOD UGV proposals point to a semi-automatic control system that works in MUM-T mode. In this envisioned scenario, a combat UGV moves between infantry soldiers, and its course can be corrected by the nearest fighter using voice commands. Combat UGVs could also move ahead of the infantry, focusing on the movements of neighbouring soldiers.

The Russian military experts are deliberating other UGV concepts and tactics, such as envisioning teams of light and heavy UGVs working with UAVs in storming an urban target. Such teamwork involves ISR and strike units to uncover the adversary's weapons and defences, followed by the aerial reconnaissance and combat UAV group made up of quadcopters and light drones that carry out strikes on the enemy using guided munitions. In the meantime, a long-range aerial reconnaissance UAV group carries out constant surveillance. Then, heavy combat UGVs are envisioned to take up firing positions under cover of artillery fire and attack their targets. The engineering UGVs then make passages through the remaining enemy defences. Medium and light UGVs cover the attacking units with suppressing fire, hitting enemy firing positions in buildings or defensive structures. Should the adversary prove resilient, remote-controlled platforms with explosive charges are sent to the target and detonate. After that, the target area is fully captured by motorised rifle and assault units.

This UGV-UAV team concepts can be potentially applied outside of urban combat settings, in countering a peer adversary's forces and attritting their capabilities with the increasing use of uncrewed ground assets acting in concert with other weapons systems. Some of the UGVs envisioned in this scenario are remote-controlled, others are semi-autonomous, and some can be fully autonomous within the narrow confines of their mission sets. Prior to the Ukraine invasion, the Russian defence industry showed signs that it was in fact leaning towards applying heavy UGVs in urban setting. Of special interest for Ukraine-like combat environment are the Shturm UGV based on a T-72 tank platform, and the Vikhr/Udar UGV based on the BMP-3 infantry fighting vehicle (IFV) platform. At the same time, there is no additional news of these platforms going through their paces and combat stress tests.

A key issue with much of the Russian UGV development and testing is a lack of standardisation – this is a problem identified years ago at one of the first annual "Robotisation of the Russian Armed Forces" conferences. Multiple UGV projects were developed and tested separately from others, while no clear data exists whether such tests in fact mimicked an actual complex battlefield environment. Likewise, international sanctions against the Russian defence industry and Russia's high-tech companies may impact the scaling-up of the necessary AI and autonomy technologies beyond a few existing UGV examples. The developers of Marker are claiming the UGV will enter mass production at the conclusion of trials in Ukraine – a potentially significant accomplishment in light of Russia's massive losses of military ground vehicles in Ukraine, and the MOD's need to replenish its stocks with more modern and modernised equipment. At the same time, there is no sign of the earlier claimed acquisition of Uran-9 UGVs by the military, perhaps also a sign of the military industry's stress during the war.

With very few Russian UGVs tested in actual combat, it's difficult to judge the full extent and scope of the MOD's claims of AI and autonomy testing in such systems. Remotely-operated UGVs appear to be more practical at this point in the war, used after certain territory was secured to clear it from mines and UXO. Yet such use places operators in unavoidable relative proximity to the vehicle, possibly putting them in danger should the UGV location be tracked and attacked by Ukrainian forces. The Marker UGV project remained Russia's most public example of AI and autonomy for years, and it remains so today with the claimed tests by Dmitry Rogozin's team. Such tests in Ukraine may open the possibility for subsequent trials of other vehicles. Using a UGV in combat instead of human soldiers is exactly why such technology exists. Whether the Russian military and industry can meet the challenge of proving such technology is ready for war remains to be seen. ■

Credit: TASS

Variant Nerekhta UGV armed with a KORD 12.7 mm HMG.

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Dagger Fallen – Assessing Ukraine's Downing of the Kinzhal Missile

Mark Cazalet

While Ukraine has since claimed to have downed multiple Kinzhal air-launched ballistic missiles, at the time of writing this article in early May, Ukraine's purported tally stood at just one. This article explores how such an interception is possible, and what evidence to look for when assessing such claims.

On 5 May 2023, Ukrainian local news outlet Defense Express announced that Ukraine's defence forces managed to shoot down a Russian Kh-47M2 Kinzhal air-launched ballistic missile at around 02:40 on 4 May over Kyiv. As evidence, the news outlet provided two photographs purporting to show missile debris from the wreckage. The debris shown in the 5 May pictures was identified as the unitary warhead assembly used in both Kinzhal and in the Iskander family of ballistic missiles by Ukraine Weapons Tracker and a member of the Fenix Insights team.

If indeed confirmed as Kinzhal rather than Iskander, this would mark the first successful interception of a Kinzhal. This has drawn a lot of attention, given that many people are under the impression that, as a hypersonic weapon, the Kinzhal is very difficult to shoot down. As such this has led various commentators in the defence sphere to question how this interception could occur and what would be capable of such an interception. While the author would advise caution in drawing conclusions until better evidence emerges, he can at least explain how such an interception would be possible. However, explaining this properly first requires a brief crash course in hypersonics.

Credit: Office of the President of the Russian Federation

The Kh-47M2 Kinzhal shown on its MiG-31K host aircraft During the Victory Day Parade in Moscow on 9 May 2018.

A Crash Course in Hypersonics

There are many misconceptions about what hypersonic missiles are, how they work, and what they are capable of. To begin with, most definitions of 'hypersonic missile' focus on the fact that such missiles can attain speeds of Mach 5 (1,715 m/s) or greater. What doesn't get mentioned as often is that quite a lot of missiles already in service fit into this category without the fanfare of being 'hypersonic' – for instance, most ballistic missiles fit into this category.

To take a classic example, an Intercontinental Ballistic Missile (ICBM) such as Minuteman III, for instance, is estimated to possess an average speed of Mach 13.8 (4,762 m/s), when averaged out over the course of its flight. It would start its journey at a relatively slow speed during the boost phase, before speeding up in the mid-course phase, and finally attaining its maximum speed during the terminal phase, where it could reach speeds estimated at around Mach 17.5 (6,000 m/s) to Mach 23.3 (8,000 m/s). This is incredibly fast, and by way of comparison, the latter figure is around the same speed as a High Explosive Anti-Tank (HEAT) shaped charge jet! As such, although the ICBM is by definition a hypersonic weapon, most of the literature around 'hypersonics' doesn't concern itself with ballistic missiles.

Instead, the majority of the literature concerns itself specifically with manoeuvring, endo-atmospheric hypersonic weapons. Generally speaking, these manoeuvring hypersonic weapons broadly fit into two categories:

1) Hypersonic Cruise Missiles (HCMs) – these are air-breathing missiles which fly at endo-atmospheric altitudes, using a supersonic combustion ramjet (Scramjet) engine to enable sustained hypersonic flight while in the atmosphere. Due to being air-breathing, these missiles are limited to flying at altitudes where the air is sufficiently dense to power the engine – approximately 43 km down to around 15 km.
2) Hypersonic Glide Vehicles (HGVs) – these are hypersonic gliders which are boosted to high endo-atmospheric altitudes (typically the high mesosphere) by a carrier rocket, before being released to glide unpowered through the atmosphere (typically the stratosphere) hypersonically. If required, the glide vehicle may 'skip' one or more times on the upper reaches of the atmosphere to increase its range, but would eventually pull into a sustained glide once they descend to their target. As they have no engine, they are effectively reliant on gravity and aerodynamics to sustain their speeds. As a rough approximation, the peak of their trajectory would be approximately 70 km, while their sustained glide altitude would be from about 40 km to 35 km.

As the name suggests, these weapons typically have greater capacity to manoeuvre in flight than ballistic missiles – although it should be noted that even ballistic missiles and/or their payloads

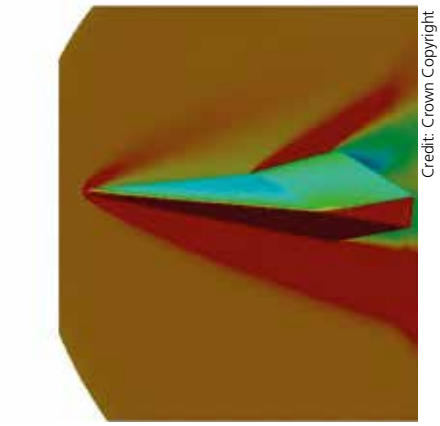
can also have some capability to manoeuvre, as shown with various concepts which made it into service, such as the Manoeuvrable Re-entry Vehicle (MaRV), Multiple Independently-targetable Re-entry Vehicles (MIRVs), and the Fractional Orbital Bombardment System (FOBS). However, these tend to be less discussed than HCMs and HGVs, and as such, when most sources are talking about 'hypersonic weapons', they are typically referring to these latter two types.

The Kinzhal is neither of these, as it is essentially a modified variant of the 9M723 Iskander, a theatre ballistic missile (TBM) which is launched from an aircraft. Nonetheless, it benefits from some of the key characteristics of hypersonic weapons generally, most notably that it is very fast for the majority of its trajectory, making it difficult to detect, track, and shoot down – however, its range of manoeuvre is understood to be more limited than an HCM or an HGV, making its trajectory somewhat more predictable.

Along with the benefits of hypersonic flight come some negatives, with a particularly noteworthy example being the plasma sheath phenomenon. As hypersonic objects move through the atmosphere at speeds close to Mach 10, their interaction with the air at high speeds causes them to generate a plasma sheath around the body. This sheath is effectively maintained while the object remains sufficiently low in the atmosphere and at a high enough speed. This effect is dependent on atmospheric pressure as well as speed, and as such is most intense at lower altitudes. This plasma sheath causes attenuation of radio waves which are trying to pass through this layer, which effectively results in three operationally-relevant effects:

a) It will weaken radio energy hitting the body and reflecting from it, which results in an effective decrease in the vehicle's radar cross section (RCS). This phenomenon has previously been nicknamed 'plasma stealth'.
b) It also prevents an on-board radar seeker from being able to search for targets, since its own signals will be attenuated. [As a side note: an infrared seeker is also not a good alternative, since the hypersonic vehicle is surrounded by so much heat that it would cause image washout for the seeker.]
c) It effectively prevents external communication with the missile, in essence meaning it cannot be directed from outside using radio control.

As a result of the latter two effects, in order to effectively perform targeting, using its seeker and/or GNSS guidance, the missile first needs to slow down to at least



Credit: Crown Copyright

The rendered image shows some of the aerodynamic forces at work on a hypersonic body in the atmosphere.

lower-hypersonic speeds (at least Mach 8, probably even lower for ease of targeting). This makes the missile significantly easier to down when it is in this portion of its flight.

In fact, even if the plasma sheath phenomenon were not a factor, hypersonic objects are still typically forced to at least partially slow down as they descend to low altitudes, since the air becomes denser, and hence provides higher resistance and more friction. Attempting to fly at hypersonic speeds in this denser air is not only more difficult from a propulsion perspective, due to drag, but it also imposes significant material strain in the form of heat and pressure. The object will have a heat limit and a dynamic pressure limit – failure to stay within these limits risks destruction of the airframe.

Back to Kinzhal

With the above information in mind, it should be somewhat clearer that hypersonic weapons are not the invincible terrors they are sometimes claimed to be. Yes, they are typically far more difficult to shoot down than slower targets during their hypersonic phase of flight, but as shown – they do not necessarily always stay at hypersonic speeds.

Additionally, in the case of Kinzhal, the weapon is effectively a TBM, with a lower potential to change its heading in-flight than HCMs or HGVs, and thus making its trajectory somewhat more predictable if detected post-launch. The ultimate destination of the weapon is also made more predictable by the choice of targets near the end of the missile's calculated trajectory – presumably Kyiv would only possess a limited range of targets the Russians would want to expend a Kinzhal on, and the Ukrainians probably know what these are.

Given all the above, it is far from implausible that a Kinzhal could be successfully engaged and downed. However, the highest likelihood for success in defeating it would likely require the missile to be engaged during the terminal phase, when it has slowed from its estimated maximum speed of around Mach 10, to a terminal speed well below this. Engaging in the terminal phase would in turn require that the right defence system is already pre-positioned very close to the target, to improve the odds of a successful intercept. This could also be further helped by radars detecting and continuously tracking the Kinzhal along its flight path toward the target, giving the air defenders more warning and more precise information on their target's speed and direction.

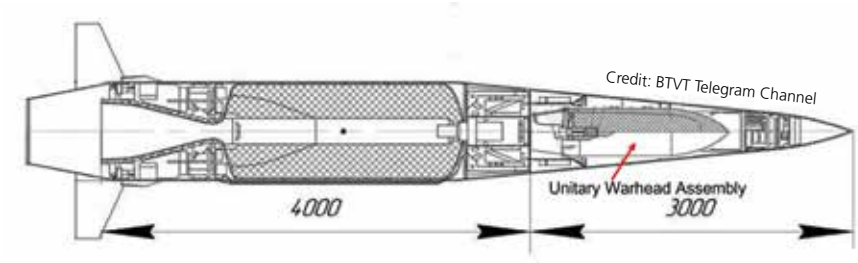
Assessing the Evidence

Although the Ukrainian Air Force was reluctant to confirm the incident on 5 May, in the days following the incident, soft evidence to confirm the downing emerged in the form of official announcements by Ukraine's Air Force on 6 May, and Ukraine's Minister of Defence, Oleksii Reznikov on 7 May, followed by Pentagon Press Secretary Air Force Brigadier General Pat Ryder on 9 May. All three confirmed the missile in question was a Kinzhal and credited the PATRIOT system with the intercept. Finally, on 10 May, further hard evidence emerged, curiously in the form footage showing Kyiv Mayor Vitali Klitschko presenting pieces of the wreckage to a group of German-speakers.

The three pictures of the wreckage released on 5 May were identified by Ukraine Weapons Tracker as portions of the unitary warhead assembly used in both Kinzhal and in the Iskander family of ballistic missiles. Two pictures showed the rear of the assembly (a blackened hollow cylinder), while the third picture showed the front of the assembly, with a crack. The 10 May footage and photographs showed more angles of the unitary warhead assembly from the Kinzhal, along with several other components including a tailfin.

For clarity, the Unitary Warhead Assembly is an internal component of the missile which houses the singular warhead

and fuze, and is located inside the front portion of the missile, as shown in the diagram below:



Pictured is a diagram of the Kinzhal which has been edited to show the unitary warhead assembly located in the front portion of the missile, behind the nose cone and seeker.

Interestingly, the warhead assembly is reminiscent in shape to a BetAB-500ShP concrete-piercing bomb, which is designed to penetrate reinforced targets such as bunkers. This may be an indication that this version of Kinzhal is intended for use against hard targets, which in turn may also explain why it was being launched at Kyiv, which possesses both critical command posts in bunkers, and VIPs staffing them. An alternative interpretation for the warhead assembly's thickness was floated by Mayor Klitschko, who stated that the thickness was due to thermal insulation shielding the warhead. However, this is likely mistaken, given that the warhead assembly would already be partially shielded from heat by the missile's skin.

So far, a portion of the evidence for the interception is reliant on official announcements. Taken by itself, the imagery shown so far is insufficient evidence that a Kinzhal missile was downed by PATRIOT. Fundamentally, there are two main problems which remain based on the photographs released at the time of writing:

1) All of the debris shown so far could belong to either a Kh-47M2 Kinzhal or a 9M723 Iskander.
   a. The best evidence to definitively prove that it is Kinzhal would be the distinctive rear, which has a boat tail and two short-chord fins which are not present on the Iskander.
2) None of the debris displayed so far shows damage consistent with a SAM interception.
   a. Proving this would require assembling more debris from the wreckage, to demonstrate the portions of the missile directly affected by the interception. As it stands, it is unclear if the missile was downed or crashed due to another cause, such as a guidance failure.

Despite the above problems, in this author's opinion, the balance of probability suggests that the interception probably did take place, however more evidence would need to be present to put the issue beyond doubt.

What Should be Expected in the Evidence?

With a PATRIOT interception, there would be different evidence depending on the missile used. As the Pentagon leaks have revealed, Ukraine should have access to both the PAC-2 GEM-T (ATM1T) and the PAC-3 (ATM2) missiles.

In the case of a PAC-3 interception, one would typically expect catastrophic destruction from direct impact at high supersonic speeds between a PAC-3 missile weighing 312 kg and a Kinzhal estimated to be around 4,000 kg. Even with the weight of both roughly halved to account for expended propellant, at the two missiles' terminal speeds, the PAC-3 would have a kinetic energy close to 200 megajoules, while Kinzhal would have a kinetic energy of over 2,500 megajoules. By way of comparison, the latter is several hundred times the kinetic energy of a modern APFSDS penetrator fired from a tank gun. Consequently, following a collision between these objects, one would expect there to be almost nothing left of the front of the Kinzhal. So far evidence of this has not been shown, but it is possible that the missile could have struck a portion of the Kinzhal which has not been shown so far.

It would also theoretically be possible for some smaller holes or cuts, to also be present in a PAC-3 interception. Although the PAC-3 missile is primarily reliant on hit-to-kill for target defeat, it is also provided with a relatively small 8.2 kg warhead, known as the 'lethality enhancer'. This contains 24 steel cycloid fragments arranged in two concentric circles, with each fragment weighing 95 g. Upon warhead activation, these cycloid fragments are released in a radial pattern at a relatively low expansion velocity due to the small quantity (around 350 g) of explosive material. As these rings of fragments expand outwards, they effectively serve to increase the diameter of the missile, and thereby improve the probability of successful target defeat. However, the lethality enhancer is typically only employed against non-ballistic targets, so against a Kinzhal the much more likely probability would be evidence of catastrophic damage at a single point of impact.

In the case of an interception by PAC-2 GEM-T, one would expect to see a fairly large quantity of small holes or larger cuts present in the outer casing of the missile caused by fragmentation from the large, 84 kg HE-FRAG warhead detonating in proximity to the Kinzhal. These are conspicuously absent, it is possible that they simply hit other portions of the Kinzhal during the intercept, and these portions have not yet been shown. Further photos of debris from the wreckage would be needed to confirm this.

Credit: US Army Space and Missile Defence Command/Jason Cutshaw

The US Army test launches a Patriot PAC-3 missile during a 2019 test.

So What (Probably) Happened?

The interception was certainly technically possible for the reasons outlined above, and PATRIOT would be a good candidate for the interception, given that both missile variants operated by Ukraine (PAC-2 GEM-T and PAC-3) were intended to defeat ballistic missiles, which Kinzhal is an example of. In this author's opinion, if the PATRIOT system was indeed the culprit, then the most likely candidate was probably the PAC-2 GEM-T (ATM-1T) missile, for a number of reasons.

Credit: Mark Cazalet

Three-quarter view of M901 Semitrailer Mounted Launcher for PATRIOT, on display at Gatow Airfield in December 2022.

Credit: Mark Cazalet

Rear view of M901 Semitrailer Mounted Launcher for PATRIOT, on display at Gatow Airfield in December 2022.

Firstly, the damage does not appear consistent with what one would expect from a PAC-3 impact – the only damage visible is the fist-sized hole in the front of the unitary warhead assembly. This hole is far too small for a PAC-3 impact which has a diameter of 255 mm, and the damage is not extensive enough, since catastrophic damage would be expected in a PAC-3 collision. The fist-sized hole and cracks are therefore probably the result of collision with the ground, rather than the work of a SAM.

Secondly, the PAC-3 missile's typical point of aim against ballistic missile targets is in the front portion of the missile, behind the nose. This is because on most missiles, the warhead would be situated here, so it makes for a logical point of aim when trying to guarantee defeat of the missile and minimise the risk of collateral damage, both of which PAC-3 aims to do.

It is possible that a PAC-3 could have missed the front and instead struck the middle or rear, however, in this scenario, the blackened rear of the warhead assembly would seem a bit strange. As evidenced by the Kinzhal wreckage from 14 September 2022, the warhead assembly seemed to show no signs of deflagration despite falling from a great height and the near-total destruction of the missile, and the missile propellant burning. Therefore, one can conclude that the explosive filler is probably fairly insensitive, meaning that in the 4 May 2023 wreckage, something had to introduce more energy directly into the warhead's explosive filler to cause deflagration. It is also likely that if the PAC-3 had struck close enough to the warhead assembly to trigger deflagration of the explosive filler, then the damage to the warhead assembly would probably be catastrophic, and thus more obvious.

Going further, it's also likely that the warhead assembly was almost or fully intact when the deflagration of the explosive filler took place, since the front of the assembly is fairly 'clean' grey while the rear is blackened. This suggests that the point of impact or damage came from behind the warhead, probably toward the midsection or rear of the missile. This also further suggests that the hole in the front of the warhead assembly occurred due to impact with the ground – otherwise one would expect part of the front to also be blackened as a result of the deflagration. Furthermore, the majority of the missile itself was probably intact while the deflagration took place – the clue here is the fact that all components shown on the 10 May footage showed signs of having been burned, even the steering fins, which are way toward the rear. It's quite possible that this was caused by the warhead deflagration passing through the body of the missile in flight.

An alternative explanation for the burn damage could be remaining rocket propellant, but one would expect most of it to have been expended by the time the missile was so close to its target. Additionally, the 14 September 2022 Kinzhal wreckage can be used as a comparison, since this incident notably featured combustion of the propellant but not the warhead. In the former case, the burned components showed mainly white soot deposition, while on the 4 May 2023 Kinzhal wreckage, the burned parts showed mainly black soot deposition.

So, taking the above points together, what (probably) happened if the official announcements are accurate? From this author's perspective, the most likely explanation is that the Kinzhal was probably intercepted by a PAC-2 GEM-T missile, which detonated in close proximity, showering the rear portion of the Kinzhal with fragments. This probably caused significant damage to the rear control surfaces and electronics, along with fragment(s) entering the warhead assembly either through the rear or by penetrating the assembly casing. This would then explain the deflagration of the explosive filler around the rear of the assembly, and fire causing damage along the length of the missile. Following this, aerodynamic stress on the missile structure probably caused the missile to break up into several pieces in mid-air, pushing the warhead assembly clear of the rest of the debris, and causing it to fall into the sports field. The impact with the ground probably caused the hole seen in the photograph of the front, along with the majority of the cracking, and of course the Astroturf seen jammed into the cracks. This should roughly fit the available evidence, but of course cannot be confirmed without further evidence.

Closing Thoughts

While it is certainly plausible that a PATRIOT conducted a successful intercept of a Kinzhal, this does not mean that the details of the incident have been proven beyond reasonable doubt. This article has posited a possible scenario to explain the available facts, but this is based on incomplete evidence and should be subject to revision if and when new evidence comes to light. Until more information surfaces, final judgement on the matter will need to be reserved. At least now it should be clear how such an interception could happen, and what signs to look for when determining the culprit. ■

Trident II and Standard Missile 6 set Landmarks in Missile Performance

Doug Richardson

Any missile system whose development does not exploit the latest advances in technology is likely to become one of the ill-conceived and less than successful weapons whose designers and end users would like to consign to the oblivion of history. Yet projects which successfully push technology to the very limits of what is possible can sometimes redefine the state of the art.

Two current US Navy (USN) missile systems are good examples of weapons that provide their user with a landmark level of performance. One is the Lockheed Martin UGM-133 Trident II series of submarine-launched ballistic missiles, the other is the Raytheon Standard Missile 6 surface-to-air system.

The oldest of the 12 Ohio-class submarines armed with Trident entered USN service from 1984 onwards, with the last examples being deployed in the mid to late 1990s. Decommissioning at the rate of one per year is due to begin in 2027. Louisiana, the last of the class, recently completed her mid-life Engineered Refuelling Overhaul (ERO), and is expected to remain in service until 2042.

At least 12 new SSBNs will replace the 14 current Ohio-class boats. Originally known as the Ohio Replacement Submarine, then as the SSBN-X Future Follow-on Submarine, it was finally titled the Columbia-class. There is already a USN attack submarine named Columbia (SSN-771), so the lead boat of the new class is to be named District of Columbia. Construction started on 4 June 2022.

Although the boats that make up the Ohio-class were built with 24 launch tubes, the Colombia-class will have only 16, a move expected to reduce the average procurement cost. A programme to develop a Common Missile Compartment (CMC) was set up to define the missile tubes and other hardware needed to house and launch either the current Trident II/ D5 missile or any future missile. The result was the creation of a quad-pack of four vertical-launch tubes that will be used by the Columbia-class, each of which will carry four CMCs, and by the UK's next-generation SSBN, each of which will carry three.

Author

Following an earlier career in engineering, **Doug Richardson** is a defence journalist specialising in topics such as aircraft, missiles, and military electronics.

Credit: US Navy

The last US Navy Ohio-class submarine to be built, the Louisiana is expected to remain in service for a further 20 years.

Extending the Life of Trident

Trident II D5 has been in service for almost three decades and is expected to remain operational for at least two more decades. To cope with this stretch-out in service life beyond the 30 years originally planned, the D5 Life Extension (D5LE) programme was launched to update critical but aging missile electronics systems by creating electronic assemblies able to match the form, fit, and function of the original hardware. The upgrade is done when individual rounds are removed from service for what would have been normal maintenance. Initial deliveries of the D5LE standard missiles began in 2017, and the programme is expected to continue until around 2025.

The first eight Columbia-class boats will initially be armed with D5LE missiles, while the ninth will be the first to carry the follow-on Trident II D5 Life Extension 2 (D5LE2) missile, which will be retrofitted to the first eight during their Extended Refit Period in FY39-49. D5LE2 is expected to combine existing technology in areas such as rocket motors and igniters with redesigned and updated guidance components. One problem that the USN faces is that unlike previous SLBM programmes, D5LE2 does not have the benefit of a healthy industrial base that has maintaining production and continuous development. Production lines for critical components were shut down over the last decade, so the US SLBM industrial base will have to be reconstituted.

Flight testing is expected to begin in the mid-2030s, leading to Low Rate Initial Production (LRIP) in FY34, and entry into service in 2039. USN planning assumes

that the Columbia-class and its D5LE2 armament will remain survivable throughout their planned life while facing what the USN has described as "a dynamic threat environment driven by two near-peer competitors".

Warhead Evolution

USN Trident II D5 missiles can carry W76 or W88 warheads. Each missile can carry up to 12 W76 warheads or eight W88 warheads, but in practice is limited to eight warheads under the 2002 Strategic Offensive Reductions Treaty (SORT).

Originally deployed on UGM-96 Trident I missiles, and then on the UGM-133 Trident II, the W76-0 had a yield of 100 kT, but was replaced by the 90 kT W76-1 between 2008 and 2018. A W76-1 Life Extension Program (LEP) was completed in 2019.

One controversial aspect of this upgrade is the introduction of a new MC4700 arming, fuzing, and firing system. In its original version, the W76 warhead used a fixed height-of-burst fuze, so there was no form of compensation if an individual warhead was falling short or long of its target. Since the lethal distance of the warhead was similar to the circular error probable (CEP) of the Trident II missile, only about half of the warheads aimed at a single target could be expected to fall within that lethal distance.

Located in the nose of the reentry vehicle (RV) the new MC4700 – sometimes dubbed the 'super-fuze' – uses a radar sensor to measure its altitude prior to beginning atmospheric reentry. Comparing the result with the height expected had the RV been following the optimum trajectory will show whether the actual trajectory is higher or lower than planned. Higher would mean that the warhead was going to land beyond the nominal aim point, while lower would show that it would short of the intended aim point.

If the aim point were to be shifted downrange by a distance roughly equal to the CEP, most warheads would overfly their target, but the MC4700 would be able to detonate the majority at an altitude that lay within the calculated lethal volume above the target, ensuring that a high percentage of warheads would achieve a successful 'kill'. Such an increase in lethality is inherently destabilising, say opponents of the 'super-fuze'.

Announced in the Trump administration's 2018 Nuclear Posture Review, the programme to develop a low-yield W76-2 version was fast-paced. It was in production a year later, and is thought to have entered service in late 2019. Deliveries were completed in mid-2020. The speed

Credit: US Navy

This test launch of a life-extended Trident II (D5LE) missile was conducted by the Ohio-class boat Maine.

Credit: UK MoD

Vanguard, the lead boat of the UK Royal Navy's class of four Trident-armed submarines, heads out to sea to conduct a test firing at the Atlantic Missile Range. The tall communications mast is a temporary fitting required for operations at the US range.

Credit: UK MoD

A Trident 2 missile launched by Vanguard begins its first-stage burn.

of the programme suggests that no significant engineering work was needed, and that the new configuration was based on existing components. It may have drawn on UK experience with that country's Holbrook warhead, which offers two selectable yields.

W88

Deliveries of the W88 warhead started in 1989. Intended to act as a more powerful alternative to the W76, it is reported to have a yield of 475 kT. An upgrade programme resulted in delivery of an improved version designated W88 Alt 370 starting in July 2021. This introduced a new arming, fuzing, and firing subsystem, and replaced limited-life components such as the gas-transfer system and neutron generators.

W93

Work on a new warhead designated W93 started in 2021, and the initial Phase 1 concept assessment led in 2022 to a Phase 2 feasibility study that included potential design options. Development engineering is due to begin under Phase 3 starting in 2027. While major nuclear components of the W93 will be based on currently-deployed or previously-tested designs and components, modern technologies will be used to improve safety, security, and flexibility to address future threats. Attention will also be paid to ease of manufacturing, maintenance, and certification. The W93 warhead will be compatible with the D5LE and D5LE2 missiles, and is intended to replace the W76 and W88 warheads from 2034 onwards. Designed by Los Alamos National Laboratory, it will be carried on the new Columbia-class submarines and will use a new aeroshell, the Mark 7 reentry body.

UK to Maintain its SSBN Fleet

The UK's Vanguard-class SSBNs entered service in 1993-1999, and were designed for an operational life of 25 years, so should have been retired starting in 2018. A 2007 White Paper published by the UK House of Commons Defence Committee stated that detailed work to assess the scope for extending the life of those submarines had begun, but noted that "some major components on the submarines – including the steam generators, other elements of the nuclear propulsion system, and some non-nuclear support systems – were only designed for a 25-year life", but could be revalidated for a further period of around five years.

In December 2015, Vanguard, the lead boat of the class, began a 'Long Overhaul Period and Refuel' programme. The work was conducted by Babcock at its facility in Devonport Royal Dockyard, and involved more than 25,000 individual engineering tasks. Around 7,000 welds were surveyed and repaired as necessary, and approximately 2.3km of cabling was installed. More than 200 upgrades were carried out, and 26,000 items of ship's equipment were overhauled. Expected to take three years, in practice it involved an unplanned second nuclear reactor refuelling required by the presence of radiation in the reactor's coolant water due to a microscopic breach in the fuel cladding. As a result of this extra work, the submarine did not begin its third commission until July 2022. No reactor refuelling is envisaged for the other three Vanguard-class boats, so their upgrade programmes should go more quickly.

A Concept Phase for what was originally known as the 'Successor' class started in September 2007. Two potential configurations were studied. One was based on the Astute-class SSN, but would have internal systems reconfigured to cope with the increased size, weight and crew numbers, and would be propelled by an installation based on a PWR2/2b plant derived from the existing UK nuclear propulsion plant. The other would use Astute technologies updated where necessary in order to achieve the desired performance or improve maintainability, and would be powered by a PWR3 plant based on current US technology. Although the latter option would be more expensive, it was selected in 2011 on the grounds that it was expected to provide improved nuclear safety.

The resulting new generation of Trident-armed UK submarines will form the Dreadnought class, the first taking that name, and the remaining three being Valiant, Warspite, and King George VI. Work on the lead boat started in late 2016 at the BAE Systems Submarines shipyard at Barrow-in-Furness. It is due to enter service in the early 2030s. The new class is being designed for a service life of around 35 to 40 years. Steel cutting for Valiant began in September 2019, and for Warspite in February 2023. All four are expected to have a service life of around 35-40 years. Production and delivery of the missile tubes that form part of the Common Missile Compartment were delayed, but all 12 missile tubes for Dreadnought had been delivered to the UK by the end of 2021.

Following the UK's 1998 Strategic Defence Review, the number of operationally available Trident warheads was reduced, whilst the number of warheads carried on each Trident submarine would be reduced from 96 to 48. Each Trident II D5 missile is capable of carrying up to 12 warheads, but the review stated that no more than three would be fitted to each UK-operated missile. Some missiles are reported to carry a single warhead.

The 2010 Strategic Defence and Security Review announced that the UK stockpile would be reduced to 180. This remained the plan until March 2021, when the UK stated that it planned to increase the number to 260 by the middle of the decade. The reason for the increase was defined as "risks to the UK from major nuclear armed states, emerging nuclear states, and state-sponsored nuclear terrorism."

The UK Warhead Programme

The current warhead carried by UK Trident missiles has the designation 'Holbrook'. It was also known as the Mark 4, but this was changed to Mark 4A to reflect an ongoing programme to update the arming, fuzing and firing system in order to replace hardware that was becoming obsolete. This upgrade is also reported to involve the gas-transfer system and new high-explosive components. The transition from the current Mark 4 warhead to the Mark 4A is ongoing.

No detailed information on the Holbrook warhead is publicly available, but the Eighth Report by the UK Parliament's Select Committee on Defence published in 1998 noted that "the nuclear warhead on UK's Trident II D5 missile is reported to be closely related to the American W76 warhead, a thermonuclear warhead with a yield of around 100 kilotons." Holbrook is known to have two selectable yields – probably a high yield of around 100 kT, and a lower of less than 10 kT.

The UK Government's plan to develop and field a replacement for the Holbrook warhead was formally notified to the UK Parliament in February 2020. Designed in parallel to the W93 and thought to share some non-nuclear components, the new British warhead is expected to enter service in the 2030s. Like the US W93 warhead, it will use the US-developed Mark 7 aeroshell.

SM-6 Redefines 'Long Range'

With the RM-174A Standard Missile 6 (SM-6), originally known as the Extended Range Active Missile (ERAM), the USN has fielded an extended-range weapon optimised for use against air-breathing endo-atmospheric targets such as cruise missiles, but can also be used against fixed and rotary-wing aircraft, unmanned air vehicle, anti-ship cruise missiles, and lower-tier ballistic-missile threats. Targets out to the horizon can be engaged with the help of the ship's SPY-1 radar, but those located over the horizon will require cueing by other assets.

Development of the SM-6 began in 2005, and trials began two years later. Initial low rate production was begun under a USD 93 M contract awarded to Raytheon in September 2009, and the first missile was delivered to the USN in April 2011. Full-rate production was approved in May 2013, and in November of that year the SM-6 achieved Initial Operating Capability (IOC) on board the Arleigh Burke class destroyer USS Kidd.

SM-6 uses the Mk 72 Solid Rocket Booster, Mk 104 Dual Thrust Rocket Motor, ordnance section, and SCS of the earlier RIM-156A SM-2MR Block IV, but teams these a new guidance section and power control/telemetry section based on existing hardware from the AIM-120C-7 Advanced Medium Range Air-to-Air Missile (AMRAAM).

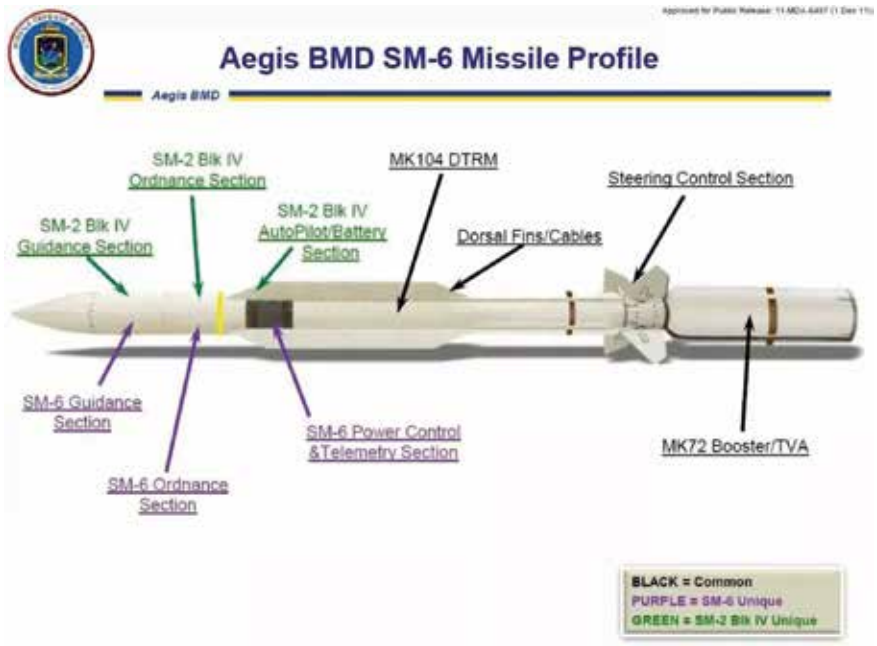
Credit: UK MoD

Artist's impression of a Royal Navy Dreadnought-class submarine.

Active homing makes the SM-6 independent of the launch ship's radar illuminators, allowing a greater number of simultaneous engagements, and giving the missile an ability to engage targets that are beyond the range of the ship's radars, or screened from the ship's radars by terrain features, or below the ship's radar horizon.

This over-the-horizon intercept capability of the SM-6 will play a major role in the Navy Integrated Fire Control-Counter Air (NIFC-CA) concept. When integrated with other networked sensors via networks such as the Cooperative Engagement Capability (CEC), it will be able to engage targets at very long ranges – possibly beyond the range of any prior endo-atmospheric air defence missile system.

Unlike earlier Standard-series missiles, the SM-6 does not need to be offloaded from the ship in order to undergo the testing normally conducted after about two years of service. This feature should help to reduce the missile's life-cycle costs.



Credit: MDA

Standard Missile 6 is based on the earlier Standard Missile 2 Block IV. In this diagram, components titled in black are common to both missiles, while those in green are SM-2 Blk IV hardware that are replaced by the SM-6 hardware shown in purple.

Credit: US Navy

The Arleigh Burke-class guided missile destroyer John Paul Jones (DDG 53) launches a Standard Missile-6 against supersonic over-the-horizon target.

Credit: US Navy

A US Navy mobile ground-based launching system for SM-6 missiles was demonstrated in Europe during September 2022.

An upgrade designated 'Dual I' offers improved anti-ballistic missile (ABM) capability. This was achieved by the installation of a more powerful processor able to run the targeting software needed to intercept a warhead that had not been destroyed by a midcourse interception, and is now descending from the upper atmosphere at high speed. On 14 December 2016, two SM-6 Dual I missiles were launched against what was described as a "complex, medium-range ballistic missile target" and successfully demonstrated that their blast-fragmentation explosive warhead could defeat this class of threat.
On 17 January 2018, the USN approved plans to develop the SM-6 Block IB, which will feature a new 53 cm (21 in) rocket motor and missile steering control section, plus modified control surface areas (CSA) suitable for integration with existing components of the SM-6 Block IA missile. These modifications will increase the missile's speed and range, and may provide an ability to engage hypersonic threats.

Alternative Roles

In February 2016, the then Secretary of Defense Ashton Carter confirmed that the SM-6 would be modified to give the weapon a secondary role as an anti-ship missile. Given that the missile is much more expensive than an anti-ship missile, this will be a secondary role. However it fits with the USN's concept of 'distributed lethality' in which ships can operate in dispersed formations, providing more strike options to joint-force commanders, and complicating the planning task faced by an adversary. This anti-ship capability was demonstrated for the first time on 18 January 2016 when the Arleigh Burke-class guided missile destroyer John Paul Jones (DDG-53) sank the decommissioned Oliver Hazard Perry-class guided missile frigate Reuben James with SM-6 during a trial conduced at the Pacific Missile Range.
The effectiveness of the SM-6 when used against a ship target will depend on the explosive power of the warhead (which weighs only 64 kg, well below the 220 kg of the warhead carried by a Harpoon missile) and the kinetic energy derived from the SM-6's high speed at the moment of impact.
To meet a perceived need for a ground-launched system able to counter reported improvements to Russian and Chinese artillery. the US Army plans to deploy a Mid-Range Capability (MRC) weapon system able to fill the range gap between the Precision Strike Missile (with a range of about 480 km) and the Long-Range Hypersonic Weapon (with a range of about 2,750 km). To be known as 'Typhon', the MRC will use a land-based variant of the Mark 41 Vertical Launching System able to fire Tomahawk cruise missiles and SM-6. Developed and built by Lockheed Martin, the first prototype MRC battery was delivered to the Army in November 2022. It consisted of four launchers, a battery operations centre, plus modified trailers, and the necessary prime movers. This hardware will allow system testing and training, and should lead to operational capability in FY23.

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Variants of the SM-6 may be under development to meet other roles. In 2021 a Boeing F/A-18F Super Hornet fighter was photographed while in flight while carrying under its left wing what appeared to be a boosterless SM-6 missile. No further details have emerged since. A boosterless SM-6 would make a formidable long-range air-to-air weapon, eclipsing the performance of missiles such as China's PL-15. A variant fitted with a passive seeker could allow suppression of enemy air defences (SEAD) from long standoff distances.

Credit: US Navy

This artist's impression shows the USN's planned Columbia class ballistic missile submarine.

Export Sales for SM-6

US approval for a proposed Foreign Military Sale to Australia of SM-6 Block I and SM-2 Block IIIC missiles was announced in August 2021, making that country the first export customer for the SM-6. These will be deployed on Australia's new Hobart-class destroyers, which are equipped with the Mark 41 Vertical Launching System (VLS). The new missiles are expected to reach initial operating capability between FY21 and FY24.

South Korea's plan to acquire the SM-6 was given the go-ahead by that country's Defense Acquisition Program Promotion Committee in April 2022. The new missiles will arm three Aegis-equipped Sejong the Great class (KDX-III) Batch-II destroyers, due to be delivered from 2024 onwards.

Under an arrangement announced by the US Defense Security Cooperation Agency in October 2022, Japan plans to purchase 32 SM-6 missiles, MK41 vertical launching systems, and related equipment and services at an estimated cost of USD460 million. The missiles will be installed on Japan's two Maya (Improved Atago)-class destroyers. A plan to equip the two Atago-class destroyers with SM-6 is reported to have been postponed.

Technology Provides a Performance Edge, But Skills Need to be Maintained

In terms of maximum range, Trident II and the SM-6 set new standards. No official range figure has been released for Trident II, but it is believed to be around 12,00km. Russia's R-29RMU2 Layner missile has a similar range, but this was only achieved by using storable liquid propellants. Although Russia's most modern SLBM, Bulava is thought to have a maximum range of up to 10,000 km, it combines solid-propellant first and second stages with a storable-liquid third stage.

The official published range of the SM-6 is 240 km, but this is thought to be a conservative figure. Unofficial estimates have ranged from 370 km to 460 km. The Russian Navy's only warship with long-range SAM systems is the single Kirov-class cruiser Pyotr Velikiy. Its S-300FM Fort-M (SA-N-20) system has a maximum range of 150 km. China's HHQ-9 is in service on Type 052C destroyers (the first Chinese warship with area air-defence capability), the Type 052D destroyer, and the Type 055 destroyers. The maximum range of the HHQ-9 is reported to be more than 100 km.

A classic advertising slogan devised in the 1940s read "When you care enough to send the very best". Although devised to advertise greetings cards, it applies equally well to the world of guided missiles. Having and using the very best can give the vital edge in combat, but the skills needed to develop and manufacture such weapons are not easy to maintain. Disbanding engineering teams at the end of a programme, and recruiting from scratch the team needed for a later programme is not a good way of doing things.

Continuity in development and manufacture can play a major role in the effective running of high-technology programmes, ensuring that one generation of engineers passes on its expertise to the next. The junior engineer who helped design Boeing's B-17 Flying Fortress could well have been an engineer on the company's B-29 Superfortress and B-47 Stratojet, then a senior engineer on the B-52 Stratofortress, but when that chain of developments was broken with the selection of North American for the B-70, Boeing was out of the bomber business.

Experience counts, but once lost, it is hard to regain. Russia has not had much success with its planetary-exploration spacecraft in recent years, and a Western visitor to a Russian spacecraft design bureau has described seeing many empty offices, and a staff that mainly consisted of ageing engineers close to retirement, and young but inexperienced newcomers.

Lockheed Martin's SLBM design team has had a long-term relationship with the USN, and significant numbers of personnel on both sides have been associated with the SLBM programme for decades. The company sees this relationship as a factor that accounts for the Trident missile's long series of successful launches. However, as the recent problems in extending the life of the D5 variant demonstrate, there are penalties to be paid if that level of continuity is interrupted either in design or in production. ■

THAAD Comes of Age

Sidney E. Dean

After three decades of development, the THAAD ballistic missile defence (BMD) system – once considered destined to fail – is praised as the most advanced BMD system in the world.

As defined by the US Defense Department's Missile Defense Agency (MDA), the Terminal High Altitude Area Defense (THAAD) element provides the US military's Missile Defense System (MDS) "with a globally-transportable, rapidly-deployable capability to intercept and destroy ballistic missiles inside or [just] outside the atmosphere during their final, or terminal, phase of flight." It is designed to provide cover to a large area, to defend US and allied/partner forces and facilities, as well as civilian populations and infrastructure.

THAAD is configured to combat short- and medium-range ballistic missiles (SRBMs; MRBMs) and retains a limited capability against intermediate range ballistic missiles (IRBMs). The interceptor missile does not employ an explosive warhead, but destroys the target through the kinetic energy of a direct impact ("hit-to-kill" method.) As an upper tier BMD system, THAAD intercepts are conducted at high altitudes. Precise performance parameters are classified. The maximum engagement range is generally estimated to be approximately 200 km; the minimum intercept altitude is thought to be circa 40-50 km, with a maximum intercept altitude of 150 km. High altitude intercept has two main advantages: any Nuclear, Biological, or Chemical (NBC) payload carried aboard the incoming warhead will be dispersed, reducing its lethality when it does reach the ground. Secondly, should the high-altitude intercept attempt fail, there will be time for a second intercept attempt by THAAD or another BMD system.

While planning and procurement are under the aegis of the MDA, THAAD batteries are operated and maintained by the US Army Air Defense Artillery. Via their command and control element, THAAD batteries are tied into the greater MDS architecture. They primarily exchange tracking and targeting data with the Navy's AEGIS BMD system (which, like THAAD, is an upper-tier interceptor system) and the Army's lower tier PATRIOT system to form a layered intercept capability. The networking takes place via the US military's central Command and Control, Battle Management, and Communications (C2BMC) system. C2BMC is responsible for persistent target acquisition, tracking and cueing of targets as well as distribution of fire-control quality data to all elements of the BMD system. Sensor data from across the BMD and aerospace surveillance/early warning spectrum flow into the C2BMC, where it is collated into a comprehensive threat picture and used to calculate an optimised response by the various elements of the BMD system. As described by the Army, each system targets different portions of an enemy missile's trajectory, or even different threats, and a networked intelligence and communication system ensures that one or more of the interceptor systems will be launched when needed.

Credit: US Army

A THAAD Launcher is offloaded from a C-17 Globemaster III on Guam in March 2022 as part of OPERATION TALON LIGHTNING.

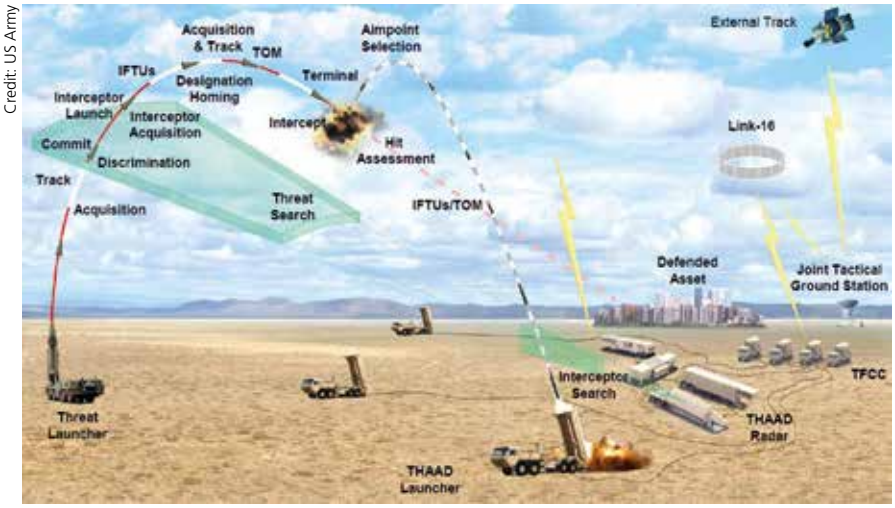
Components of THAAD

Lockheed Martin Missiles and Fire Control is the prime contractor for the THAAD program, and also provides the interceptor missiles. Major components of THAAD include the launcher vehicle, interceptor missile, radar, as well as a fire control and communications system. A standard battery configuration consists of six launcher vehicles with a total of 48 launch-ready missiles, one command,

Credit: MDA

Flight Experiment THAAD 01 (FET-01; formerly FTT-15) was conducted in 2017, and saw the successful interception of an air-launched, medium-range ballistic missile (MRBM) target.

Credit: US Army



This graphic shows how the THAAD system is networked via fibre optic cables to its various components to detect, identify, and engage an incoming missile.

control and communications element, and one radar. However, a battery can operate as many as nine launchers at a time.

Launchers are mounted on Heavy Expanded Mobility Tactical Truck (HEMTT) A2 vehicles produced by Oshkosh Defense. The truck-mounted launcher can be transported into a theatre of operations by transport aircraft or by ship; within theatre it can move via C-130 aircraft, rail, road or off-road. The HEMTT's overland mobility includes the ability to climb a 60% gradient and ford 1.2 m of water. Each launcher carries eight interceptor missiles. After launching its missiles, the launcher can be quickly reloaded in the field.

In October 2022 Lockheed Martin announced the delivery of the 700th THAAD interceptor missile to the MDA. The previous milestone of 600 delivered missiles was set in August 2021. The 6.2 m long interceptor missile weighs 662 kg at launch. It consists of a single solid-fuel booster stage topped by a liquid-propellant-filled kinetic kill vehicle. The missile attains a speed of Mach 8. At this speed it would reach its maximum intercept range within less than 90 seconds, offering a manoeuvring target little time for evasive action.

THAAD utilises the Raytheon Integrated Defense Systems AN/TPY-2 radar in terminal mode to guide the interceptor missile towards the target, providing updated tracking data until impact. The high-resolution X-band phased-array radar can distinguish between missile payloads and other objects such as missile debris. When deployed in terminal mode the AN/TPY-2, is capable of engaging all classes of ballistic missile threats, and has a detection and cueing range of 1,000 km. The 12.8 m long, 34 tonne radar antenna unit has two rear axles; it is towed for transportation and detached for operations.

The fire control and communications platoon connects the various THAAD subsystems together; plans and executes intercept solutions; and provides an interface for the THAAD batteries to network with external command and control echelons and integrate with the C2BMC.

Additional essential elements of the battery include Humvee support trucks, a prime power unit generator vehicle producing 4,160 volts, electronic equipment and data processing unit, as well as a cooling vehicle to maintain the radar's operational temperature. The various components of the battery need to be connected to one another via fibre optic cable to enable operation. According to US Army personnel directly involved with THAAD operations, setting up or moving the unit is a matter of hours or even days.

Credit: Raytheon

The Raytheon AN/TPY-2 radar detects, classifies and tracks ballistic missiles and can guide interceptors to descending warheads.

THAAD to Date

The THAAD concept's origins date to 1987, and the first flight test took place in April 1995. Initially the program fared poorly. The first two flight tests – neither of which involved an intercept attempt – were successful. However, the next six flights – all of which involved intercept attempts – ended in failure. The program was restructured, and flight testing resumed in August 1999 with the successful exoatmospheric destruction of a warhead that had separated from its booster; the intercept occurred at an altitude of 147 km. Since then, THAAD has demonstrated a high degree of effectiveness and reliability. All 16 test intercepts conducted between 1999 and 2019 were successful, as were numerous non-intercept and interoperability experiments. According to an assessment by the Congressional Research Service published in November 2022, many experts currently consider THAAD to be the most advanced BMD system in the world.

Over the past two decades the MDA and Lockheed Martin have worked to further develop the system's capabilities, networking options, and reliability. Two major breakthroughs were achieved in the 2019-2022 timeframe.

In 2020 the MDA was able to demonstrate direct integration of the PATRIOT air defence system into the THAAD fire control system. During the first experiment in February 2020, THAAD successfully

Credit: US Army

A THAAD launcher and a globe-shaped Transportable Tactical Command Communications (T2C2) node on the island of Rota, Mariana Islands. The T2C2 node serves as the portable interface between the centralised fire control unit and dispersed THAAD launchers.

provided targeting data acquired by the AN/TPY-2 radar to the PATRIOT weapon system, which was able to develop an intercept solution. On 1 October 2020, the exercise was repeated, and this time the PATRIOT unit successfully intercepted the target missile. By 2022 the integration reached a higher level. On 29 March 2022, the THAAD system successfully launched a PAC-3 MSE (Missile Segment Enhanced) to intercept a tactical ballistic missile target without the support of a PATRIOT fire unit. This validated the concept of attaching one or more PATRIOT launchers to a THAAD battery. Full integration of the PATRIOT PAC 3 MSE launchers into the THAAD fire control system permits THAAD to directly control intercept of missiles flying too low for the main system to engage, and enhances the PATRIOT's odds of a successful intercept. As the AN/TPY-2 has considerably greater range than the PATRIOT batteries' organic radar suite, this new capability enables PATRIOT interceptors to be effectively deployed at the missile's maximum range. It further enhances the flexibility of the greater missile defence system, permitting a more efficient allocation of interceptor missiles, expansion of the defended terrain while simultaneously preserving the more sophisticated THAAD interceptors for the most challenging targets.

The second major development is the remote fire kit which was introduced in 2019. It enables dispersal of the individual launchers of a THAAD battery hundreds of kilometres apart from one another and from the battery's radar and fire control unit. The interface to the battery's radar and fire control centre runs through the Transportable Tactical Command Communications system which deploys with the individual launcher. The dispersed launch capability creates a more layered defensive architecture and increases the area the system can defend. To date this capability has been tested on the Mariana Islands and on the Korean peninsula, where the tactical requirement to counter potential adversary missiles is deemed the greatest.

Moving Forward

Fielding of the first operational THAAD battery began in 2008. Seven batteries are currently in service, the last of which was established in 2016. Two of these batteries are currently deployed overseas, one in South Korea and one on Guam. Intermittent and sometimes prolonged deployments to NATO territory, Japan and several Middle Eastern have previously been conducted.

The system is also available for export. In 2017 the United States government agreed to sell THAAD to Saudi Arabia. The formal contract for Lockheed Martin to deliver 44 launchers and 360 missiles to Riyadh was signed in 2020, with a target initial delivery date of 2023. According to the US Army Corps of Engineers, the first four of several planned operating sites will be ready by 2026, with the remainder complete by 2028. The total acquisition cost for Saudi Arabia will amount to circa USD 15 Bn.

Credit: MDA

THAAD interceptor in flight.

The United Arab Emirates became the first foreign operator of the BMD system, signing a contract for two THAAD batteries in 2011, and sending its first crews to the US for training in 2015. The UAE also became the first nation to achieve a combat intercept, using THAAD to down a Houthi-launched missile on 17 January 2022. In August 2022 the US State Department announced approval for the sale of an additional 96 interceptor missiles plus support equipment to the UAE.

Back in the United States, the MDA in April 2022 awarded Lockheed Martin a contract to produce an eighth battery which is expected to be fielded in 2025. "With 16 of 16 successful flight test intercepts, and recent combat success clearly documenting the effectiveness of THAAD, adding an eighth battery will further enhance readiness against existing and evolving ballistic missile threats," said Lockheed Martin Missiles and Fire Control, Upper Tier Integrated Air and Missile Defense vice-president Dan Nimblett when announcing the new contract.

Beyond the plans for an eighth battery, Lockheed Martin has announced that it continues to implement incremental capability improvements within the weapon system to improve capability against current and emerging threats. The Pentagon continues to finance this initiative, and the MDA has requested USD 220 M for THAAD development efforts in FY 2024. The funds would support continued development and integration of system upgrades to enhance reliability and readiness, and improve the ability to engage emerging threats across the current target spectrum. An additional USD 47.6 M is requested for terminal defence testing of THAAD as part of the MDA's comprehensive Integrated Master Test Plan. The planning includes flight and ground testing as well as inclusion in wargames and exercises. Operations and maintenance of THAAD batteries are expected to cost an additional USD 89.3 M in FY 2024.

Beyond these upgrades of the base system, Lockheed Martin has for the past several years proposed development of an Extended Range variant or 'THAAD-ER' designed to counter hypersonic glide vehicles (HGVs). The extended range would require a two-stage interceptor missile and a redesign of the launcher. Lockheed Martin has postulated that an initial operational capability could be achieved within four years once development were initiated. To date, the MDA has not agreed to finance development of an ER variant. ■

Modernising Slovakia's Ground-Based Air Defence

Martin Smisek

In February 2023 the Ministry of Defence of the Slovak Republic completed the Feasibility Study for Acquisition Projects of Air Defence Firing Means which lays out future steps for the modernisation of the 11th Air Force Brigade.

Like other components of the Armed Forces of the Slovak Republic (Ozbrojené sily Slovenskej republiky, OS SR), the Slovak ground-based air defence is facing a significant decline in combat capability as a result of very low defence spending in recent years. While the inadequacies with reconnaissance and surveillance systems has been remedied by the acquisition of new Israeli radars ordered from ELTA Systems in March 2021, the purchase of replacements for obsolete surface-to-air missile systems is still in the making.

Current Situation

All Slovak ground-based air defence assets are operated by the Slovak Air Force within the 2nd and 11th Air Force Brigade. The former unit with the headquarters at Zvolen conducts command and control duties as well as continuous radar surveillance of the Slovak airspace and provides a complete air situation picture to the relevant entities. Its Radar Surveillance Battalion operates eight radar surveillance companies at Michalovce, Veľká Ida, Ožďany, Močiar, Hlohovec, Mierovo and Prešov. It is currently equipped with P-37MSK, RL-4AM Morad-L and PRV-17 (Odd Group) radars. The brigade's armament is supplemented by one stationary VERA-NG passive surveillance system.

The old radar equipment will be replaced by the new Israeli 3D radars. In total, six ELM-2084M-MMR, five ELM-2084S-MMR/GBAD and six ELM-2138M MC radars were ordered for EUR 148.2 M including VAT (EUR 123.5 M excluding VAT). Their deliveries for the 2nd and 11th Air Force Brigade were planned to take place from April 2023

Author

Martin Smisek is a Czech freelance journalist specialising in Czech armament programmes and Czech and Slovak military history since WW II.

Credit: Rafael Advanced Defense Systems

In the medium-range surface-to-air missile system category, Slovakia is considering the purchase of the SPYDER-MR system from Rafael Advanced Defense Systems.

Credit: Bundeswehr

The MANTIS C-RAM system donated by Germany in 2023 represents the first modernisation of Slovak air defence firing means in the last 20 years.

to 2025. However, the entire project is facing delays and the first 3D radars will not be delivered until 2024.

The 11th Air Force Brigade headquartered at Nitra is responsible for the air defence of important political, economic and military centres of Slovakia as well as for the protection of Slovak ground forces against aerial attack. The unit is composed of three air defence missile groups equipped with four batteries of the 2K12 Kub (SA-6 Gainful) at the 2nd Anti-Aircraft Missile Group and 54 9K38 Igla (SA-18 Grouse) MANPADS (man-portable air defence system) and 24 OT-90 armoured personnel carriers at the 3rd Anti-Aircraft Missile Group.

The sole S-300PMU (SA-10 Grumble) system of the 1st Anti-Aircraft Missile Group was completely retired in April 2022 and handed over to Ukraine as military assistance during the Russo-Ukrainian War. Additional air defence equipment was donated to Ukraine in March 2023, comprising one 1S91 missile guidance radar and two 2P25 launchers of the 2K12 Kub system, together with 52 3M9ME and 148 3M9M3E missiles. With the current obsolete armament, the 11th Air Force Brigade is capable of performing its tasks until April 2025, when the service life of 9M39 missiles of the Igla system ends, or November 2027, when the lifespan of 3M9M3E missiles of the Kub system comes to an end.

During 2023, the 11th Air Force Brigade is expected to receive two MANTIS C-RAM (counter rocket, artillery, and mortar) systems donated by Germany. Following the outbreak of the Russo-Ukrainian War, Slovakia's air defence has been reinforced with MIM-104 Patriot PAC-3 and SAMP/T systems from the USA, Germany, the Netherlands and Italy since March 2022.

Future Capabilities

According to present plans, the Slovak Air Force requires the acquisition of ground-based air defence/missile defence systems for the protection of the Slovak territory capable of providing:

- Defence against tactical ballistic missiles with a range of up to 1,000 km for at least six defence infrastructure objects on the Slovak territory.
- Defence for objects in the west and east of Slovakia including air bases against aeroplanes, helicopters, cruise missiles as well as Class II and III unmanned aerial vehicles (UAVs).
- Defence for at least four objects, such as important cities (Bratislava and Košice) and nuclear power plants, against rocket, artillery, and mortar (RAM) munitions.

Overview of the required types and numbers of systems to fulfil air defence/missile defence operational requirements

System	Number	Solution Under Consideration
Air defence/missile defence for the protection of the Slovak territory		
Surface-based air defence operations centre	1	SAMOC (Airbus), SBADOC (Aliter)
Group operations centre	2	SAMOC (Airbus), GOC (Aliter)
Long-range surface-to-air missile system with tactical ballistic missile defence capability	2 systems (6 launchers each)	Patriot PAC-3, SAMP/T, BARAK MX ER
Medium-range surface-to-air missile system	4 batteries	IRIS-T SLM, SPYDER-MR, BARAK MX MR, NASAMS, VL MICA, EMADS, KSAM
Very short-range air defence system/short-range air defence system	4 firing units as MANPADS (4 launchers in each) 2 firing units on BOV 8×8 vehicles (4 launchers in each)	Stinger, Grom/Piorun, RBS-70 NG, Mistral 3, StarStreak, Chiron
C-UAV system (for defence against Class I UAVs)	8 firing units	SkyRanger, Protector RWS, LIDS, Drone Dome, HELWS
C-RAM system	4 firing units	SkyNex, Titan, HELWS, Iron Beam
Medium-range 3D radar	1	ELM-2084M-MMR
Short-range 3D radar	2	ELM-2084S-MMR (both already ordered)
Optoelectronic sensor	12	SkySpotter (for the 2nd Air Force Brigade)
Air defence for the protection of the Land Forces units		
Group operations centre	2	SAMOC (Airbus), GOC (Aliter)
Medium-range surface-to-air missile system	2 batteries	IRIS-T SLM, SPYDER-MR, BARAK MX MR, NASAMS, VL MICA, EMADS, KSAM
Very short-range air defence system/short-range air defence system	4 firing units as MANPADS (4 launchers in each) 4 firing units on BOV 8×8 vehicles (4 launchers in each)	Stinger, Grom/Piorun, RBS-70 NG, Mistral 3, StarStreak, Chiron
C-UAV system (for defence against Class I UAVs)	12 firing units	SkyRanger, Protector RWS, LIDS, Drone Dome, HELWS
C-RAM system	2 firing units	SkyNex, Titan, HELWS, Iron Beam
Short-range 3D radar	2	ELM-2084S-MMR (one already ordered)

First Stage of Modernising Slovakia's ground-based air defence (For air defence of Slovak territory against aeroplanes, helicopters and cruise missiles & air defence of heavy mechanised brigade/heavy mechanised battalion group declared for NATO)		
Procurement proposal	**Year**	
	2025	**2026**
Medium-range surface-to-air missile system	1 battery (1 tactical operations centre with 3 launchers and associated equipment)	-
Very short-range air defence system/short-range air defence system (MANPADS)	-	12 launchers with associated equipment

Second Stage of Modernising Slovakia's ground-based air defence (For air defence of Slovak territory against aeroplanes, helicopters, UAVs and cruise missiles)		
Procurement proposal	**Year**	
	2027	**2028**
Medium-range surface-to-air missile system	1 battery	2 batteries
Very short-range air defence system/short-range air defence system (MANPADS)	4 firing units	-
Very short-range air defence system/short-range air defence system (on BOV 8×8)	-	2 firing units
C-UAV system	4 firing units	4 firing units
Group operations centre	1	1
Tactical operations centre for very short-range air defence system/short-range air defence system (MANPADS)	4	-
Optoelectronic sensor	4	-

Third Stage of Modernising Slovakia's ground-based air defence (For air defence of heavy mechanised brigades/mechanised brigades)			
Procurement proposal	**Year**		
	2029	**2030**	**2031**
Medium-range surface-to-air missile system	2 batteries	-	-
Very short-range air defence system/short-range air defence system (on BOV 8×8)	2 firing units	2 firing units	4 firing units
C-UAV system	-	6 firing units	6 firing units
Surface-based air defence operations centre	1	-	-
Group operations centre	-	1	1
Medium-range 3D radar	1	-	-
Short-range 3D radar	-	1	1

Fourth Stage of Modernising Slovakia's ground-based air defence (For tactical ballistic missile defence of the Slovak territory, C-RAM protection of Slovak territory and command posts of heavy mechanized brigade/mechanized brigade)				
Procurement proposal	**Year**			
	2032	**2033**	**2034**	**2035**
Long-range surface-to-air missile system with tactical ballistic missile defence capability	-	1 system	-	1 system
C-RAM system	-	2 firing units	2 firing units	2 firing units
Optoelectronic sensor	8	-	-	-

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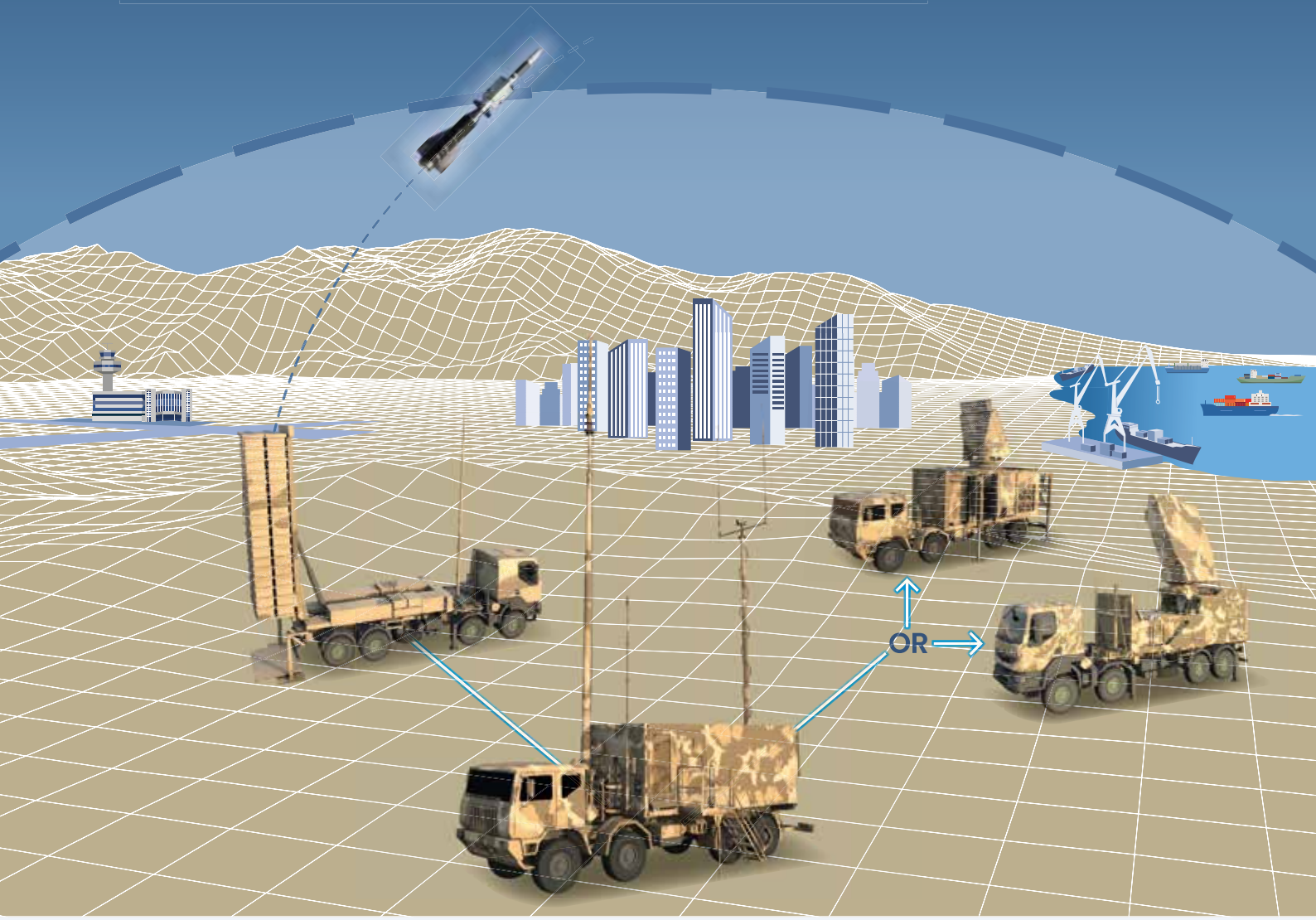

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Credit: Armáda České republiky

Candidates for the new Slovak man-portable air defence system include the Swedish RBS-70 NG system, which is operated in the neighbouring Czech Republic by the 25th Anti-Aircraft Missile Regiment.

- For the protection of the Land Forces units of the OS SR, the Slovak Air Force wants to acquire air defence systems for providing:
- Defence for manoeuvre battalions and heavy mechanised brigade command post/heavy mechanised battalion group declared for NATO – against aeroplanes, helicopters, cruise missiles, Class II and III UAVs as well as RAM munitions.
- Defence for manoeuvre battalions against aeroplanes, helicopters, cruise missiles, Class II and III UAVs.
- Defence for mechanised brigade command posts against aeroplanes, helicopters, cruise missiles, Class II and III UAVs along with RAM munitions.

To achieve these capabilities, the acquisition of not only new air defence missile systems but also new surveillance radars, BOV 8×8 armoured vehicles (the Slovak variant of the Patria AMV XP armoured personnel carrier), mobile operations centres and communications equipment (L3Harris Falcon IV radio stations, Link 16 terminals) will be required.

The Acquisitions

The Ministry of Defence of the Slovak Republic proposes to start the implementation of the 1st stage of the procurement immediately, basically for maintaining the current capabilities, with deliveries expected 2025 and 2026. The required numbers of equipment within this stage of the modernisation are one medium-range surface-to-air missile system and 12 very short-range air defence systems/short-range air defence systems in portable configuration (MANPADS). The total estimated costs for the implementation of the 1st stage are approximately EUR 196.5 M EUR including VAT. The funds for the procurement are included in the Programme Plan of the Ministry of Defence of the Slovak Republic for the years 2024 to 2029, as well as in the budget of the Ministry of Defence for the year 2023, allowing for initial payments after the signing of potential contracts.

The Ministry of Defence recommends the acquisition in a government-to-government (G2G) format, which should better secure product prices for the duration of the contract. The advantages of this approach are seen as increasing the guarantee of delivery of the procured equipment and also providing the opportunity for deeper military cooperation as well as deepening bilateral partnerships at the intergovernmental level.

The implementation of the next stages of the procurement of the air defence firing systems and its timing will depend on the financial situation of the Ministry of Defence and the funds allocated in the subsequent years. According to the current schedule, the acquisition is planned in additional three phases until 2035. However, the precise overall operational requirement will need to be additionally confirmed by the wargame and subsequently implemented in related strategic documents before further stages can be implemented. ■

Credit: URC Systems

In the category of C-UAV systems, for example, the ANDROMEDA with JAM-U directional anti-drone jammer and GOT-U optoelectronic surveillance subsystem is available on the market.

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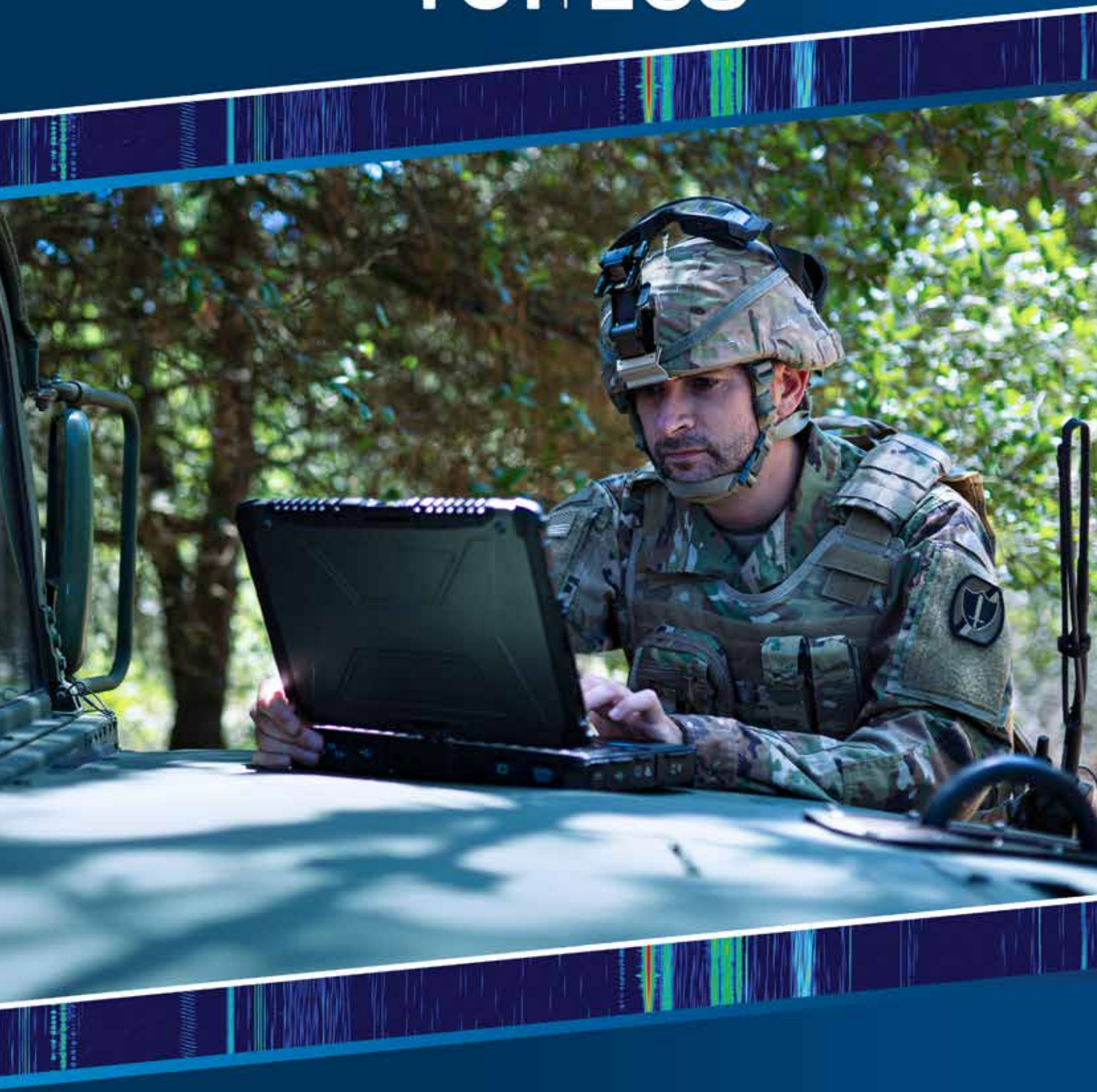

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Israel's Counter-UAV Technologies: Securing the Skies

Tamir Eshel

Israel was among the first nations to recognise the potential threats of unmanned aviation, particularly from Iran and its proxies in the region. Consequently, over the past several decades, Israel has solidified its reputation as a leader in the unmanned aviation sphere.

Since the Second Lebanon War in 2006, Iran has conducted drone attacks from Lebanon, Syria, Iraq, and Iran. Although few have penetrated Israel's airspace, with few such cases compared to rocket strikes launched by Lebanese and Palestinian non-state armed groups. Yet these incidents still exposed a capability gap that Israel sought to address. Israel has focused on neutralising the Iranian drone threat by implementing doctrinal changes, operations, and techniques. Technological advancements now address drone dangers at various operational levels. Nevertheless, the dramatic proliferation of unmanned aerial vehicles (UAVs) and loitering munitions (LMs) reflects lessons learned by both sides in the war in Ukraine, stemming from the Iranian deployment of advanced drones in support of Russia, and the significant military potential of dual-use drone technology, as demonstrated by the Ukrainian side. Today, Israel is prepared and equipped to confront the ever-evolving and imminent drone threat, despite the exponential growth in adversarial capabilities.

Credit: Xtend

The Griffon system developed by Xtend uses a detachable arresting apparatus to intercept and disable rogue drones

An Evolving Threat

The threat posed by UAV is continuously evolving. Historically, UAVs, along with precision-guided bombs and missiles, represented asymmetric capabilities reserved for developed, primarily Western nations combating irregular forces, such as insurgents or terrorists. This characterisation may have been accurate until the early 2000s, but it is no longer realistic. With the entry of China and Iran into the UAV arena, specifically regarding LMs, military and paramilitary forces have gained access to advanced aerial capabilities with unprecedented potential.

Iran has emerged as a capable UAV developer, introducing and deploying new capabilities regularly. Iran also garners extensive combat experience with these systems, which offers valuable feedback for developing new capabilities to challenge adversaries. Iran's arsenal now includes tactical drones capable of operating over hundreds of kilometres on reconnaissance and attack missions, large jet-powered drones for fast, long-range missions carrying large air-dropped bombs, low-observable platforms primarily used for reconnaissance, and autonomous drone-based 'mini-cruise missiles'. The latter 'dark drones' do not rely on data links or satellite navigation (GPS), rendering them virtually immune to electronic attacks. LM utilise autonomous guidance or remote operation to home in on specific targets. LM often employ a communication channel and seekers, enabling operators to select and designate targets for the drone

Credit: Robotican

Goshawk, developed by Robotican, autonomously intercepts drones by swiping the rogue drone with an arresting net.

Credit: IAI

ELI-2139 Green Lotus tactical multi-sensor system for air and ground situational awareness.

to pursue. This communication link allows drones to operate in coordinated groups or swarms, presenting a more formidable challenge to defenders.

Iranian drones have been deployed in Syria, Iraq, and Yemen, where they have honed advanced operational concepts using various types and multiple drones in simultaneous attacks. Iranian drones have also been extensively used by Russian forces in Ukraine, resulting in devastating attacks. Israel also faces ongoing challenges from these drones supplied to Iranian proxy organisations in its own region.

Another developing threat is the militarisation of commercial drones, a trend observed in Ukraine. Inexpensive, do-it-yourself (DIY) drones constructed from commercially available kits are repurposed into attack platforms. These range from small hobbyist drones used for intelligence gathering and artillery spotting to larger drones that carry multiple grenades or small bombs dropped by operator command, and even fast, highly manoeuvrable racing drones rigged with a single warhead utilising 'first person view' (FPV) to become a guided missile that hunts, chases, and strikes moving targets.

The war in Ukraine has unleashed a DIY Pandora's Box, setting a precedent for non-state armed groups to harness this advanced technology for future use. These technologies provide both a means for conducting reconnaissance and delivering strikes. The latter can be amplified by targeting hazardous, flammable, and explosive materials to achieve secondary effects, striking high-value targets, or deploying drones in diversionary attacks as part of larger operations.

Managing Drone Traffic

Moving forward, an important factor to consider is the increasing volume of commercial drone activity as users adopt drone technology for various applications. Detecting and locating low-flying rogue drones or drone swarms within airspace congested by commercial activity necessitates automated unmanned traffic management (UTM) systems to oversee all authorised drone activity in a country. The Israeli start-up company High Lander developed such a system, which was tested this year by one of the Israel Air Force (IAF) Air Control Centres. The company was also selected to provide UTM capabilities to Israel's national police force.

Airspace management is only one aspect of controlling UAV activity at low altitudes. The drone threat is too complex to be addressed by a single solution, and it is challenging to determine which entity is responsible for providing the solution. Should it be the military, the police, the Ministry of Transportation, an aviation authority, or an internal security agency? This remains an open question in Israel. While some sectors are covered—the Israel Defense Force (IDF) and Air Force have implemented solutions, as has the airport authority as part of their ongoing security plans, but not the country as a whole. The Israeli Ombudsman's office recently reported that the country has yet to adopt more comprehensive protection against drones. Fortunately, there is no shortage of Israeli technological solutions.

When tasked with dealing with drones, various entities employ different means. Civilian organisations, such as security companies protecting VIP residences, office buildings, commercial sites, mass gatherings, municipal operators, and government agencies responsible for transportation or public services, focus on safeguarding specific areas or activities from intentional or unintentional drone interference. They aim to detect any drone activity over the protected area and deny unauthorised operators access. Equipment for these agencies is often limited to commercially available

Credit: Tamir Eshel

The I-TACT family of optoelectronic systems from Controp.

Credit: Tamir Eshel

Two mobile C-UAV systems integrated by UAE-based Resource Industries and displayed at IDEX-2023 were D-Fend Solutions' EnforceAir and the Pitbull remotely-operated weapon station.

systems and services. As for mitigation, taking down a seemingly 'hostile' target could be considered illegal when protecting civilian and commercial spaces. It may result in lawsuits from individuals exposed to damage or harm by the drone or countermeasures against it. Consequently, such enforcement should be measured and scalable, minimising collateral damage.

C-UAV Situational Awareness

Israeli manufacturers IAI/Elta Systems, Elbit Systems, and Leonardo DRS (formerly RADA) offer ground-based radars designed or optimised for C-UAV missions. These radars employ Active Electronically Scanned Array (AESA) radars and micro-Doppler signal processing techniques to efficiently detect and track multiple slow-flying, low-altitude targets at ranges of several kilometres over a 90° sector. Several units can be combined for full 360° coverage. While DRS offers its radar as a component integrated by other manufacturers, such as Rafael's Drone Dome, Elbit Systems and Elta provide their radars as part of their own C-UAV solutions. Introduced in 2022, Elbit Systems' DAiR radar can detect hundreds of targets, including small drones and humans, at 12–15 km ranges. It is compatible with the All-purpose Structured EUROCONTROL Surveillance Information Exchange (ASTERIX) protocols, enabling seamless information sharing with C4I systems.

Elta Systems offers tactical C-UAV capabilities with its ELI-2139 Green Lotus system, a multi-sensor system designed for tactical low-tier ground-based air defence (GBAD), counter-UAV (C-UAV), and counter-rocket, artillery & mortar (C-RAM) missions. This modular solution combines S- and X-Band radars, VHF/UHF direction-finders/ communications intelligence (COMINT) systems, as well as a day and infrared (IR) optoelectronic sight. The mobile system is capable of automatically detecting, tracking, classifying, and identifying, a wide variety of aerial targets, including fighter aircraft, helicopters, UAVs, drones, and low radar cross section (RCS) targets such as missiles, rockets, artillery, and mortar shells. It is also capable of detecting and classifying ground targets, such as vehicles and slow-moving persons. All multi-sensor data is collected and processed within the system's unified command and control (C2) console, which automates detection, classification, and identification to provide a comprehensive situational awareness picture (SAP).

Optoelectronic sensors are also employed to identify drones; typically, they are triggered by other detection and tracking systems, such as radars and electronic surveillance systems. Combined with radars, these sensors serve as validation technology to reduce false detections and classify and verify targets. Sophisticated optronic IR cameras identify drones based on visual and temperature-related identifiers, ensuring that detected objects are actually drones. Optronic systems can support detecting and verifying UAV targets at extremely long ranges, particularly when engaging fixed-wing, high-flying drones detectable by radar but requiring tracking assistance from other systems. Controp recently introduced a comprehensive range of optronic systems for mobile, deployable, and fixed C-UAV and air defence applications under the I-TACT product line. Optimised for spotting and tracking low-signature targets, the I-TACT line provides passive scanning, classification, and tracking of drones at ranges from 6-40 km or small drones at 1-6 km. I-TACT can be integrated into existing optronic systems with the performance level required for

detection, recognition, and identification (DRI) at range. Enhanced image processing capabilities improve the I-TACT system's performance, allowing the system to focus on specific regions of interest in the picture to improve target recognition, automatic flight path prediction, and tracking, enabling users to improve their passive UAV detection and engagement.

Drone Guards

Numerous C-UAV systems developed by Israeli companies for civilian and military applications utilise passive and active sensors for early warning, detection, classification, and situational awareness. One of the pioneering systems in Israel, the Elta ELI-4030 Drone Guard, features an open system architecture, enabling the integration of various sensors and effectors such as radars, passive COMINT, and optronic systems for target detection and verification.

The C2 System used by Drone Guard unifies all functions into a single system and employs automated threat analysis and AI-based decision-making tools, decreasing operator workload and allowing the system to be crewed by relatively few operators, even in high-demand scenarios. Drone Guard offers numerous threat mitigation methods, including target flight control takeover via cyberattack, communication and navigation (GPS) protocol disruption through jamming, or engagement with a weapon system. Other potential interception methods which can be integrated include drone-deployed disruptive measures, and accurate stabilised fire from various weapons mounted on remote weapon stations (RWSs). Using an optimal sensor and effector configuration, Drone Guard can detect and track drones up to 40 km away, identify targets up to 20 km away, and neutralise selected targets up to 10 km away.

Scanning the electromagnetic spectrum for rogue drones is an effective surveillance method against remotely controlled or monitored drones. D-Fend Solutions' EnforceAir system uses passive receiver antennas to detect the unique communication signals commercial drones use within an area. The received telemetry signals can be decoded to determine information such as the drone model, current position, and position at take-off. This information can also be used as part of responses against the operator, and for conducting a remote cyber-takeover of the drone. Radio Frequency (RF) cyber-takeover techniques are tailored to overcome specific protocols of commercial or DIY drones. The system automatically executes RF cyber-takeovers of drones, forcing them to perform a safe landing and minimising the risk of collateral damage. These cyber solutions are particularly suited to urban areas, as they do not require direct line of sight.

Credit: Airobotics

The Raider DKD from Iron Drone.

Credit: Skylock

DRONELOCK DKD solution from Skylock.

Drone-Kill-Drone Solutions

When more forceful means of interception are required, then ballistic nets, chaff projectiles, or so-called 'Drone-Kill-Drone' (DKD) solutions are utilised. Some DKD solutions use expendable or reusable kinetic drones, while others use deployable armaments carried by drones. An example of the latter capabilities is the Iron Drone from Airobotics, which is designed to defend assets against hostile drones in complex environments with minimal collateral damage. As a fully automated solution, it uses the Raider, a small interceptor drone. During an intercept, Raider flies autonomously towards its designated target, tracking the target automatically using a day/night camera provided with computer vision software, and deploys a ballistic net to incapacitate the rogue drone, with the net subsequently deploying a parachute to and safely lower the target to the ground.

Another Israeli C-UAV system utilising the DKD concept is Robotican's Goshawk, an autonomous system employing a drone which deploys an arresting net to capture hostile drones in mid-air. Capturing the rogue drone allows Goshawk to perform controlled disposal of the captured drone at any chosen location, such as an explosive pit for a weaponised drone, or a safe site

for further inspection. Its relatively minimal potential for collateral damage makes Goshawk suitable for operation in populated areas and high-risk locations.

When a rapid response is crucial and minimal facilities are available to handle the situation, the Xtend Griffon enables an operator to deploy a fast interceptor drone system. The Griffon comprises a drone with an underslung net mounted on a rigid frame. Upon capture of the target drone, the net is detached and falls to the earth with the target. The control system employs virtual reality and sensor fusion technologies, which provide the operator with assistance enabling them to conduct semi-automated interceptions. This allows an operator with no flight experience to use the system.

Other kinetic C-UAV interceptors use drones which rely on hit-to-kill for target defeat. Skylock, a C-UAV solution provider, employs two kinetic intercept methods – the DRONELOCK, a quad-rotor drone which autonomously intercepts hostile drones by ramming them, relying on the force of the kinetic impact to down the target. DRONELOCK leverages proprietary onboard AI and machine vision processing to track its targets. On the rapid interception side, Skylock offers the Sky Interceptor, which is essentially a rocket equipped with a non-explosive 'countermeasure cloud' warhead and proximity fuze. The warhead contains a condensed mesh of thin rubber strips, and upon activation, the warhead releases these strips into a large countermeasure cloud, which will entangle the propellers of any drone present within or passing through it, and thereby causing it to crash. The countermeasure cloud covers a relatively wide area, enabling the system to engage drones performing evasive complex manoeuvres and drone swarms. Effective at ranges of 1-3 km, Sky Interceptor rockets can be launched from ground or aerial platforms.

Credit: Tamir Eshel

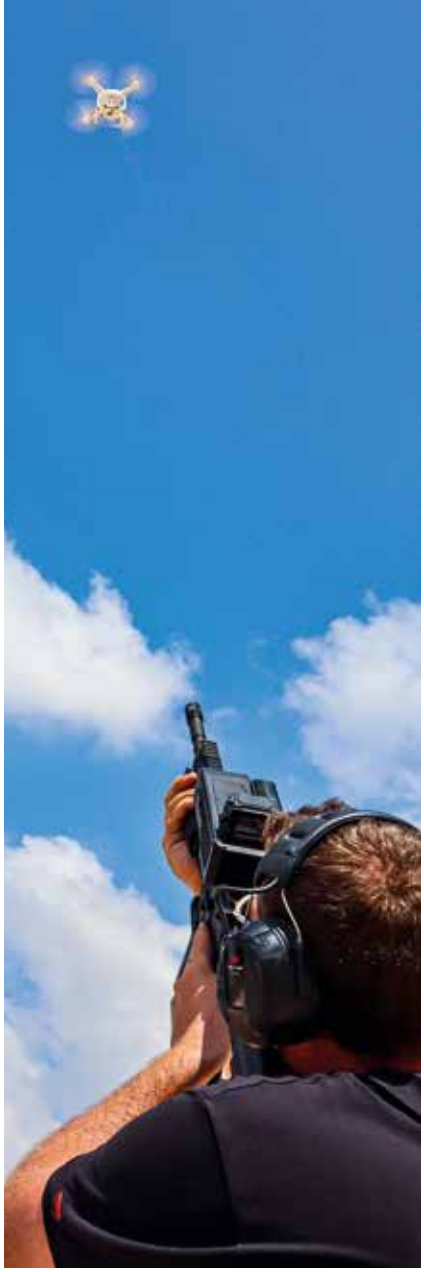
Rafael is developing the LITE BEAM, a 7.5 kW laser effector to defeat small drones.

Lethal Countermeasures

Some sophisticated drones may be immune to cyber-takeover or soft-kill solutions, leaving the hard-kill option as the only way to prevent a drone attack. Using common small arms against drones is extremely difficult, requiring luck, good visibility and eyesight, favourable wind conditions, and sniper-like weapon control. To simplify this task, SmartShooter developed the SMASH family of fire control systems, which enable operators to engage moving targets such as UAVs using standard firearms fitted with the system. The SMASH range of small arms fire control systems essentially comprise a traditional small arm optic integrated with cameras, a laser rangefinder, a tilt sensor, a meteorological sensor, and a fire control computer with computer vision and ballistic calculation. The system operates by the user designating a target, following which the system tracks the target and continually calculates an optimal point of aim to ensure a hit on that target. This is displayed on the sight, informing the operator where to aim their weapon. The operator is then free to pull the trigger, however the system electronically locks firing pin release until the weapon's point of aim aligns with the optimal point of aim set by the fire control computer. This arrangement makes it much easier to engage moving targets such as UAVs with small arms.

Another solution embedded into RCWS is General Robotics' Pitbull-AD, a RWS fitted with soft-kill effector in the form of the DroneShield DroneCannon jammer, and the hard-kill component consisting of a 7.62 mm or 5.56 mm machine gun. The fire control system is capable of automatic target detection, tracking and recognition, as well as establishing fire inhibition zones.

Addressing the need for C-UAV for naval vessels, Rafael has optimised the capabilities of its TYPHOON Mk 30-c naval RWS defeat UAVs out to ranges of 3,000 m. The use of airburst ammunition and improvements to the original system's automatic target recognition and fire correction are offered as an upgrade for existing TYPHOON users.



Credit: Smartshooter

Smartshooter enables rifles equipped with SMASH fire control systems to become counter-drone weapons.

Rafael also offers a high-energy laser (HEL) effector as part of its Drone Dome C-UAV system. The HEL interceptor can be used as a complementary measure, with the advantages of engagement at the speed of light, unlimited magazine capacity, and negligible cost per interception. LITE BEAM is a 7.5 kW HEL intended for use against small drones, as well as ground targets such as improvised explosive devices (IEDs) and unexploded ordnance (UXO). It is capable of engaging targets from ranges of a few hundred metres out to 2,000 m.

As drone technology continues to proliferate, Israel, as with others, must adapt to address these evolving threats. C-UAV capabilities remain a primary concern for local authorities, government agencies, and defence, security, and commercial sectors. As such, their countermeasures are anticipated to remain in the spotlight for the foreseeable future. ■

Keeping one step ahead of the next UAS threat

Interview with Misho Tkalcevic, CTO at TCI

European Security & Defence speaks with Misho Tkalcevic, Chief Technology Officer at TCI (part of SPX CommTech), on emerging UAS threats and the specialised Radio Frequency (RF) technologies keeping defence teams one step ahead.

Photo: SPX CommTech

Defence team using the SPX CommTech BLACKBIRD COMINT and drone detection and geolocation software

SPX CommTech's BLACKBIRD COMINT and drone detection and geolocation software

Q: How are today's defence teams engaging with UAS technology?
A: Unmanned aircraft systems (UAS) have advanced significantly and both specialist military-grade and commercial drones are playing critical roles in conflict in Europe and further afield. Importantly, these devices use the Radio Frequency (RF) spectrum to facilitate accurate and real-time situational intelligence gathering and communications across teams, improving strategic decision-making, interception of enemy data exchange, and the defeat of malicious UAS.
A more emerging development is the use of UAS in enabling network-centric warfare to become more data-centric. UAS are connected to a network of other communications and intelligence-gathering devices to paint an accurate picture of a situation from many vantage points, creating significant information advantage for dispersed defence teams. Teams with the most precise information from multiple sources will likely win and, to do so successfully, the information exchange must be instantaneous so that the best tactical and deployment decisions can be made.

Q: What challenges do commercial drones present on the battlefield?
A: Today, drones and UAVs are used on both sides of the conflict, from Ukraine to Israel and beyond. The weaponisation of commercial drones has been driven by their increased accessibility and subsequent lower cost, creating new challenges for security and the battlefield.
Firstly, amateur drones can have a disproportionate impact for their cost and size, potentially destroying military kit thousands of times more expensive. Secondly, detecting and defeating commercial drones can be a challenge. Traditional RF radars are effective at detecting large airborne threats, but hostile compact commercial drones, travelling at increased or decreased speeds, are much harder to detect and therefore defeat. The RF detect for commercial drones means these existing systems need to be re-calibrated. Another challenge lies in how defence organisations appropriately prioritise and respond to threats. Using high-cost military-grade UAS to respond to low-cost UAS threats, usually deployed in volume, often doesn't make sense.

Q: What's driving innovation in this space and what could the future hold?
A: Access to technology and the agility of commercial communications are driving improvements to communications intelligence (COMINT) and counter-UAS. As a result of commercial devices being introduced in modern battlefields, we will no doubt continue to witness an interesting pollination between commercial and military communications. Essentially, striking a balance between accessibility and the right technology will determine if there is a more disruptive solution that might change the defence landscape.

Q: How is SPX CommTech planning to identify and deliver the appropriate solution?
A: At SPX CommTech we're learning on a daily basis by listening to the experience and needs of customers, partners and those on the battlefield. By combining decades of technology innovation and expertise with agile and collaborative teams, we're focused on delivering sustainable and exceptional results to customers across the globe.
For instance, our Battlespace portfolio enables defence teams to safely detect, defeat and exploit RF signals to enhance COMINT and counter-UAS. BLACKTALON detects, tracks and defeats UAS engaged in hostile activity or surveillance by a nuisance drone enthusiast, insurgents, state actors or hostile militaries. Already deployed in Eastern Europe, BLACKTALON provides comprehensive situational awareness and mitigation as a standalone or networked capability, as a multi-layered counter-UAS, or as a component of a Ground Based Air Defence (GBAD) system. We also recently introduced an upgrade to our BLACKBIRD COMINT and drone detection and geolocation software.
Ultimately, our main goal is to innovate and deliver specialised technologies to defence teams for a smarter, more secure future for all.

For more information on SPX CommTech's solutions visit www.tcibr.com.

Photo: SPX CommTech

Defence team using the SPX CommTech BLACKTALON Counter Unmanned Air Systems (counter-UAS) solution

Portable Unmanned Assets

Tamir Eshel

In today's rapidly evolving battlefield, small-unit tactics and the ability to operate in complex environments are critical to the success of military operations. Emerging technologies, such as unmanned platforms, loitering munitions, and AI-driven solutions, are transforming how soldiers engage with adversaries and navigate challenging terrain. This report examines the latest innovations in portable unmanned assets, providing insight into how these technologies enhance warfighters' capabilities and address the needs of small-unit tactics.

Military operations often rely on the ability of small units and individual soldiers to execute missions autonomously. From special operations teams to infantry squads, soldiers undergo rigorous training to function cohesively, survive in the field, and sustain themselves for extended periods. They carry their personal and squad weapons with full ammunition loads, personal survival gear, observation systems, night vision and communication equipment, food, water, and medical kits. Additionally, spare batteries are necessary to power those electronic devices, collectively amounting to over 60 kg per individual and nearly half a tonne for an entire squad. Consequently, something else must be removed for every extra asset added to a soldier's load.

Credit: Marom-Dolphin

The Wild Goose electrically powered robotic hauler from Marom Dolphin is fitted with Smartshooters' SMASH HOPPER lightweight, remote-controlled weapon mount.

One potential solution to the weight challenge involves utilising a robotic load carrier to offset excess weight. However, to withstand all-terrain operations, such a carrier must be robust and heavy enough to be able to carry the load. A powered loader would be more convenient and advantageous, a niche filled by the Marom-Dolphin's WILD GOOSE tactical hauler. This electric-powered robotic vehicle transports heavy loads over different terrain while preserving full combat effectiveness and troop mobility. Available in two or four-wheeled configurations, the two-wheeler model weighs 28 kg and has a load carrying capacity of 70 kg, while the four-wheel hauler can carry 140 kg. The hauler consists of modular units, allowing soldiers to combine two of the two-wheeler models in the field to create a four-wheeler hauler. The haulers connect to the soldier through an ergonomic and elastic goose-neck quick-release connector, ensuring hands-free movement, vehicle stability, and unhindered weapon operation.

As a four-wheel robot, the hauler can become an unmanned weapons carrier, mounting an automatic weapon carried by the squad in a small remote weapon station, and then remotely operated by a squad member. This feature allows the squad to strategically position support weapons, even in exposed locations, while operating from behind cover. The same configuration can allow for casualty evacuation by carrying a stretcher, using the soldier's goose-neck connector for guidance. In this mode, the hauler frees up three soldiers who would otherwise be needed to transport a wounded comrade to safety.

Supporting warfighters in various roles, unmanned aerial vehicles (UAVs) offer innovative capabilities, such as the automated image-based medical sensing (AIMS) developed by the US-based company Areté. AIMS enhances battlefield or mass casualty

Credit: Tamir Eshel

The Automated Image-Based Medical Sensing (AIMS) system developed by Arete can be used by any camera, In the 2021 trials, it was demonstrated on an Ascent Aerosystems' SPIRIT coaxial drone.

triage by remotely locating, characterising, and monitoring casualties from the point of injury to field care. The system employs the drone's camera, augmented by computer vision and on-board medical sensing software, to detect human casualties, assess wounds, measure respiration and other vital signs, and document patient status and changes. In 2021, Areté demonstrated this capability in a field test, achieving a TRL-6 level of readiness for this critical capability.

Special operations teams may consider remotely controlled weapon mounts such as Smartshooter's SMASH HOPPER P to establish covert firing positions in ambush

scenarios. This lightweight, low-profile stationary remote weapon station (RWS) can accommodate assault or sniper rifles and can be assembled by one person in the field. Equipped with pan and tilt motion control, the system benefits from the company's fire control software developed for the SMASH range, providing target detection and tracking to enable accurate fire.

Small Loitering Munitions and their Applications

Among the robotic assets developed for the warfighter are various nano-loitering munitions. This new weapon category brings beyond line of sight (BLoS) attack capability to the individual soldier and squad level.

Defendtex, an Australian company, offers the unique D40 expendable grenade-sized munition, designed for launch from 40 mm grenade launchers, but can also be hand-launched if required. Prior to launch, the D40 is folded in a compact state, measuring 120 mm in length and 40 mm in diameter. Upon deployment, it extends its rotors into a quad-rotor configuration and takes flight, with a top speed of 20 m/s, a maximum range of 20 km, and a flight time of 30-60 minutes, depending on payload. The drone has an empty weight of 190 g and a maximum takeoff weight of 300 g. Its modular payload can be configured for kinetic, electronic attack, ISR, smoke/flash, and flash/bang effects. Capable of autonomous flight and swarming, the D40 enables a single soldier to engage multiple targets or deliver a multiple rounds, simultaneous impact (MRSI) strike, an effect previously achievable only by a modern artillery system or a battery executing a coordinated fire plan.

Another loitering munition is the Spike Firefly developed by Rafael. This coaxial-rotor-powered VTOL drone utilises a bi-directional military-standard datalink and features a detachable high-explosive fragmentation (HE-FRAG) warhead. Easily assembled and launched by a single operator, the Firefly employs day and thermal optronic and proximity sensors for navigation towards its target, using either preset waypoints or being guided via camera Upon target detection, the operator can command the Firefly to strike or abort the attack at any time before impact. The weapon is disarmed if no target is engaged and can be safely retrieved for reuse. The Firefly boasts an engagement

Credit: Tamir Eshel

Defendtex D40 can be deployed from a 40mm grenade launcher. Each D40 round comprises separate drone and payload assemblies which are joined just before launch.

Credit: Tamir Eshel

Shield AI's NOVA 2 drone is optimised for collaborative and autonomous clearing of indoor spaces.

SWITCHBLADE 300 BLOCK 20 has a new panning camera suite enabling direct cueing while circling.

range of 500 m in dense urban terrain or 1,500 m in open areas, with a mission endurance time of 15 minutes. A complete Firefly system includes three loitering munitions, spare batteries, a control tablet, and a backpack, with a combined weight of 15 kg.

SpearUAV, another Israeli company, has developed the VIPER, a canister-launched loitering munition with autonomous hovering capability. VIPER provides organic, responsive, precision fire support at the squad level, allowing operators to neutralise immediate threats such as enemy snipers and RPG teams without dependence on higher-level assets. Featuring a low acoustic and visual signature, day and thermal camera sensor with automatic target recognition capability, VIPER utilises AI-driven obstacle avoidance sensors for safe flight, even in challenging terrain. It can operate individually or as part of a collaborative swarm controlled by a single operator during complex missions. VIPER has an interchangeable payload bay, with current options including explosive, non-lethal, or electronic warfare payloads. In 2022, Spear partnered with Leonardo DRS to market the VIPER in the US.

Turkish company STM has developed the KARGU, to provide reconnaissance and precision strike options for ground forces. The KARGU weapon system operates through fully autonomous navigation, requiring only 60 seconds for pre-mission preparations. Upon target identification using its on-board cameras, supported by automatic target recognition software, KARGU transfers control to the operator over the secure, AES-256-bit encrypted datalink. The operator maintains full control and can then authorise the strike. KARGU weighs 7.6-7.8 kg depending on the payload, and is armed with a proximity fuzed 1.3 kg HE-FRAG warhead with 840 pre-formed 4 mm cuboid fragments. The platform has a mission endurance of 30 minutes, and can operate up to 10 km from the control station and at altitudes of 3 km, in wind conditions of 10 m/s.

In the US, Aerovironment is now offering the Switchblade 300 Block 20. This is a tube-launched loitering munition featuring a foldable wing design. The predecessor Block 10 model has seen extensive combat use in Iraq, Syria, Afghanistan, and Ukraine. The updated Block 20 model introduces a tablet-based control system, streamlining usability, planning, and training for the operator. Additionally the updated model received an improved Digital Data Link (DDL) range with AES-256 bit encryption, a new day/IR panning camera suite enabling it to be cued onto target while circling and carrying out continuous positive identification (PID).

Weighing 1.77 kg, the Switchblade 300 Block 20 can be made ready and deployed by tube launch in less than two minutes, allowing it to be quickly employed. Its winged configuration allows for a dive velocity of 50 m/s, significantly faster than the terminal speed achieved by multirotor drones. It has an endurance of over 20 minutes, can operate up to 10 km from the controller, and reach altitudes of 4.57 km.

Innovations in Indoor and Underground Operations

Small loitering munitions have revolutionised small-unit tactics, particularly in complex urban terrains, by placing precision lethality in the hands of individual warfighters. However, drones and loitering weapons have limitations regarding indoor or underground operations. New platforms specifically designed for these environments, employing cutting-edge AI and machine vision technologies, now support warfighters engaged in close-quarter battle (CQB) scenarios, even indoors.

Situational awareness is crucial in CQB, and traditionally it has been achieved through assault teams meticulously clearing buildings room by room. This time-consuming and dangerous process exposes soldiers to significant risk, and is even more complex when clearing underground facilities, or high-rise buildings. Drones designed for these tasks can perform as effectively as humans but with greater speed. As most indoor spaces are unoccupied by the enemy, drones can use their sensors to map indoor areas, scanning every corridor and space for signs of life or booby traps. To expedite the process, surveillance is conducted autonomously, with the drone only reporting the precise target location or using effectors against the target when a suspected enemy is detected. These drones utilise various technologies to ensure accurate navigation without GPS and maintain continuous communication links, often using advanced self-healing MESH networks.

Examples of drones designed for indoor use include the Nova 2 from US-based Shield AI. This drone employs state-of-the-art path planning and computer vision algorithms to autonomously navigate complex subterranean and multi-story buildings, for up to 16 minutes hovering time, at ranges of up to 150 m indoors. The full autonomy eliminates the need for RF or teleoperation links. As Nova 2 clears a building, detected threats are automatically added to a map, and users are alerted through vibration notifications. It uses ten sensors, five Intel RealSense stereo depth cameras, four IR cameras, and a long-wave infrared (LWIR) camera. Throughout the flight, the drone generates a 3D indoor multi-story and outdoor map of the building and its surroundings, highlighting door and window entry

points and providing a common operating picture of the scene. It features top and bottom payload attachment points, high-speed data interfaces, power connections, and remote ejection capabilities to accommodate a variety of payloads. With a gross weight of 1.5 kg, Nova 2 can carry external payloads of 250 g in each of the top and bottom payload slots.

The Xtender is another drone optimised for indoor operation, from Israeli company Xtend. Unlike the Nova 2, the Xtender relies on human guidance for indoor flight. The drone can support payloads weighing up to 150 g, and these can be radio relays or other loads required in complex scenarios. Its control system is provided with Xtend's proprietary Mark & Fly XOS operating system, which supports multiple drones' coordinated swarming. The company offers a single-hand controller which is linked to a wearable communications system and virtual reality goggles, enabling the user to guide the drones using simple hand gestures and monitor the environment through their cameras.

A third drone optimised for indoor operation is the Rooster, developed by the Israeli company Robotican. This unique design combines a quadrotor drone encased in a rugged, barrel-shaped frame that serves as a protector screen and a wheel, enabling the Rooster to both fly and roll on the ground. This hybrid configuration enables rapid, agile movement and extended endurance for indoor missions. The hybrid system uses rotors in flight and conserves power when rolling on the ground or stationary. By employing multiple Roosters, the vehicles can establish a self-healing mesh network to relay communications between the vehicles and maintain continuous data links to the controller. This enables more reliable operation in environments such as caves, rubble-strewn areas, or complex built-up environments. The Rooster weighs 1.45 kg and can carry payloads of up to 300 g. It can hover and fly for 12 minutes or roll for up to 45 minutes, but by combining movement and static observation, it can support a longer mission time out to around 90 minutes.

As military technology advances, increasingly sophisticated personal unmanned assets are giving soldiers unprecedented new capabilities to carry employ. By leveraging the power of unmanned systems, AI, and advanced communication networks, these solutions are setting new standards for small-unit tactics and transforming the capabilities of special forces and dismounted infantry operations. ■

Credit: Tamir Eshel

Rooster is a hybrid robotic system for indoor surveillance, using the rotors at full power for flight and reduced power when rolling on the ground or stationary.

Trends in Personal Weapon Sights and Ancillary Systems

David Saw

These days it is no surprise to see an assault rifle festooned with all sorts of accessories, all accommodated on rail systems attached to the body of the weapon. There appear to be no limits as to what users wish to attach to weapons, almost to the point where the original assault rifle appears to be totally unbalanced due to all the bits and pieces that some users feel are absolutely essential to conduct their mission. Certainly Special Operations Forces (SOF) seem to be particularly keen on maximising the accessory count on their weapons.

The roads to personal weapons having the ability to accept a profusion of different sights, accessories and ancillary systems has been a long one. There are a multitude of reasons for this, some are technical, a lot of the technologies that are commonplace today were, exotic and expensive, and in many cases not that impressive, or simply did not exist in the 1970s for example.

Then innate conservatism comes into play, the infantry have been using rifles with iron sights virtually forever, teaching marksmanship is a fundamental part of the training regime and obviously gets results. Spending money on optical sighting systems for ordinary infantry might be considered unnecessary, and as an expensive and pointless luxury when existing methods are perfectly satisfactory. Again if we use the 1970s as our starting point the quality versus cost argument did not appear to be that persuasive in terms of an optic for an individual rifle.

On the other hand, there were no objections to fitting telescopic sights to sniper rifles, people had been doing this for more than a century! Obviously in that period the quality of optical sights increased significantly. Today, there is a vast choice of sniper rifles, and these come in a multiplicity of calibres. In parallel there is a large selection of precision optics that can be utilised by these sniper rifles offering high precision anti-personnel/anti-materiel capabilities at extraordinary ranges, compared to previous sniping capabilities. The asymmetric conflicts in Iraq and Afghanistan proved conclusively that possession of a high quality sniping capability is essential on the modern battlefield. Ideally having the ability to acquire different rifle solutions, usually in different calibres, for anti-materiel and anti-personnel applications.

Credit: French Army

French forces on exercise in Estonia, with their standard HK416F 5.56×45 mm assault rifles, note the blank firing adaptor. The HK416F rifles are equipped with Aimpoint CompM5 optics, France ordered 120,000 CompM5 optics in July 2018.

Early Solutions

In the past though the picture as regards sniping was far less indulgent, sniping was acknowledged as having real value, but weapons that were specifically designed for sniping applications were simply not considered as necessary. The British Army provides an excellent example of how sniping and the provision of equipment for sniping has changed over the years. The starting point for this is with the Lee Enfield bolt action battle rifle in 7.7×56 mmR (.303) calibre, this was manufactured in Britain from 1895 until 1956. Like many others, the British Army would base its sniper rifle on the in-service rifle.

When the No.4 Mk.1 Lee Enfield was the standard production rifle, the most accurate rifles were identified during the production process and put to one side for conversion to a sniper rifle. This saw changes to the wooden rifle furniture to the sniper configuration and attachment points were added to mount the No.32 3.5× telescopic sight, with the weapon designated as the No.4 Mk.1 (T). This was followed by the No.4 Mk.1* (T), with the No.32 sight undergoing various improvements as well. These 7.7×56 mmR sniper rifles remained in service to the end of the 1960s.

By this point, the 7.62×51 mm NATO round had been the standard round in the British Army for some 15 years and it was decided to develop a sniper system that used this

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calibre. The solution selected was to convert some 1,000 No.4 Mk.1 (T) and No.4 Mk.1* (T) to the 7.62×51 mm calibre with a new free-floating barrel, change the wooden furniture to accommodate the new barrel and refurbish the No.32 telescopic sight. The end result was the L42A1 rifle which served for nearly 20 years.

It was the competition to replace L42A1 that would mark the transition of sniper rifles to the specialised high performance systems that they are today. A small British company, which has a fascinating history, called Accuracy International (AI) had been established as a small-scale precision rifle manufacturer for civilian competition shooting. AI had developed a rifle called the Precision Marksman (PM), British Special Forces, in the form of the Special Boat Service (SBS), evaluated the PM in 1984 and decided to buy eight in 1985. Then the Special Air Service (SAS) decided to purchase 32 rifles in the same year.

Credit: Crown Copyright

An image from Helmand Province, Afghanistan, a British sniper with C Company, 2 Royal Anglian, with the .338 Lapua Magnum (8.6×70 mm) L115A3 sniper rifle with a Schmidt & Bender 5-25×56 scope and suppressor fitted. The L115A3 can also be fitted with an image intensifier or thermal imager which can be viewed through the scope.

The Revolution Commences

AI had entered the military market and its Special Forces customers provided feedback on improvements into the design. Then an unexpected opportunity emerged, the British Army was looking for a new 7.62×51 mm sniper rifle to replace the L42A1 and AI decided to enter a developed version of the PM into the trials for the new sniper rifle. The competitors were Heckler & Koch (HK), Remington, Parker Hale and SIG Sauer. It appears that AI entered the trials not expecting to win, they wanted to see what military trials were like and what lessons they could learn for future developments.

The rifle AI entered into the trials was unique, it was modular and based on a chassis system and used non-traditional materials. It was also extremely accurate; the effective range of the L42A1 was 600 m and it could provide harassing fire out to 800 m, the AI rifle had an effective range of 900 m and could deliver harassing fire out to 1,100 m. AI won the competition and in March 1985 were awarded a contract for 1,212 rifles, designated as the L96A1, with first deliveries in 1987.

The L96A1 in conjunction with its Schmidt & Bender PM 6×42 telescopic sight, known as the L13A1, delivered a revolution in British sniping. Apparently one unanticipated side effect was that more people were passing the sniper course with the L96A1, than with the L42A1. Others took notice of the L96A1, with the Swedish Army approaching AI for a new sniper rifle, based on the L96A1, that was optimised for their operational environment, and this resulted in the Arctic Warfare (AW) sniper rifle, again in 7.62×51 mm. In 1991, Sweden ordered 1,100 AW rifles from AI.

The AW was widely sold internationally and was also adopted by British Special Forces, being used for a number of applications including the Counter-Terrorism Sniper Rifle (CTSR), with the rifle being given the L118A1 and the L118A2 designator. The L118A2 differs by having a folding stock. This is a 7.62×51 mm weapon and is equipped with a Schmidt & Bender 3-12×50 L17A1 telescopic sight mounted on a MIL-STD-1913 (Picatinny) rail. Another Picatinny rail can be mounted on the front block, and this will accommodate the Sniper Thermal Image Capability (STIC) from Qioptic, this places the thermal imager in front of the main sight thus providing a thermal capability. Alternatively, there is a mounting point over the sight for a Simrad image intensifier, this can then be placed in front of the main sight to give an image intensification capability.

New Calibres Emerge

The Schmidt & Bender L17A1 sight and the STIC system are also used on another AI product in service with the British military, the L121A1 precision anti-materiel rifle in 12.7×99 mm NATO (.50 BMG). This is also known as the AW50 rifle. The L17A1 sight was also integrated with the L96A1, replacing the earlier L13A1 sight, as part of an upgrade programme. AI were also developing their weapons to accommodate new rounds, working with Lapua for .338 Lapua Magnum (8.6×70 mm), and utilising the .300 Winchester Magnum (7.62×67 mmB). AI rifles in .300 Winchester Magnum were acquired by the German military as the G22 and featured a Hensoldt 3-12x56 scope, the next iteration was the G22A1 and this featured a Schmidt and Bender 3-12x50 scope. The G22/G22A1 were then upgraded to the current G22A2 configuration, and this has a Steiner-Optik M5Xi 5-25×56 scope. The German military operate other AI rifles in 12.7×99 mm NATO and 7.62×51 mm NATO calibres.

At the end of the 1990s British Special Forces adopted the AI AWM rifle in .338 Lapua Magnum as the L115A1 with the Schmidt & Bender 3-12×50 mm PM II scope. The L115A2 model had a folding stock and a new bipod, with many L115A1s upgraded to the new configuration. The British Army then entered the fray with a requirement known as the Sniper System Improvement Programme (SSIP). The SSIP was about more than acquiring a new sniper rifle, it also included image intensification and thermal capabilities, laser rangefinders and spotting scopes.

In 2007 AI were awarded a contract for 582 L115A3 rifles, with first deliveries in April 2008 to replace the L96A1. The weapon has a Schmidt & Bender 5-25×56 scope and like the earlier L118A1 this scope can be integrated with thermal or image intensification systems. The rifle can be equipped with a suppressor, interestingly French sniper rifle manufacturer PGM Precision offer a suppressor for their own rifles and also for AI rifles in Lapua or Winchester Magnum. The reason that the SSIP went for a .338 Lapua Magnum rifle was the need to be able to engage targets at extended ranges, out to beyond 2,000 m. One British Army L115A3 sniper in Afghanistan neutralised a target at 2,475 m.

British Army snipers operate in two-person teams, the sniper and the spotter, with the spotter being equipped with the Sniper Support Weapon (SSW). The SSW is a variant of the LM Defense LW308 Modular Weapon System (MWS) adopted by the British Army as the L129A1 designated marksman weapon. This is a semi-automatic 7.62×51 mm system, with a 6×48 Trijicon ACOG sight. The SSW variant mounts a Schmidt & Bender L17A2 3-12×50 scope and utilises a suppressor from Surefire in the US. Should the L115A3 sight be damaged, the SSW L17A2 scope would be attached to the sniper rifle and the SSW would revert to iron sights.

Other sniping developments that should be taken into account include a number of issues related to the telescopic sight to reduce its signature ranging from a lens hood to the integration of an anti-reflection KillFlash system on the sight. Also the sight would be fitted with laser filters to protect against lasers on the battlefield. Also worthy of note is ongoing British investment in sniping capabilities; Greek company Theon Sensors, in association with British partner Active Electronics, was contracted to supply an initial quantity of 500 Thermis CS thermal imaging systems for the Sniper In-Line Low Light System (SILLS) - Long Wave InfraRed (LWIR) Thermal Sight "Weapon Sight 2" programme. Previously the company had supplied clip-on night vision and thermal solutions for a Canadian Forces sniper programme.

Credit: Australian DoD

A Royal Australian Regiment (RAR) officer at the Australian Combat Training - Jungle Training Wing in the field element of the Regimental Officer Basic Course (ROBIC). Note the EF88 rifle with blank firing adaptor and the Raytheon Elcan Specter DR 1-4 optic. The optic supports accurate engagements out to 600 m and beyond.

In a more weapon related context, British Special Forces wanted to get even more range out of the L115 and took to using a heavier 300 grain .338 Lapua Magnum round, as this was longer than the standard round they loaded these rounds singly. Later the new L115A4 variant was fielded, this had a new magazine and magazine well to handle the 300 grain round. There was an intention to upgrade existing L115A3 weapons to the L115A4 standard, this idea appears to have fallen by the wayside and only Special Forces have the L115A4.

Capability Cascades

Technology has transformed the capabilities of the modern sniper rifle, it is well to remember that in 1970 that the British Army was content to refurbish a sniper rifle and telescopic sight from the 1940s, convert it to 7.62×51 mm and that was considered perfectly acceptable to remain in frontline service until the end of the 1980s. Equally it was considered as perfectly acceptable for the ordinary infantry soldier whether equipped with a 7.62×51 mm battle rifle or a 5.56×45 mm assault rifle to just rely on iron sights. Change was on the way though, and just as with sniper rifles, the infantry rifle would embark on its own evolutionary voyage. The starting point would be Austria adopting the Sturmgewehr 77 (Steyr AUG) with its integrated Swarowski 1.5× optic. Then came Britain with the L85 5.56×45 mm assault rifle and the L9A1 Sight Unit Small Arms Trilux (SUSAT), a 4× optic.

Weapon optics manufacturers that can be said to have made a major contribution to the small arms optics area are Raytheon Elcan, Aimpoint and Trijicon. When Canada adopted the C7/C8 5.56×45 assault rifle family, Raytheon Elcan were tasked with the development of an optic for these weapons resulting in the Specter OS (known as the C79 to the Canadian Forces) which arrived at the end of the 1980s. Since then the family of Specter optics has evolved and the company would go on to sell more than 475,000 Specter systems. This total has since grown, due to the fact that at the end of 2021 Raytheon Elcan and Leonardo Germany won the Germany Army HKV Main Combat Sight programme for 107,929 optics based on the Specter DR 1-4× system.

Aimpoint has been providing their Comp series for over 20 years, in July 2018 they won a contract to supply the French military with 120,000 CompM5 optics for integration with the HK416F assault rifle over the six years following the contract announcement. In April this year, Aimpoint was awarded a seven-year framework contract for the British Support Weapons Enhanced Sighting Systems (SWESS) programme. The SWESS - Light Battlesight Project covers 5.56 mm and 7.62 mm machine guns with the CompM4 sight combined with ballistic adjustable mounts and 3× magnifiers. The other SWESS element covers heavier support weapons such as Carl Gustaf M4, 40 mm AGL and 12.7×99 mm heavy machine gun.

Trijicon had developed the TA01 4x32 Advanced Combat Optical Gunsight (ACOG) in 1987 and this was rapidly adopted by US Special Forces and foreign customers. The ACOG also provided the basis for the US Marine Corps Rifle Combat Optic (RCO), while the Trijicon Variable Combat Optic Gunsight (VCOG), a 1-8×28 optic, was selected as the Squad Common Optic (SCO), the successor to the RCO. In excess of one million ACOG have been sold.

The US Marine Corps also seems to be leading the way in terms of adopting a suppressor for the majority of its small arms. They have conducted extensive suppressor field trials over a number of years and in 2020 acquired 6,700 systems, followed by a further buy of 7,000 systems. An additional 30,000 systems will enter service this year, being used by M4/M4A1 carbines, the M27 Infantry Automatic Rifle (IAR) and the M38 Designated Marksman Rifle, a version of the M27.

In the final analysis, fit a rifle with Picatinny, M-LOK or any other viable modern rail system and you can attach all sorts of sights and other devices, depending on mission requirement and/or budget. However, others might find the future US Army XM5 rifle, replacing the M4/M4A1, and the XM250 automatic rifle, replacing the M249 SAW, being built by SIG Sauer, as the optimum solution, with most of the required capabilities already installed!

Using the 6.8×51 mm Common Cartridge Family, the weapons are fitted with a SIG Sauer SLX suppressor and the Vortex Optics XM157 fire control system (FCS). The US Army states that: "The XM157 integrates a number of advanced technologies, including a variable magnification optic (1X8), backup etched reticle, laser rangefinder, ballistic calculator, atmospheric sensor suite, compass, Intra-Soldier Wireless, visible and infrared aiming lasers, and a digital display overlay."

There are other possibilities though, Future Soldier Systems offer the potential to integrate the soldier and the weapon with a complete range of fire control and sensor systems, with sensors mounted on and separate to the soldier. Therefore the future of infantry weapons and sights would seem to offer a whole range of avenues to explore. ■

Credit: USMC

The US Marine Corps spent years evaluating the benefits of suppressors such as this unit mounted on an M4 carbine. Reduced noise signature has a tactical benefit, it also reduces the potential for the shooter to suffer hearing damage. Suppressors are now being issued for all primary Marine Corps small arms

AIMPOINT – A LONG TIME SUPPLIER OF SIGHTING SYSTEMS TO MILITARY AND SPECIAL FORCES

Aimpoint AB, a privately owned company with headquarters in Malmö, Sweden, invented and launched its first electronic red-dot sight in 1975, making this remarkable tool a major advantage on hunting grounds, shooting ranges, and the toughest combat arenas.

Today, Aimpoint offers a wide range of red dot sights suitable for most firearm applications – from handguns to crew served weapons. The smallest sights in the Aimpoint portfolio weighing only 60 g, belong to the ACRO™ series. Primarily designed for use on handguns, the ACRO sights can also be mounted on carbines, shotguns or utilized as a backup sight on magnified scopes and thermal imagers. The ACRO series has been tested and proven to withstand extreme shock, vibration, temperatures, and material stresses generated by firing over 20,000 rounds of .40 S&W ammunition.

For crew served weapons Aimpoint offers the FCS13RE™ – a fire control system that is a direct view, Dynamic Universal Reflex Sight (DURS). It utilizes an integrated laser range finder and ballistic computer to give the gunner an aiming point corrected for range, type of munition, terrain angle, and environmental conditions. The FCS13RE provides an extremely high probability of first round hits on both stationery and moving targets during day and night. The system can be enhanced with a magnifier, a thermal imager, and is compatible with all generations of military night vision. Aimpoint's fire control system is in use in almost 20 countries.

Aimpoint's products belong to the next generation multiweapon sights. With a wide range of mounting solutions for each product, the same product can be used on different weapon platforms.

Millions of Aimpoint red dot sights are in use worldwide today, and in addition to the US Army, most NATO countries currently trust Aimpoint sights as part of their standard equipment. The following is a glimpse of the latest contracts signed, showing a trend on the market.

USA
The Aimpoint® FCS13RE™, which is a proven system delivered to other NATO militaries, is currently deployed as the primary Fire Control Systems on the M3E1 MAAWS lightweight 84mm Carl-Gustaf produced by SAAB Dynamics for use by the U.S. Army, U.S. Marine Corps, and U.S. Special Operations Command.

UNITED KINGDOM
Aimpoint has been awarded a seven-year framework contract within the Support Weapons Enhanced Sighting Systems (SWESS) program for the British Armed Forces. Aimpoint will supply both the FCS13-RE™ Fire Control System with the TH-60™ thermal clip-on for SWESS-Heavy Mature Project and the CompM4™ sight combined with ballistic adjustable mounts and 3X-Mag™ magnifiers for SWESS-Light Battlesight Project.

CANADA
The FCS13-RE™ Fire Control System and TH-60™ thermal sight systems will be used by the Canadian military on deployed operations as the primary day and night Fire Control System (FCS) on Canada's in-service M3 84mm Carl Gustaf produced by SAAB Dynamics. The combo FCS-Thermal optic was chosen for this program as it fully met or exceeded all of Canada's strict technical performance requirements. Deliveries of the Aimpoint FCS13-RE™ and TH-60™ are scheduled during 2023. The system will be fielded by the Canadian Army.

Photo: AIMPOINT

FCS13RE – fire control system

SWEDEN
The Swedish Army awarded Aimpoint with a contract to deliver the CompM5™ red dot sight as a replacement of the first generation of red dot sights delivered by Aimpoint 20 years ago. The CompM5™ is used on the infantry weapons Ak5C/D. The CompM5™ is combat proven and in use in many countries, including by the French Armed Forces.

Photo: milpictures.com

CONCLUSION

Forty-seven years after launching its first red dot sight, Aimpoint's products are trusted more than ever. Aimpoint will continue to produce the highest quality weapon optics that increase lethality and survivability of the soldiers serving their countries.

Soldier Communications – Rugged, Capable, and Interoperable

Tim Guest

Staying in contact at individual soldier level on today's battlefield is hard at the best of times, but some environs present tougher conditions for effective radio communications than others. This is why US and UK forces are now adopting some of the same soldier radios and have been assessing their new systems in extreme jungle conditions.

Towards the end of 2022, the UK MoD announced a contract worth GBP 90 M signed with L3 Harris for 1,300 Falcon IV AN/PRC-163 handheld radios to upgrade land-based radio capabilities. The new radios are set to support ground-to-ground and ground-to-air communications and improve overall battlefield effectiveness down to individual soldier level.

The handheld Falcon IV AN/PRC-163 is a multi-mode radio (MMR) designed for use by infantry, dismounted or mounted, and will help meet the UK's MMR requirement. UK Defence Procurement Minister Alex Chalk stated that the radios would replace legacy systems and "boosts [the UK's] interoperability with allies". These sentiments were echoed by L3Harris, which said the new radios would enable UK land forces to communicate and interoperate with NATO and US allies using a solution that can be adapted for differing deployments and operational requirements. In February 2023, as British signallers were deployed to Belize to put the new radios to the test, L3Harris added that the tactical radio order actually comprised not only the AN/PRC-163 multi-channel handhelds, but also the AN/PRC-167 multi-channel software-defined radio (SDR) manpacks. This follows years of work by the UK towards procuring new MMR radios to improve land-based tactical communications. Keith Norton, Vice President and Managing Director, L3Harris Communications Systems UK, said the "tried-and-tested radios will make for speedier deployments, faster decision-making, and improved soldier safety."

The introduction of the two-channel L3Harris MMR radios into the UK Armed Forces' tactical networks will provide greater flexibility in its communication options, plus access to a large library of resilient waveforms, as well as enhanced resilience against adversarial electronic attacks for deployed allied forces. In this regard, it is worth mentioning that several thousand of the latest SDRs, of one kind or another, have been supplied to the Ukrainian Armed Forces by L3Harris and have proven very effective operating even in highly degraded radiofrequency-compromised environments under 'attack' by Russian electronic warfare (EW) systems.

Credit: L3 Harris

Aside from the UK, the AN/PRC-163 handheld has already been adopted by a number of NATO Allies.

A New UK Handheld

Equipped with industry-leading mobile ad-hoc network (MANET) technologies, including TSM-X, ANW2 and others, the L3Harris Falcon IV AN/PRC-163 multi-channel handheld radio delivers dual-channel cross-banding capabilities in a single radio optimised for SWaP (size, weight and power) that supports seamless and simultaneous networking for over 200 users. Mission-critical information at a is displayed on the radio's LCD screen. Moreover, situational awareness (SA) information is advanced through the intelligence, surveillance and reconnaissance (ISR) mission module's full-motion video capabilities.

The Falcon IV AN/PRC-163 handheld is a software-defined radio, supporting simple updates to future waveforms and provides simultaneous voice and data over SATCOM/TACSAT, LOS and MANET modes, as well as fast, in-field updates as a tactical scenario evolves to offer new capabilities. Furthermore, an external mission-module, hardware interface enables users to quickly add options such as ISR video and satcom. The AN/PRC-163 with its battery it weighs just 1.25 kg (2.75 lbs), operates in temperatures from -30 °C to +55 °C (-22 °F to 140 °F) and can survive water immersion to depths of 20 m. It also provides secure network connections to computing devices, including Android smartphones. Its channel 1 standard waveforms are VHF/UHF LOS, ANW2 C, SINCGARS, P25, with optional waveforms including SATURN, HPW, IW Phase 1/2, HAVEQUICK I/II, SCM and e-BFT (DoD only). Its channel 2 waveforms are ANW2 C, UHF LOS, UHF SATCOM, with optional TSM-X, L-TAC, Wraith waveforms. Both channels have additional future waveform capabilities built in.

To the Test

Credit: UK MoD/Cpl Danny Houghton

UK airborne signallers have been testing the army's new L3Harris handheld MMRs in the jungle, among the most challenging environments for radio communications.

Wasting little time after contract award by the MoD, UK airborne signallers from 216 (Parachute) Signal Squadron, Royal Corps of Signals, part of 16 Air Assault Brigade Combat Team, the British Army's global response force, set off earlier this year to test the new radios in the jungles of Belize. This environment offered some of the most challenging of conditions for radio communications to work effectively, if at all. The squadron set out to test the full range of the AN/PRC-163's capabilities on 'Exercise Mercury Canopy' where the damp, hot and humid conditions, together with dense and at times impenetrable vegetation, not only limits line-of-sight communications, but also attenuates radio waves like few other scenarios. Added to that is the hostile environment's ways of trying its best to wreck both man and machine through water ingress, dirt, mud, insects, fungal growth, if soldiers fail to maintain rigorous care and cleaning disciplines. Over five weeks of manoeuvres, the signallers lived in the Belizean jungle for extended periods, learning how to look after themselves and their kit, adapting and incorporating their new communications systems within their soldiering skill routines so they and the radios could survive the demands of jungle extremes.

"As a signal squadron, we would normally deploy in support of other units, but Belize has been a fantastic and unique opportunity for us to focus on learning by doing," said Maj. Liam Crane, Officer Commanding 216 in a British Army report. He added, "MMR is two radios in one. It provides line-of-sight voice and data over wideband radio between a unit on the ground, while simultaneously communicating anywhere in the world via satellite. The mesh networking capabilities mean that we can run applications, so troops out in the Belizean jungle and back at our headquarters in Colchester are working off the same information at the same time."

The signallers found the new MMR equipment provided the necessary bandwidth in the jungle to handle the huge amounts of data involved in modern operations. They also found that while challenges presented themselves in the extreme conditions at many different junctures, the squadron was able to learn how to use the equipment in ways to get around any number of obstacles as they occurred. Overall, the British signallers said that the new MMR performed very well under those conditions and that while it had been a real challenge to learn how to use new Army equipment with new capabilities. They also noted that beyond its versatility, a key benefit of the MMR is the smaller and more energy-efficient package it comes in. "With water, rations and ammunition, soldiers can be carrying up to 60 kg. MMR fits in a webbing pouch where a Bowman radio can take up half of a daypack. Operating in the heat, humidity and tough terrain of the jungle, we're really feeling the benefit of that reduced bulk," added Maj. Crane.

Credit: UK MoD/Cpl Danny Houghton

Section Commanders from 216 Parachute Signal Squadron come together and check the mapping on their ATAK devices during a patrol through the jungle.

Alongside the UK, the AN/PRC-163 radio has already been widely adopted by the US Army, US Marine Corps, US Special Operations Command, US Air Force, and a number of NATO Allies.

US Colleagues – Same Kit, Similar Extremes

Following new equipment fielding and training in the summer of 2021, some of those US Forces with the new radios included the 3rd Infantry Brigade Combat Team (IBCT), 25th Infantry Division (3/25 ID), which set out in August of that year to conduct 'Exercise Bronco Rumble'. This was a company-level, air-assault exercise at the Kahuku Training Area on Oahu, Hawaii, designed to test the capabilities of the US Army's integrated tactical network (ITN), including their new AN/PRC-163 MMRs and associated devices.

The ITN is a flexible, mobile network solution available down to dismounted soldiers that incorporates commercial solutions into existing tactical networks. Under the mountainous and jungle extremes of Hawaii, the aim of the exercise was for the

Credit: US Army/Kathryn Bailey

A platoon leader wearing the Integrated Tactical Network (ITN) dismounted kit at Kahuku Training Area, Hawaii, which includes two-channel AN/PRC-163 leader radios, a single-channel shadow radio and the ATAK end-user situational awareness device.

Credit: US Army/Staff Sgt Alan Brutus

A Soldier with the 3rd Infantry Brigade Combat Team, 25th Infantry Division checks his ATAK end-user device in Hawaii, during Bronco Rumble. Paired with a two-channel Falcon IV L3Harris PRIANC-163 leader radio, the ATAK map-based software application enables co-ordination among troops with features such as a position data, chat, mission planning and shared overlays.

brigade to test its ability to conduct operations over large distances, including between neighbouring islands, while still maintaining operational control. The 3/25 ID was the third IBCT to receive and evaluate the ITN and its component radios in order to provide feedback to the Army as part of its overall network modernisation strategy, much in the same way as the UK's 216 (Parachute) Signal Squadron did in Belize.

Fielded at that time, the Capability Set 21 ITN included commercial single and two-channel radios, end-user cellular devices, the tactical radio integration kit box, which integrates the ITN's radio variants to create a single battlefield network, in addition to small aperture satellite terminals, a variable height antenna, and various support technologies such as servers, gateways and cross-domain solutions. These capabilities were all housed in tactical operations centres, integrated into vehicles, or are part of a dismounted soldier's kit.

At the heart of the ITN are its radios, including the manpack mobile user objective system (MUOS) tactical satellite radio and the Falcon IV AN/PRC-163. The MUOS boosts over-the-horizon tactical satellite (TACSAT) communication capabilities, not just upwards to brigade or battalion level, but now all the way down to company and individual troop level, which participants on the exercise in Hawaii said was 'a game changer'. The manoeuvres tested possible scenarios between islands that mirrored what the US contemplates it might be faced with in a future Pacific conflict, with the communications holding up well. One platoon leader described the configuration of his ITN radio components, with a shadow radio used to talk among his platoon connected to his Falcon headset, his PRC/163 'leader radio' also connected, that enables seamless communications with his platoon, as well as with higher headquarters, for such tasks as calling up fire support and medevac. Ensuring a commander on the ground can talk to subordinate as well as higher commanders is an overarching aim of the system. The platoon leader added that the AN/PRC-163 leader radios also provide the signal to the ITN's Android tactical assault kit (ATAK) hand-held end-user situational awareness device, used to display real-time Position Information Location (PLI). With little knowledge of the terrain, the assaulting force on Hawaii Island had to rely on the ATAK devices to establish PLI of friendly forces and SA of the jungle and open terrain. The AN/PRC-163s were also noted as being able to enhance soldiers' primary, alternative, conting ency, emergency (PACE) plans, with the two-channel radio offering a back-up, secondary channel switch should the primary channel fail.

When it came to logistics support during the exercise, the ITN's SA capabilities through use of its ATAK handheld devices was a major boost to support and track critical convoys, supplies and medevac missions. Integrated and bolstered by the beyond-line-of-site capabilities of the MUOS, ATAK was crucial in extending lines of communication, ensuring logistics flow and aiding individual soldier safety.

That many of the ITN's elements are entering service with several allied forces beyond just the US and UKbodes well for allied interoperability and joint capabilities in an increasingly threatening climate of peer-to-peer aggression.

Austria Opts for SquadNet

In late-March 2023, Austria awarded Thales a contract for the provision over 2,500 SquadNet tactical radios to support the Austrian Army's digital transformation. This is the second significant European order for this radio after Belgium and strengthens the product's position on the soldier radio market in Europe. According to Thales, SquadNet combines a unique networking waveform with built-in GPS, Bluetooth and programmable encryption to provide reliable, secure critical communications capabilities. Able to operate for 28 hours on a fully charged battery, this makes the radio highly suited for dismounted troops. It provides voice, location reporting and

data-sharing options and is equipped with Thales' SABRE battlefield software system, which allows users to view the location of all team members overlaid on a map, and allowing target data and other points of interest, including navigational information, to be communicated to each individual.
The SquadNet soldier radio is a rugged voice radio with advanced functionality for resilient infantry squad-level communication. Its features include a point-to-point/LOS range of up to 2.5 km; an automatic relay mode; blue-force tracking; SA; target, text and picture-sending capabilities; duplex, multiple voice nets and frequency hopping waveforms. It is available in 430-470 MHz and 865-880 MHz variants. GPS location data can be shared across a network bridge, or gateway, to provide a real-time command overview. For charging purposes, power can be drawn from USB-equipped power sources, such as laptops and portable solar panels, enabling personnel to scavenge power from multiple sources, wherever they find them. This, combined with the extended mission life of 28 hours provided by a rechargeable battery, reduces the need to carry spare batteries, thereby freeing up vital personal carriage space for ammunition, food and water.
With an automatic relaying mode and environment-resilient waveform, Thales says that the SquadNet soldier radio ensures communications can be maintained even in difficult propagation conditions, such as urban, wooded and mountainous terrain, thereby supporting effective collaborative combat on the battlefield. ■

Credit: Thales

The Austrian armed forces have ordered over 2,500 Thales SquadNet tactical radios.

Cut of the Cloth

Tim Guest

Whether for shelters, parachutes, combat clothing, camouflage and more, some highly advanced technologies go into the making of textiles found in the many diverse and demanding applications across today's operational environments.

Conducting operations in exacting military scenarios for extended periods places huge demands on individual soldiers, airmen and sailors and requires that, as far as is technologically possible, they each be protected by their clothing and equipment from combat hazards and the extreme elements that nature will throw at them. Inadequate protection leaves personnel susceptible to natural, though avoidable, health hazards such as respiratory and other disease, as well as combat dangers such as fire. However, with the right protective gear, injury and worse can be avoided and missions achieved. From the extreme cold of high-altitude environments or polar regions where frostbite and hypoxia are natural dangers, to risks of heat exhaustion in hot, desert locations, even without facing battle threats, soldiers are in constant jeopardy and rely on their clothing and equipment for a serious level of protection. Marines and sailors also confront numerous hazards of conducting operations at sea, and fighter pilots face extreme G-forces. Whether on land, at sea, or in the air, one common threat facing them all during combat is that of the always present danger of fire.

In all of these scenarios, the first important layer of protection is an individual's clothing, and along with the private sector, extensive research is being conducted at many defence/civil research establishments around the world into the technology of advanced textiles. One such defence establishment is the DEVCOM Natick Soldier Center (SC) in the US, which is responsible, amongst other things, for the technology, research, development, engineering, fielding, and sustainment of US military clothing, shelters, airdrop systems, as well as other soldier support items, with each category involving some of the very latest textile technologies and research. On the civil side in the UK, though with defence partners, is Nottingham Trent University's Advanced Textiles Research Group (ATRG), which is conducting research into advanced textiles and electronically active wearable technology. ATRG works closely with leading commercial and defence establishments and along with seven partners, including the UK's Defence Science and Technology Laboratories (DSTL) and QinetiQ, is currently involved in a major project researching electronically-active yarns, where electronic functionality is embedded within yarns and textiles.

These are just two of the many global organisations at the forefront of textile tech, developing everything from cold weather kits, anti-G suits, flame resistant/retardant (FR) materials for combat uniforms, nuclear/biological/chemical protective suits and much more. With special material properties to suit specific applications, technical textiles are designed to minimise attrition among a fighting force, whether resulting from natural or combat threats.

Credit: USMC/Cpl Meshaq Hylton

Camouflaged fabric disrupts and reduces the visibility of the wearer or equipment to optical and sensor threats, such as radar, thermal imagers and multi spectral sensors.

What Applications, What Textiles, What Properties

There are two categories of technical textiles used for defence applications. The first includes materials incorporated into defence systems, such as parachutes and harness lines, seating materials, internal vehicle finishings, materials (fire resistant/retardant; FR) for tents, tarpaulins and shelters such as field hospitals. The second encompasses individual equipment and clothing, from MTP (multi-terrain pattern) camouflaged combat kit, pilot suits, helmets, packs, webbing and carriage solutions, and more.

For tents and shelters, textiles used, whether incorporating natural fabrics such as cotton or synthetics and blended yarns, these must be waterproof and resistant to physical changes under wet conditions (no degradation, no absorption, no expansion), and must also be anti-fungal and FR-treated. They must also be lightweight to aid mobility/transportability, yet tough enough to ensure they remain intact during what also needs to be a fast and easy

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assembly and deployment process. As well as providing protection from the elements, military tented-style shelters will often offer chemical and biological protection and be designed to avoid infrared and radar detection.

When it comes to parachutes, their critical functions in crucial applications such as individual para drops, equipment/cargo pallet drops, drogue chutes for slowing aircraft on landing, controlled-descent flare chutes and more, demand that their component parts of textile canopy, harness, rip cords and suspension lines are carefully made to exacting standards. Their fabrics, typically high-tensile, nylon, multi-filament yarns of woven ripstop, 32 to 200-denier weave, must be thin and lightweight, yet strong and designed and constructed with an exacting relationship between their strength, weight and air porosity characteristics, with a high overall strength-to-weight ratio. The thin textile allows chutes to be folded to a required volume and the textile's careful construction will help determine the chute's air permeability, which, in turn, determines the rate of descent or retardation for a specific application.

In terms of items of individual clothing and ensemble gear, webbing, individual armour, etc, for different scenarios, the main function is to maximise survivability in combat and all weathers, as well as offering effective camouflage properties, protection against ballistic impact and potential chemical, biological and nuclear events. As such, advanced integrated combat clothing must be durable and resistant to extreme weather conditions, with high tensile and tear strength, fabrics might be FR, and display effective abrasion resistance. While displaying such properties, individual clothing must still be comfortable, lightweight and easy to wear.

Credit: US Army/Visual Information Specialist Paolo Bovo.

A US Army paratrooper conducts a water jump into Lake Garda near Pacengo, Italy, on 26 April 2023. Parachute fabric must be thin and lightweight, yet strong with an exacting relationship between strength, weight and air porosity, with a high overall strength-to-weight ratio.

For the latest body armour produced from technical textiles and fabrics such as Dupont's Kevlar, DSM Netherland's Dynema (recently acquired by Avient Corporation in the US), and Teijin Aramid's high-performance aramid fibres, Technora, Twaron and others, each company has its own manufacturing processes. That said, construction of armour in layers using such fabrics is typically done in a way to ensure each layer reduces and absorbs the energy of an impact by a projectile or shrapnel to its maximum potential, with those fibres impacted dispersing the energy through the weave to adjacent fibres. A plain balanced woven fabric construct, for example, will maximise crossover points and, therefore, the number of paths energy dispersion can take from point of impact.

Fire resistance (FR) is a critical, required characteristic of many protective and personal clothing ensembles, whether for the likes of emergency ground crew at an air base, or firefighting teams aboard naval vessels, as well as for such applications as aircraft seat coverings. Flame retardant/FR fabrics are designed to resist burning and self-extinguish if ignited. The FR properties of a garment are either the result of the textile material itself being inherently flame resistant, such as aramid, PBI (polybenzimidazole) and PFR rayon fibres, or from the textile itself being specially treated with a flame retardant application. Such FR fabrics or treatments essentially must impart a limiting oxygen index (LOI) percentage on a protective garment higher than 21% (the

Credit: US Navy/Mass Communication Specialist 3rd Class Erica Higa

Sailors from various commands conduct training at the 19F3A Firefighting Trainer at Naval Base San Diego, in April 2023.
Fire resistance is a critical, required characteristic of many protective and personal clothing ensembles, whether for the likes of emergency ground crew at an air base, or firefighting teams aboard naval vessels.

Credit: Dupont

Aftermath of testing done on a Nomex garment at Dupont's ThermoMan demonstration unit using a full-size mannequin made of epoxy resin/glass fibre compound, fitted with 122 thermal sensors (except hands and feet). In the exposure chamber, the garment was subjected to temperatures of between 600 °C and 1000 °C, created by 12 propane gas burners. The exposure lasted from 3 – 25 seconds.

level of atmospheric oxygen in the air), or above, for the textile to be categorised as FR. The LOI is measured by passing a mixture of oxygen and nitrogen over a burning specimen of the textile, and reducing the oxygen level until a critical level is reached, with LOI values also dependent on the surrounding temperature of the fabric sample; the percentage of oxygen required for combustion reduces as the surrounding temperature is increased.

For many of the abovementioned items, such as combat gear and uniforms, tents and shelters, camouflaged fabrics are used in order to disrupt and reduce the visibility of the wearer or equipment to optical and sensor threats, such as radar, thermal imagers (TI) and multi spectral sensors. With TI, specifically those with uncooled sensors, becoming increasingly widespread and miniaturised for use as modern thermal weapon sights, companies such as Switzerland's SSZ Camouflage Technology have developed camouflage clothing systems and textiles to counter such threats as effectively as possible. As an example, the company's lightweight sniper suit is treated in a way that makes it highly efficient in both visual and thermal signature reduction, which together with selected colour options, enable an individual soldier to merge with almost any environment.

While briefly mentioning Kevlar above, Dupont is also the company behind the Nomex range of FR-textile-based clothing systems, which includes: Nomex Essential 450A, Essential Arc 650 and Essential Ripstop 600. The Nomex Essential 450A fabric, for example, is engineered for pilots and aircrews to offer inherent flame protection – embodied in the fibres themselves – while minimising static discharge; the system is lightweight, comfortable and its FR protection meets US DoD MIL-C-83429B specification. The 450A's FR fabric gives protection for longer exposures and higher temperatures and is a plain weave Kevlar. Moreover, its Nomex antistatic-fibre blend with inherent FR cannot be washed away or worn out of the garment; it will also not melt or drip. A Dupont spokesperson told ESD that, "To meet growing needs for camouflage pattern, DuPont is closely working with leading mills in the Industry to offer 100% Nomex camouflage-printed fabrics for high-end, confined-space applications like tank crews and army flight personnel, as well as highly durable Nomex-blend camouflage fabrics for combat uniforms."

Keeping Warfighters Warm

Mentioned earlier, though looking at its research into new ways of protecting soldiers from extremes of cold, the Natick DEVCOM SC highlighted its recent work in 2022 in developing the Tactical HEated Apparel Technology, or TacHEAT, which enables actively heated protective clothing for troops operating in cold weather environments. The system, which has been rolled out slowly over the past two years, is designed to improve an individual's lethality and existing mission performance in cold weather environments through improved tactility and dexterity, resulting in extended mission duration.

The DEVCOM SC, under the government's Small Business Innovative Research (SBIR) programme, partnered with Human Systems Integration, Inc, to develop a new technology that embeds heating elements into the clothing system to prevent hypothermia, and protect hands and feet from frostbite. Using a combi-

Credit: US Army/Spc Mackenzie Willden

US Army Jumpmasters Qualified Paratroopers assigned to the 19th Special Forces Group (Airborne), pull in the static lines in a UH-60 Black Hawk Helicopter after the successful exit of 6 paratroopers, in January 2023. DEVCOM SC's first prototype TacHEAT heated clothing systems were evaluated by pilots and rear crew of the US 160th Special Operations Aviation Regiment (Airborne) across their fleet of helicopters and suit applications, including for the Air Warrior ensemble.

nation of novel e-textiles and wearable technology, the centre's longstanding textile technologist, Carol Winterhalter, led the development of an electronics-based system that can be powered by a soldier-worn battery, including the conformable wearable battery (CWB), to heat the resistive heating elements of the army combat shirt, gloves, briefs, and boot liners. The technology platform can be dropped into any clothing system, and the clothing and e-textile components can all be machine washed. Two TacHEAT systems are under development for both mounted and dismounted troops that are scalable and prevent heat loss around the body. The heated glove system is integrated into the combat shirt and gloves, and features a heater control module with a haptic switch for multiple heat levels, all powered by the CWB.

During FY 2020, the first prototype heated clothing systems were purchased directly by the US 160th Special Operations Aviation Regiment (Airborne) for evaluation with pilots and rear crew across their fleet of helicopters. The systems received positive feedback during the evaluation and a follow-on quota for more than 100 systems was requested for the 2021-2022 winter season. Additionally, a US Navy Special Operations Command group also purchased 12 TacHEAT systems in 2020; then, in 2021, the USAF purchased ten sets through a Defence Logistics Agency contract with all purchases to date qualifying as SBIR Phase III procurements.

Winterhalter, for her part, was awarded the Major General Harold Greene Best Innovation Individual Award in 2022 for her work and contribution to the programme, upon her retirement following a distinguished career as an expert textile technologist pioneering flame resistance, wool-blended uniforms and high-performance fibres to protect and enhance soldier performance well into the future.

Regarding TacHEAT, the centre said in a statement that the system was highly desired because, "it addresses the historic need to protect aircrew members from all branches of the military against exposure to cold weather elements in a manner that allows for continued dexterity of the hands and tactility of the fingers during flight operations and post jump/ejection sequence activities of rotary and fixed wing aircraft." Endorsing those sentiments and the system itself, deputy product manager at Air Warrior (AW), James Isaacs, said that he expected "advancements of this technology may lead to improvements in lethality for aircrew by providing relief from cold environments where reduced tactility affects mission performance." For its part, AW is a modular, integrated, rapidly reconfigurable combat aircrew ensemble, in which advanced textile technologies are being employed, designed to saves lives and maximise army aircrew mission performance. Previous aviation life-support equipment consisted of a non-integrated assemblage of protective and survival gear, whereas AW uses a systems' approach to equip aircrew and close the capability gap between human and machine. AW modules are being fielded incrementally in blocks to rapidly provide enhanced capabilities to soldiers and to leverage and integrate clothing and equipment, such as the army aircrew combat uniform and ballistic protection. The ultimate aim of AW is to provide enhanced mission effectiveness, leveraging advance textiles in clothing and equipment to maximise aircrew survivability.

TacHEAT should certainly fit well into AW plans. User feedback on the DEVCOM system is continuously provided to shape and finalise the two-system design for both mounted and dismounted operatives, in order to include modular and configurable power and electronic architectures being designed for manufacture under a SBIR Phase II contract. This SBIR Phase II effort is expected to significantly reduce the cost of prototype TacHEAT systems as they transition to low rate initial production and manufacture.

Credit: US Army/Staff Sgt Matthew Foster

Soldiers assigned to Chaos Company, 3rd Battalion, 8th Cavalry Regiment, 3rd Armored Brigade Combat Team, 1st Cavalry Division, during Bull Run live-fire exercise, Poland, November 2022. Natick SC research conducts advanced R&D into, amongst other things, the technological needs of effective individual soldier camouflage.

The Future

As technical textiles and wearable tech R&D make progress, it can be expected that further transformation of traditional fibres, yarns and textiles into highly sophisticated 'smart textiles' will take place. According to leading test and engineering textile technology company, James Heal, "Developments are being made to monitor and maintain records of physiological activities and vital signs using smart textiles in military garments and these innovations are designed with the wellbeing of the wearer in mind, bridging important gaps between military textiles, and other areas such as medical textiles."

As to the future, Peter Goodwin, technical specialist at James Heal noted: "militaries can expect to see integrated devices and systems such as nanotechnology and skin-like camouflage, enabling automated detection of the environment, or threat, which will adjust functionality and/or protection level to adapt to external changes. The military textiles space is undergoing significant innovation." ■

Good Detection is Good Protection: Missions and Technologies in CBRN Detection

Dan Kaszeta

This correspondent has covered various aspects of the Chemical, Biological, Radiological, and Nuclear (CBRN) detection business for a number of years in this magazine, often with emphasis on manufacturers and markets. The manufacturers and markets remain largely the same as discussed in the past. As an active consultant in the field, your correspondent is often explaining many fundamental basics of the CBRN detection field. As such, an overview of exactly what detection technologies are in use and what they are actually used for in the field, seems in order. Detection is sometimes treated by the uninitiated as an end unto itself – but detectors are only as good as the decisions the user makes with the information they produce.

What to the layperson might be called 'CBRN detection' is actually a large bundle of tasks. Hardware is configured in many different ways in this space. 'CBRN detection' as a broad category of equipment, includes, of course actual detection, answering the question "is there a threat present?" in a way not dissimilar to a household smoke alarm. There is also identification, which seeks to identify a hazard. Measurement seeks to provide a qualitative or quantitative measurement of a substance. 'Monitoring' is a broader term, often used, which means several different things, depending on country and context. These different types of instruments can be used for a variety of military missions. Products and markets have evolved for all of the mission sets described below.

The most easily understood mission is warning. Detection equipment can provide warning that allows protective measures to be taken. In chemical terms, this means taking rapid protective actions like putting on masks or closing up hatches of vehicles. In radiological terms, it means moving away from a hazard, limiting time near a hazard, or putting shielding between a person and a hazard. These are broadly termed as 'detect to warn'. In biological terms, the hardware simply does not work as quickly or as accurately, so there's a term called 'detect to treat.' This phrase means detecting quick enough to allow medical interventions. Again, a lot of this is similar to the household smoke alarm – the alarm goes off and everyone runs out of the house, saving their lives. Most of these technologies and products are 'point detection' which detects on the spot, not at a distance. 'Standoff detection' – the ability to do it at a distance, is becoming more credible in chemical detection. However, many challenges in that segment persist, as has been discussed previously in this magazine. (See ESD issue 01-2018)

A variant on the detection mission is dosimetry. This, at present, is only a radiological concept. Dosimetry measures the accumulated radiation dose over a period time. A moderate dose rate of radiation that might be not particularly worrisome for an hour might be exceedingly problematic over the course of days or weeks. Therefore, as with civilian workers in medicine and nuclear power, there are scenarios when military personnel need to monitor their accumulated exposure to radiation.

Credit: US Army/Spc. Eric Unwin

The M4 JCAD, also known as the LCD outside the USA, is a widely used ion mobility chemical warfare detector.

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Another mission for detection equipment is 'contamination avoidance.' If you take many individual detections, along with reporting about enemy incidents, you can start plotting them on a map and doing some calculations which range from abject guesswork all the way to highly sophisticated computer modelling. These calculations will yield a plot on a map that gives an estimate of where contamination or hazards might be found. Such plots, in theory, can be used to help plan offensive and defensive operations. However, because of the general lack of CBRN warfare in modern times, decades contamination avoidance doctrine is largely untested.

Another role for detection instruments is point source monitoring. This is the detection of a hazard on a surface. This can be of great value in several types of military operations. CBRN reconnaissance uses such monitoring to check if a route or operating area has been contaminated. These are referred to as route or area CBRN surveys, which serve to verify and update the hazard areas calculated in contamination avoidance procedures.

Point source monitoring also has a valuable role in decontamination. Decontamination is time-consuming and resource-intensive. But with detection equipment, personnel, terrain, and vehicles can be tested to see if there really is contamination. The effectiveness of decontamination can be evaluated using detection equipment. Much use of radiation detection to check decontamination was publicly viewed after the Fukushima nuclear accident.

As a practical matter, CBRN detection and point source monitoring can be heavily affected by background. There is always radiological and biological background; biological background is one of the many reasons that real-time biological detection is still unavailable. Chemical background becomes a problem as well, not just on the battlefield where smokes, fuels, and vehicle exhaust are problematic. It is also a problem in urban environments, where household cleaning products and gardening chemicals are but a few of the chemical 'background noise' problems that cause false positives.

In more specialised roles and missions, identification of unknown substances becomes a valid operational requirement. Usually, this is more time-consuming and often requires more specialised sensors. Verifying use of chemical warfare agents on the battlefield has global political ramifications. There are also many potential scenarios where military forces might encounter unknown substances. First alleged use of CBRN material on a battlefield is a serious allegation requiring impeccable investigation. Possible manufacture of CBRN materials or weapons by insurgency or irregular forces is a threat in some potential operation. As such, a whole mission set of SIBCRA (Sampling and Identification of Biological, Chemical and Radiological Agents) has evolved. This has yielded both man-portable identification instruments that can be taken to the field by specialised teams and small deployable laboratories which can process samples in theatre without having to transport them long distances for analysis.

The various different types of CBRN detection missions are summarised in the table below:

Credit: USMC/Lance Cpl. Jesus McCloud

U.S. Marine Corps Cpl. James Dietrich, Sampling Team Leader, with Chemical, Biological, Radiological and Nuclear (CBRN) Platoon, G-3, 3d Marine Division, gathers samples of simulated biological agents on Combat Town, Okinawa, Japan, 21 March 2017.

Technologies

When it comes to actually unpacking the technologies that seek to accomplish these missions, we have to understand that the CBRN threat is diverse. 'CBRN' covers a spectrum of threats that are, in fact, quite different from each other in terms of their properties and behaviour. It should come as no surprise that CBRN detectors use a range of technology. Broadly speaking, chemical detection seeks to identify and interrogate molecules, using principles of chemistry and physics. Biological detection seeks to interrogate pathogens and toxins, using a mix of biology and chemistry. Radiation detection uses physics to react

Detect to Warn	Providing rapid warning to deployed troops to allow them to take protective measures like donning masks. Speed at a premium. Proliferated sensors, so economy also at a premium
Detect to Treat	Accurate analysis of threats to allow proper medical prophylaxis or treatment. Accuracy more important than speed
Contamination Avoidance	Provide information to allow for situational awareness of where hazards may be present on the battlefield
Route and Area Survey	Determining whether a route or specific area has chemical or radiological contamination. Ruggedness and speed required.
Decon Quality Control	Checking whether decontamination has been performed adequately. Ruggedness at a premium.
SIBCRA	"Sampling and Identification of Biological, Chemical and Radiological Agents" – detailed analysis of samples and identification of unknown materials. Accuracy more important than speed or economy.
Dosimetry	Economy needed as widespread distribution of dosimetry is necessary.

Wet chemistry	Use of colour-changing chemicals. Time consuming but effective.
Ion Mobility	Current state of the art for field CW detection. Sacrifices some precision for speed. Small and cheap enough for widespread use
Flame ionisation	Long-time distant second place contender for field CW detection.
Raman	Identifies liquids and solids. Less good with gas and vapour. Fast but not real time. Now available in handheld.
FTIR	Identifies unknown compounds. More systems use it for solids and liquids than for gas/vapour. Not real time.
GC/MS	Gold-standard identification of unknown compounds. Still expensive and sophisticated, but getting smaller and cheaper.

with particles (alpha, beta, and neutron) and gamma waves, with the latter being are pure energy.

Chemical detection and identification devices are built to examine one or more aspects of a sample of gas, liquid, vapour, aerosol, or solid and provide information. It has long been an informal maxim that you can do this quickly, accurately, and/or economically. You can have any combination of the two, but you cannot find a sensor that does all three. For example, handheld chemical warfare agent detectors need to work quickly, in order to provide timely warning, but still be cheap enough to have a lot of them. Such a trade-off sacrifices accuracy. The detection industry is constantly making design trade-offs of this sort.

The oldest technologies are still in widespread use. These consist of wet-chemistry techniques like colour-changing indicator papers and various handheld kits containing ampoules, tubes, or sachets of reactive chemicals. Such papers and kits rely on specific chemical reactions to classify or identify chemical warfare agents. Dräger (DE), KeTech Defence (UK) and Oritest (Czechia) are examples of companies in Europe producing products in this particular segment.

The time-honoured technology for point detection of chemical warfare agents is ion mobility spectrometry. Such devices ionise a sample of vapour, using corona discharge or radioactive isotopes. They then measure how long the sample takes to move down one or more drift tubes. This works out very well for chemical warfare agents as it is very fast and can be done in a small device. Smiths (UK), Bruker (USA-Germany), and Environics (Finland) are the strong players in this technology. The LCD, which was adopted as the M4 Joint Chemical Agent Detector by the US military and has become, perhaps, the most widespread chemical warfare agent detector in the world. An alternative technology is flame ionisation. This is the province of only one manufacturer, Proengin (France), and it merits mention as many countries use it (in the form of the AP4C detector) as a secondary or confirmatory detection method for chemical warfare agents. Various single-gas detection technologies and photoionisation detectors are widespread in civilian safety and emergency response technologies but have less role in military detection. Surface acoustic wave devices had a brief look-in in the 1990s but disappeared.

Chemical identification instruments are more expensive and specialised. This segment of the market has strong overlap with both scientific and emergency responder instrumentation. Fourier Transform Infrared (FTIR) devices shine infrared light through samples to gather absorption spectra. Raman devices shine a laser on a sample and gather the spectral data from Raman scattering. Both techniques can derive the equivalent of a molecular fingerprint which can be compared to libraries to identify a compound. Both can be perplexed by mixtures and combinations. Smiths Detection, Thermo Fisher (USA), Serstech (Sweden), and Rigaku (Japan) are some examples of companies in this space.

Even more definitive field identification can be accomplished by instruments combining gas chromatography (GC) and mass spectrometry (MS) to definitively identify samples. Once strictly the province of analytical laboratories, GC and MS have been downsized over recent decades. First, mass spectrometry went into mobile CBRN recce vehicles like the Fuchs. Now, man-portable systems such as the Inficon (Switzerland) HAPSITE or the Smiths Detection Guardion bring this capability to specialist CBRN units in the field. GC combined with MS is considered a gold standard in the analysis of chemicals. These will remain somewhat expensive and specialised instruments for the foreseeable future.

The table below provides a summary of available Chemical Detection Technologies:

Biological detection is a mixed bag of technologies with much room for development. Both the 1991 Gulf War and the anthrax terrorism in 2001 resulted in significant investment in the field, but relatively few products have successfully entered the market. Biological detection remains haunted by problems with speed, accuracy, and specificity. The state of the art right now is still not much better than the 1990s. At best, this is after-the-fact 'detect to treat' types of detection, not real time 'detect to warn.' The latter has remained aspirational for this correspondent's entire three-decade career.

Trying to do biological detection in the field tends to be broken down into four com-

Credit: USAF

FTIR devices like the Smiths Detection HazmatID can help identify unknown solids and liquids.

Credit: USMC/Lance Cpl. Jesus McCloud

Many types of detection still rely on sample collection for later analysis.

ponents, which may be done separately or together in varying scenarios and environments. Air samplers collect particles and droplets for possible analysis. Some systems then look for a sudden spike in the number of particles or droplets in the respirable range, roughly 1 to 10 microns in diameter, as a biological attack would need to be in this size range to be broadly effective. Yet different systems try to use technologies like UV fluorescence or flow cytometry to distinguish between biological and non-biological material. Such technologies still can get flummoxed by natural background matter.

Finally, there are specific techniques for identifying particular pathogens or toxins of known biological warfare utility such as anthrax or ricin. The global COVID-19 pandemic has had the inadvertent effect of making the public broadly familiar with the most widespread of such technologies. Many millions of people have used COVID-19 lateral flow tests and this is the exact same technology as developed in the early 1990s for detection of biological warfare threats. These remain the state of the art for confirming the presence of threats like anthrax or bubonic plague in field samples.

Of all of CBRN detection technologies, radiation detection is the oldest and most technologically mature. Ionising radiation interacts with matter and a number of technologies detect and measure these interactions. To greatly simplify and summarise how such instruments work, gas filled tubes, scintillation crystals, and/or semiconductor materials are used for detecting and measure the various forms of radiation and are coupled with significant data processing electronics that turns the output of the detection media into useful measurements like count rate or dose rate. Variations on this theme can be used for dosimetry, which is this measurement of accumulated exposure over time. Military requirements are not actually that far away from various use cases in the nuclear power industry, border security, or emergency response. This yields significant crossover in products and markets. Thermo Fisher Scientific, Mirion (which bought Canberra), Laurus Systems, FLIR, and others all have useful products in this area.

Diagnostics – An overlooked area

An area usually ignored in military CBRN detection is a fundamentally important one. Many chemical weapons, all biological warfare agents, and radiation sickness have a delay between exposure and onset of symptom. The first indicator of CBRN warfare or terrorism might be a sudden influx of sick soldiers or civilian victims. Therefore, a holistic view of CBRN detection should include post-exposure diagnostics. All too often, military CBRN affairs disregards this aspect or assumes that somehow military medicine has somehow already solved the problem.

Some types of CBRN-induced injury or illness are rather easily diagnosed, such as the specific syndrome caused by nerve agents or, say, the specific visible signs of smallpox or skin lesions from sulphur mustard. Unfortunately, a large percentage of CBRN-related illness or injury may not be obvious to medics. An outbreak of nausea and vomiting, for example, could have either CBRN or non-CBRN-related causes. However, a firm diagnosis of a CBRN injury combined with a narrative of where the victim had been, is useful intelligence that commanders could use.

While research on CBRN-related diagnostics is not unknown, it is less visible and has resulted in far fewer practical capabilities at the field level. Some of the developments in this area remain well inside the domain of hospital and laboratory. For example, the technique of fluoride reactivation to analyse blood samples for exposure to nerve agents after the fact, remains a specialist capability in specific laboratories. Biological dosimetry, the ability to analyse biomedical samples from a patient to estimate their exposure to radiation after that exposure already occurred, is still a speculative science. We are still a long way away from having capabilities at the pre-hospital level, however. Field medics still lack specialist technology in this arena.

Future Prospects: Ubiquity and Connectivity

In terms of detecting hazards, chemical and radiological technologies are fairly mature, and we can expect to see only incremental improvements. As practical revolutionary developments, the exciting future lies in ubiquity and connectivity. Ubiquity should be a goal. Systems are smaller, lighter, and cheaper in relative terms than they were in the past. A military force serious about better force protection can proliferate chemical and radiological sensors around the battlefield. Instead of a specialist squad having to detect threats, there is at present no technical obstacle to every single combat vehicle and infantry squad having a chemical detector and a radiological detector. Every tank and armoured personnel carrier can be a CBRN reconnaissance vehicle today, if only the right people thought about it that way. The obstacles are logistical, budgetary, and bureaucratic, not technical.

Connectivity is just as important as ubiquity. A sensor on a soldier's belt that gives the soldier good information, but the soldier is distracted because he is fighting a battle (or incapacitated) is of very little value. A soldier reading an output from a sensor and reporting it by voice over a radio network is the cutting edge of 1960 technology. CBRN sensors that disseminated useful information elsewhere on the battlefield would be of great value for situational awareness and contamination avoidance. In effect, all combat units can become CBRN reconnaissance units. Such connectivity exists for other reasons, and it would be a matter of system integration not radical re-invention to make CBRN connectivity a reality.

Biological detection will continue to lag behind. It is possible that some developments will shift this area of technology towards being more useful. This correspondent remembers sitting in a meeting in the Pentagon, being told that a useful field bio detector was about ten years away. That meeting was in 1995. ■

Demonstrating Flexibility and Scale: JEF provides non-NATO options for Generating Amphibious Effects

Dr Lee Willett

Amphibious warfare – the capacity to project ground force ashore from the sea – is regarded as high-end military capability. In the worsening security situation in Northern Europe, building amphibious force is a key element of NATO deterrence and defence posture.

NATO has been broadening and deepening its amphibious capability, to offset concerns that increasing Euro-Atlantic insecurity could generate risks to member state territories on NATO's flanks. The Russo-Ukraine war has demonstrated the risk of crisis spillover into maritime regions like Northern Europe. Thus, NATO countries need to routinely practice and prove capacity to deliver effects ashore from the sea through amphibious force. This is done within NATO itself, but also by NATO countries and partners working in multinational constructs like the UK-led Joint Expeditionary Force (JEF).

The Russo-Ukraine war may appear, at first glance, to be a conflict set almost exclusively in a land context. Yet wider events around the operational theatre have underlined the relevance of the maritime domain. To the south, in the Black Sea there have been blockades on merchant shipping, uncrewed vehicle attacks from the sea against naval bases, bridges, and other maritime infrastructure, warships sunk by anti-ship missiles, and reported movements of amphibious shipping.

To the north, one of the conflict's most significant events took place in the Baltic Sea when, in September 2022, two Nordstream gas pipelines suffered ruptures, with NATO and Western countries pointing to sabotage. In May 2022, the UK-led JEF deployed its command headquarters to Latvia and Lithuania to provide strategic reassurance for the Baltic States, conducting region-specific operational planning and building deterrence against conflict spillover risk. In the event of crisis escalation around the Baltic States, a primary way for NATO to provide military support would be to deploy amphibious forces and associated shipping across the Baltic Sea, including with ships accessing the region from the North Sea through the Skaggerak/Kattegat straits maritime choke point.

More broadly across Northern European waters, NATO navies have been prosecuting increased Russian submarine activity. Such activity creates risk to critical national infrastructure on the seabed (including oil and gas pipelines, and power and data cables) or to high-value targets at sea or ashore (through launching long-range cruise missiles). Russian submarines also provide a direct threat to NATO efforts to use amphibious capability from the sea to reinforce alliance territories – for example Iceland, Finland, or Norway – should they be isolated in the event of crisis or conflict.

As instability has increased across the Euro-Atlantic theatre over the last decade, including in Northern Europe, the strategic importance of North Atlantic and High North waters as NATO's northern maritime flank has become more prominent. NATO has responded to the growing maritime insecurity in several ways. First, it has increased the operational presence and activity of its two Northern Europe-based standing naval forces (SNFs) – Standing NATO Maritime Group 1 (SNMG1) and Standing NATO Mine Counter Measures Group 1 (SNMCMG1). Second, in direct response to the Russo-Ukraine war, the alliance activated its graduated response plans for the

Credit: UK MoD

The UK Royal Navy amphibious assault ship HMS Albion is pictured in Norway's northern fjords during the Norway-hosted, NATO-focused 'Joint Warrior'/'Joint Viking' exercise in March 2023. Deploying effective amphibious capability around NATO's northern maritime flank is central to the alliance's collective deterrence and defence posture.

Author

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first time, elevating the SNFs to operating as High-Readiness Maritime Task Forces within the NATO Response Force (NRF) and Very High Readiness Joint Task Force constructs. The operational implications of this include wider deployment of NATO maritime assets across the alliance's area of responsibility, under relevant operational command authority.

Third, NATO has significantly increased the amount of amphibious activity it is conducting around its northern maritime flank. Notably, such activity has been conducted at increasingly larger scale.

Since the outbreak of the Russo-Ukraine war itself, this focus on amphibious operations has been demonstrated in a range of major amphibious exercises that have taken place across the region. Several of these have been significant for different reasons, but especially in demonstrating the increase in scale:

- In March-April 2022, the NATO-led, Norway-hosted Exercise 'Cold Response' took place in Norway's northern fjords.
- In June 2022, NATO amphibious forces assembled to support the US Navy (USN)-led 'BALTOPS' exercise in the Baltic Sea.

Credit: US Navy

A landing craft air cushion (LCAC) vehicle approaches the US Navy (USN) Wasp-class amphibious assault ship USS Kearsarge during the 'BALTOPS' exercise in the Baltic Sea in June 2022. Across 2022, the USN's USS Kearsarge amphibious ready group (ARG) deployed regularly to the Baltic region.

- In March 2023, the UK-led JEF maritime task force deployed to Norway – once more, to the northern fjords – for the Norway-hosted, NATO-focused 'Joint Warrior'/'Joint Viking' exercise.
- In April 2023, Sweden's 'Aurora' national defence exercise included serials focused on building interoperability between JEF member states (although JEF member states present at the exercise were not there under a formal JEF deployment). The JEF phase of the exercise saw JEF countries working together including to conduct an amphibious landing, with UK

Credit: German Navy

Kearsarge is pictured transiting the North Atlantic in April 2022, en route to Iceland for Exercise 'Northern Viking'. In an extensive deployment across the region in 2022, the ship and its ARG/MEU delivered amphibious capability ashore in a range of exercises at a range of locations.

Royal Marines Commandos deployed from the JEF flagship, the UK Royal Navy (RN) landing platform dock (LPD) amphibious assault ship HMS Albion.

Collectively, the conduct of these four major exercises in 12 months underlines the importance of amphibious operations as part of NATO's evolving deterrence and defence strategy for the region. More importantly, though, the new operational structures that have been demonstrated within the exercises underline how NATO has been scaling up its amphibious capability to reflect the realities of the alliance's emerging operational requirements. One primary lesson learned in the Russo-Ukraine war to date is that conventional conflict that is broad in geographic spectrum and deep in force structure commitment is an enduring model.

Demonstrating Scale

For 'Cold Response', NATO assembled five task groups. The UK Royal Navy (RN) aircraft carrier HMS Prince of Wales, deployed as NRF flagship, embarked the maritime component command staff. Three amphibious task groups (ATGs) – led by the RN LPD Albion, the Royal Netherlands Navy (RNLN) LPD HNLMS Rotterdam, and the Italian Navy landing platform helicopter (LPH) vessel ITS Giuseppe Garibaldi – delivered the main landing force from the sea. The French Navy LPD FS Dixmude supported Rotterdam's landing by deploying raiding forces ashore. Underlining the development of scale, this was the first time three ATGs had been deployed for a NATO exercise.

Credit: UK MoD

Viking assault vehicles, carrying UK Royal Marines Commandos, conduct training operations in Norway in 2022. NATO is demonstrating the capability to deploy amphibious forces ashore from the sea across its northern maritime flank.

For 'BALTOPS 22', the USN's USS Kearsarge amphibious ready group/marine expeditionary unit (ARG/MEU) deployed to the exercise in the southern Baltic Sea region, contributing two amphibious assault ships: the Wasp-class landing helicopter dock (LHD) amphibious assault ship USS Kearsarge, as ARG/MEU flagship; and the Whidbey Island-class landing ship dock (LSD) vessel USS Gunston Hall. The ships embarked the US Marine Corps' (USMC's) 22nd MEU as the landing force. Force elements from the ARG/MEU had already participated in Exercise 'Northern Viking' off Iceland, in April: while the focus in 'Northern Viking' was on securing critical access points at sea and critical infrastructure ashore, amphibious landings were also demonstrated. In August, the Kearsarge ARG/MEU returned to the Baltic, including with the San Antonio-class LPD USS Arlington, to conduct further integration training with regional allies and partners.

The deployment of the UK-led JEF maritime task group for the 'Joint Warrior'/'Joint Viking' exercises, known collectively as 'JEF Warrior', demonstrated something different. The UK-led, 10-country JEF construct is designed to operate independently of NATO and its activities, but to support NATO in these activities. JEF aims to develop integrated maritime and amphibious capability in a conflict's sub-threshold context, building deterrent effect to avert a crisis or crisis escalation, or to shape the operational theatre for any prospective NATO engagement if the crisis escalates beyond the threshold into conflict.

JEF's 10-country membership list includes: the UK, as framework nation, and Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, the Netherlands, Norway, and Sweden. For 'JEF Warrior', the JEF maritime task group consisted of four amphibious ships: the RN's LPD Albion and LSD RFA Mounts Bay; and the RNLN LPDs Rotterdam and HNLMS Karel Doorman. These amphibious vessels were supported by a range of destroyers, frigates, and patrol vessels within the JEF task group: interestingly, this supporting group included the USN DDG-51 destroyer USS Arleigh Burke. The embarked forces included Royal Marines from 45 Commando, constituting the UK's Littoral Response Group (LRG) capability.

The JEF maritime task group contributed mostly to the 'Joint Warrior' component, for which it deployed amphibious forces ashore in the crisis response phase. The exercise then transitioned into a second component, 'Joint Viking', for which the amphibious forces deployed ashore conducted high-end combat training under NATO Article V-type tasks focused on defending member state territory.

Credit: UK MoD

For Exercise 'Cold Response' off Norway in 2022, five maritime task groups assembled, based around the RN aircraft carrier HMS Prince of Wales (foreground, centre). Here, the carrier is flanked by the amphibious ships FS Dixmude and HNLMS Rotterdam (left), and ITS Giuseppe Garibaldi and Albion (right): these ships were used to generate three separate amphibious task groups for the exercise.

The JEF maritime task group first began conducting operations back in 2019, when Albion led the 'Baltic Protector' deployment, which included participation in 'BALTOPS 19'. However, 'JEF Warrior' was the first time the JEF maritime task group had included multiple amphibious assault ships and had deployed them under two ATGs, led respectively by Albion and Rotterdam. Developing this capacity enables JEF to deploy effects ashore in different places at the same time, or even at different times.

Only a short while after returning from Norway, Albion was back out at sea, heading this time for the Baltic and 'Aurora'. With LRG elements embarked again, the task group "[would] be exercising with allies and partners and demonstrating the UK's and the RN's commitment to Northern European security", Albion's Commanding Officer Captain Marcus Hember said, in an RN statement. Amphibious landings were conducted as part of a focus on protecting Sweden from attack, but with the littoral environment this time being archipelagic shallows rather than deep-water fjords.

Geography and 'Amphibiosity'

The maritime nature of NATO's northern flank and the broad diversity and spread of littoral locations across the region underlines the geostrategic significance of amphibious capability in delivering deterrence and defence in support of regional security for Northern European countries.

Russia's potential capacity to establish anti-access/area denial (A2/AD) 'bubbles' around littoral regions and maritime access points highlights particularly the importance for NATO of building capacity to deliver high-end ground forces from sea to shore to lance such 'bubbles'. Such access points include the Greenland-Iceland-UK (GIUK) Gap, which acts as gateway between North Atlantic and Northern European waters, and the Skaggerak/Kattegat

Credit: UK MoD

UK Royal Marines Commandos are pictured conducting boat drills in the Norwegian fjords during 'Cold Response' in 2022. Training in the harsh conditions is designed to build capacity to fight, rather than just to survive.

straits, which connect the North and Baltic seas.

Conducting amphibious operations around Iceland, for example, requires the ability to maintain blue-water security of sea lines of communication (SLOCs). Off Norway, once having transited North Atlantic SLOCs, a particular challenge for maritime forces is operating in the confines of the deep-water fjords. In the Baltic, the challenge is mixed, from the shallow, archipelagic waters in the west, to the more open waters in the east where the threat is closer in.

Practicing amphibious operations in each of these different environments through exercising is thus very important for NATO and its individual member states. "The reason 'JEF Warrior' is important to the Norwegians, the Danes, the Dutch, and the UK is because the geography is really important. That's where Norway could be threatened," Group Captain Kevin Latchman, a UK Royal Air Force officer and Assistant Chief of Staff J3/J5 (operational planning) on the JEF planning staff at the Standing Joint Force Headquarters (SJFHQ), Northwood, UK told ES&D in an interview on 12 April. "Exercising around that area means these countries can get better at working in that geography, in that climate .... Those are really important tactical aspects."

In terms of geography and climate, the key issue is conducting sufficient training and developing sufficient experience so that operating in such harsh environments becomes a matter of being able to fight effectively rather than simply survive. In tactical terms, alongside amphibious operations wider naval task group activity such as conducting freedom of navigation operations can disrupt any potential malign activity by an adversary directed at Norway from the sea.

The presence of two ATGs on 'Joint Warrior', and three on 'Cold Response', also points to the wider principle being developed in NATO amphibious operations – that of dispersal and disaggregation of forces, not only to reduce vulnerability but also to expand the options for and angles of attack.

Joint and combined amphibious interoperability

The JEF amphibious activity in 'Joint Warrior' was one of the most significant developments, as it demonstrated how significant capability can be brought to bear outside of, but integrated with, the NATO construct.

JEF is designed to develop interoperability, between member states but also with regional partners (ideally, NATO member states), and to use such interoperability to add mass in addressing regional security challenges and supporting NATO activities. 'JEF Warrior' was devised specifically to build such interoperability. In the exercise, JEF was assessing "How can we quickly get forces onto the landmass of Norway, to support the Norwegians and bring mass to a potential fight?" said Latchman.

Such mass could also be distributed more broadly by the presence of two ATGs. Such presence in turn adds flexibility, Lieutenant Commander Nicholas Stevenson Royal Navy, SO2 Media at SJFHQ and deployed with the Norwegian Armed Forces for the exercise, told ESD. Such flexibility includes the capacity to conduct landings in different places at different times, he explained. As well as augmenting tactical flexibility, this provides capacity to overcome any limitations posed by the operational environment (such as sea state or weather).

Such flexibility also offers strategic and operational utility for NATO. While JEF operates independently from NATO command structures, JEF can deploy forces – including multiple task groups – to places of operational relevance for the alliance. "Now, if that's useful to NATO, we could ... get forces in the right place at the right time, so if you then transition to a NATO operation, that's where JEF adds value," said Latchman. "Being able to operate and set the conditions for successful NATO action is where JEF is."

This is what was practiced, demonstrated, and achieved in 'JEF Warrior'. In the 'Joint Warrior' phase, the JEF maritime forces and the two ATGs prepared the maritime battlespace at sea at a conflict sub-threshold level, including deploying amphibious forces ashore: once ashore, those forces – exercising under 'Joint Viking' – transitioned to a high-end, NATO Article V-context activity, conducting defence of NATO member state territory. Latchman explained that 'JEF Warrior' provided the JEF maritime task group with the ability to operate what he referred to as 'left of the line' – the threshold line between crisis escalation and conflict – and then transition to a NATO operation under a Norwegian joint headquarters.

What was critical here was practising the dovetailing between the two operations at the operational and tactical levels, Lt Cdr Stevenson explained. JEF provided the build-up of the ATGs under 'Joint Warrior' 'left of the line' in terms of the conflict threshold, while 'Joint Viking' continued 'right of the line' with emphasis on the high-end warfighting that would feature in a NATO operation. 'Joint Viking' featured, for example, significant UK Royal Marines and USMC activity. "The amphibious element was not quite the cross-over, but that's where the units exercised the dovetailing between the JEF sub-threshold environment and the NATO Article V-focused environment," said Lt Cdr Stevenson.

For JEF, at the tactical and operational levels, two of the primary achievements in developing improved amphibious capability were the scaling up of the outputs to include the operation of two ATGs, and the dovetailing of the maritime

battlespace preparation and amphibious landing with the NATO-focused 'Joint Viking' activities. "It allowed us to exercise that 'ramp up' ... which we don't normally do in 'Cold Response' – and certainly not at that scale," said Lt Cdr Stevenson. "'JEF Warrior' not only scales it up, but it also gets the participating forces at the unit command level into the mindset of how to operate together as a task group in a sub-threshold environment, and then of how to adapt that and transform it essentially when you get [forces] ashore and operate on land," he added. This 'operationalisation' of the training impacted at both the operational and tactical levels, but also in terms of operating in the environment.

Conducting activities as complex as amphibious landings, and the layers of operational- and tactical-level enabling support that accompany them, is a challenging task – especially in such testing environmental conditions. Exercises like 'Cold Response' and 'JEF Warrior' provide the opportunity to refine task group, unit, and personnel skills, especially for those that have not deployed to and operated in the region before.

At an operational level, 'Joint Warrior' gave the JEF maritime task force the opportunity to generate forces at scale in the challenging conditions, including developing interoperability, and to demonstrate the capacity to do so. "['Joint Warrior'] gave us the opportunity to practice interoperability in the sub-threshold environment," said Stevenson. A good example, he noted, was the UK's Tide-class fleet tanker RFA Tidesurge, which deployed to the region for the second time, following 'Cold Response' in 2022. "At one point, the ship managed to do three replenishment-at-sea (RAS) tasks – in a pretty shocking sea state with poor visibility – with three ships from three different countries in two days," he said. Not only did this tasking prove the RAS capability for the four ships involved, but it also demonstrated the capability to the chain of command, Stevenson added.

The RN also deployed a number of P2000 coastal patrol vessels to the exercise, with the vessel class operating inside the Arctic Circle for the first time. These vessels demonstrated effective interoperability, Stevenson said, working with Royal Norwegian Navy Skjold-class corvettes as well as larger allied vessels including destroyers and frigates.

Ashore, UK units like the Parachute Regiment's 2nd Battalion gained experience of operating in an environment that is very different from some of the British Army's more recent operational locations, such as Afghanistan.

JEF's added value

JEF provides a linear point of activity between national response and any potential NATO response to a crisis. 'JEF Warrior' was seen by some of the participating JEF countries as a good landmark in the development of JEF's relevance. To date, JEF has demonstrated how multinational task groups operating outside of the NATO decision-making structure but interoperable with NATO operations can provide a swift and flexible operational and command-and-control response capability to offset threats in Northern Europe, including if NATO is not present in a region or is not able to respond. One flexible value JEF offers for participating states is that its construct is not based on consensus across the 10 members: so, it is a multilateral structure within which other multilateral structures can develop.

In terms of amphibious capability, JEF's participation in 'Joint Warrior' and 'Joint Viking' demonstrated how increased scale in capability can provide operational capacity to disaggregate and disperse forces to improve force protection and provide flexibility at the operational level. At the same time, this renewed capacity provides choice at the strategic level through generating deterrence by denial or punishment. ■

The Republic of Korea's Indigenous Submarine Programmes

David Saw

The Republic of Korea Navy (ROKN) is now deploying its third generation of domestically produced conventional submarines (SSK). As this article will show, the ROKN's first-generation SSK was a foreign acquisition that evolved into an SSK produced under licence in the Republic of Korea (ROK).

The ROK would go on to take the knowledge gained from this first-generation SSK to offer refit services to export customers and later offer new-build submarines based on this SSK design to export customers. The first-generation SSK provided an operational capability for the ROKN, equally as important was that it provided the foundations for an indigenous SSK build capability and created the basis for an industrial SSK ecosystem covering everything from subsystems to naval weapons.

What is impressive here is how rapidly the ROK has developed operational and industrial capabilities in the SSK arena. The first-generation SSK was ordered in 1987, 36 years ago, and was commissioned into the ROKN in 1993, 30 years ago. In that time, the ROK has built and commissioned the first-generation SSK and then undertaken a locally defined and managed upgrade and modernisation programme on those SSKs. It then looked overseas for a design to meet its second-generation SSK requirements, a programme known as KSS-II. A far more sophisticated SSK than the first-generation boat, the KSS-II again saw local production and technology transfer.

The first- and second-generation SSK programmes provided operational and sustainment experience for the ROKN. They also provided the industrial and programme management experience necessary to contemplate a third-generation SSK. In fact, during the 1990s, as the ROKN transitioned to becoming a true 'Blue Water Navy','they were defining a force structure plan for the 2020s that included many of the characteristics of the KSS-III we see today. KSS-III requirements included a larger displacement, long endurance for extended range operations and the ability to support a form of strategic land attack capability to deter the Democratic People's Republic of Korea (DPRK).

Credit: US Navy

ROKS Yi Sun-sin (SS 068) was built at DSME and was the lead unit of Batch III of the Jang Bogo class, seen here at Pearl Harbor for the RIMPAC exercise. The ROKN looked to improve its submarine skills via participation in major international exercises such as RIMPAC.

Starting Points

In 1948, after the establishment of the ROK as an independent state and the ending of Allied occupation, the ROKN was formed out of the Korean Coast Guard. The ROKN saw its first combat action upon the outbreak of the Korean War (1950-1953), while during the rest of that conflict it worked with US and Allied navies, establishing maritime dominance around the Korean peninsula. After the armistice that ended hostilities, the ROKN mission was primarily coastal patrol, with equipment acquired from the US, much of it surplus.

With the ROK economic situation improving, the government was able to embark on the 'Yulgok Plan' to increase self-reliance via the establishment of a national defence industry. The ROKN would benefit from this policy, initially sourcing patrol units from local shipyards. However, while the ROKN was gradually building its capabilities, its primary strategic competitor and threat, the DPRK Navy was starting to significantly upgrade its own capabilities. In the 1970s, the DPRK acquired seven Type 033 Romeo class SSKs from China and it would then go on to build additional submarines, assembling parts supplied from China.

All of a sudden, the ROKN found itself with an anti-submarine warfare (ASW) mission to add to its primary patrol and coastal defence tasks. As a counter to the DPRK's expanding capabilities and due to the growing maturity of the ROK's naval shipbuilding, the ROKN was able to field frigate and corvette classes of local design, but equipped with foreign weapons and systems, throughout the 1980s.

During this period, the ROKN was already working on defining a future structure that would expand its operational capabilities. Part of this structure would involve the possession of an SSK force, achieving that objective would require a great deal of research, and to that end, the Korea Tacoma

shipyard was contracted to build the first Dolgorae class midget submarine. This vessel had a displacement of 175 tonnes, a crew of 14, two torpedo tubes and major subsystems from Germany and Britain. The lead unit was launched in 1982 and commissioned in 1985, before being retired in 2003. Two more units were commissioned in the early 1990s, and these remained in service until retired in 2016. The Dolgorae provided a training capability for future ROKN submariners, and it played a role in improving the ASW skills of ROKN surface units. Midget submarines are also very useful in carrying out special missions, with the ROKN continuing to flirt with units of this nature over the years. However, it was the DPRK Navy which ended up developing a more comprehensive midget submarine capability.

Credit: US Navy

ROKS Na Dae-yong (SS 069) departs Pearl Harbor while participating in a RIMPAC exercise. The second unit of Jang Bogo Batch III and built at DSME, ROKS Na Dae-yong went into refit at DSME in June 2017 and was returned to ROKN service in June 2019.

The First Generation

The decision to acquire a full SSK for the ROKN had two dimensions; firstly, they wanted to acquire the best system for their operational environment. Secondly, they wanted to develop a capability to build and sustain SSKs, with the eventual objective of having the ability to design and build indigenous SSKs in ROK yards. With the US not having the ability to offer an SSK design, this offered the ROK the opportunity to evaluate the full spectrum of European SSK proposals. Added to which, the opportunity to increase national capability while reducing dependence on the US, was an equally welcome development.

In the 1980s, Europe could offer a profusion of national SSK designs, as in parallel, most of the European nations had the supporting industrial base for all critical submarine systems and subsystems. This offered the ROK the ability to acquire expertise and technology from multiple sources. After evaluating their options, the ROKN turned to Howaldtswerke-Deutsche Werft (HDW), now thyssenkrupp Marine Systems, and the Type 209 submarine design in the Type 209/1200 variant.

The first batch of three submarines was ordered in 1987, with the lead ship of the class built in Germany and commissioned as the ROKS Jang Bogo (SS 061) in June 1993. As an aside, this unit was often referred to as the Chang Bogo, changes in the transliteration of Korean to English led to it being referred to as the Jang Bogo. The second and third units were assembled in the ROK at the Daewoo Shipbuilding and Marine Engineering (DSME) yard at Okpo. ROKS Yi Cheon (SS 062) was commissioned in June 1994 and ROKS Choe Museon (SS 063) in February 1995.

Batch II vessels of the Jang Bogo class were built at DSME; these were ROKS Park Wi (SS 065) commissioned in August 1995, ROKS Lee Jongmoo (SS 066) in August 1996 and ROKS Jung Woon (SS 067) in August 1997. The third batch units have additional capabilities as they can launch UGM-84A sub-Harpoon missiles, in addition to the SUT torpedoes that are standard fit. Batch III, all built at DSME, consists of ROKS Yi Sun-sin (SS 068) commissioned in February 2000, ROKS Na Dae Yong (SS 069) in December 2000, and ROKS Yi Eo-kgi (SS 071) in December 2001.

A refit and upgrade programme has added significant performance improvements and new capabilities to the Jang Bogo class, as well as extend service life. These are said to include an increase in displacement akin to the Type 209/1400, improved high performance batteries of ROK design, new combat management system, towed array sonar, indigenous torpedo countermeasures system and new weapon options, including the ROK heavyweight torpedo. In June 2017, ROKS Na De Yong began a refit at DSME, with the SSK returning to the ROKN service on 10 June 2019.

Export Success

That DSME had mastered the art of submarine construction was proven in 2011 when they received an export order from Indonesia for three submarines. It might surprise many, but the first Asian country to export submarines was actually Japan, which supplied four Matchanu class submarines, built by Mitsubishi Heavy Industries to Thailand. The first two vessels were delivered in September 1937 and the second two in April 1938.

Since the 1970s, the Asian submarine export market has been dominated by China. Its first major programme was the supply of 20 Type 033 Romeo class SSKs to the DPRK, with the majority assembled or built in the DPRK; China also supplied eight Romeo class boats to Egypt. Also exported were ex-PLA Navy Type 035 Ming class SSKs with Bangladesh receiving two and Myanmar receiving one.

More recently, PLA Navy and Chinese submarine designs have massively increased in quality and capability. Latest generation SSK designs such as the upgraded Type 039B have been sold to Pakistan, with eight units ordered. Thailand has also opted for Chinese submarines in the form of the S26T export model, though funding has proven problematic here. The objective was to acquire a minimum of three boats, but currently only one has been contracted. Even the DPRK has exported a submarine in the shape of a Yono class midget submarine sold to Iran.

ROK submarine links with Indonesia started when DSME won a refit contract for Cakra, a Type 209/1300 class boat built by HDW and commissioned into the Indonesian Navy (TNI-AL) in March 1981. The refit and overhaul for Cakra was completed in 2005, but due to financial issues in Indonesia, a refit for sister ship Nanggala was postponed, with the vessel eventually being completed in early 2012.

The TNI-AL had been looking to add to its SSK capabilities for many years, but was unable to find a solution until the ROK offered a package of three submarines, two to be built by DSME in the ROK and a third to be assembled by the PT PAL shipyard in Surabaya, Indonesia. The units in question are an evolution of the Type 209/1400 design, based on the Jang Bogo ROKN upgrade with the addition of Indonesia-specific systems. The contract was finalised in December 2011. Lead unit KRI Nagapasa (403)

was commissioned in August 2017, and she was followed by KRI Ardadedali (404) commissioned in April 2018. KRI Alugoro (405), the unit assembled in Indonesia, was commissioned in April 2021.
A contract for a second batch of three Nagapasa vessels was agreed in April 2019, with the first unit to be assembled at PT PAL and the other two to be built at PT PAL. The contract has not come into force and there are doubts that it ever will, especially since the French defence relationship with Indonesia has become very close recently and interest has been shown in the Scorpène SSK design. With Indonesia's defence procurement process being so changeable, absolutely anything could happen regarding an SSK requirement, or perhaps even nothing at all!

Credit: US Navy

ROKS Yun Bong-gil (SS 077) was built at HHI and commissioned in June 2016, she was the second KSS-II Batch II boat. The selection of the German Type 214 submarine for KSS-II provided an infusion of advanced submarine technology that set the scene for the current KSS-III submarine programme.

The Second Generation

The second generation of ROKN submarines were acquired under the KSS-II programme. The drivers for KSS-II were, once more, both operational and industrial. For the ROKN, they were looking for a boat that offered increased operational endurance and range, hence the necessity for an effective air independent propulsion (AIP) system. Inevitably, the KSS-II would be more sophisticated than the previous generation SSK and considerably more survivable in contested environments.
Industrially, KSS-II would introduce the ROK to advances in submarine technology that could be applied to a future indigenous submarine programme. Due to the fact that the ROKN envisaged having and sustaining a large SSK fleet, in excess of 20 units, they could justify having a second build yard and for that reason Hyundai Heavy Industries (HHI) was selected to be the lead yard for the KSS-II programme.
In 2000, HDW was selected as the winner of the KSS-II programme with its Type 214 submarine. The lead unit, ROKS Sohn Won-yil (SS 072) was laid down at HHI in June 2006 and commissioned in December 2007. The second unit, ROKS Jeong Ji (SS 073), was commissioned in December 2008, with the third unit of Batch I, ROKS An Jung-geun (SS 075) commissioned in December 2009.
KSS-II Batch II vessels were contracted in 2006, with the first unit, ROKS Kim Jwa-jin (SS 076), built at DSME and commissioned in December 2014. The second unit, ROKS Yong-Bong-gil (SS 077), was built at HHI and commissioned in June 2016, followed by ROKS Yu Gwan-sun (SS 078), built at DSME and commissioned in July 2017. The remaining three boats were: ROKS Hong Beom-do (SS 079), built at HHI and commissioned in January 2018; ROKS Lee Beom-seok (SS 081), built at DSME and commissioned in May 2019, and ROKS Shin Doi-seok (SS 082), built at HHI and commissioned in January 2020. ROKS Hong Beom-do was reportedly used for the test and integration of the indigenous Haeseong III (Hyunmoo-3A) submarine-launched cruise missile on the KSS-II class and for the future KSS-III class.
The KSS-II programme provided the basis for work to commence on the KSS-III programme for a truly indigenous ROK submarine and as previously discussed, KSS-II also allowed the ROK to have two shipyards capable of building SSKs. The first and second-generation submarines for the ROK were a learning process for the ROKN. For ROK industry, KSS-III would determine if this learning process had been a success.
Filename: Shin Dol-seok

Credit: US Navy

ROKS Shin Dol-seok (SS 082) was the last KSS-II Batch II (Type 214) unit to enter service, built at HHI and commissioned in January 2020. She is seen here at Apra Harbor heading towards the US Naval Base Guam in September 2022.

The Third Generation

When the ROK started developing the KSS-III programme, its operational requirements were far more multi-layered than before. Having become a true 'Blue Water Navy,' the ROKN saw its operational area grow far beyond the waters surrounding the Korean peninsula. At this point, the ROK had become a top ten global economy, further opening up the requirements to operate at an extended range from ROK homeports. The ROKN began to define its operational area of interest from the eastern coast of Africa to the western coasts of the Americas.
The ROKN also had to take into account the evolution of the various threats that it would have to consider. For historical reasons, the ROK always has to keep a wary eye on Japan, plus there are disputes over maritime boundaries between Seoul and Tokyo to consider. Realistically though, Japan does not present a threat of any mag-

nitude. In the past, the ROKN would have been concerned with the Soviet Navy and later with its successor, the Russian Navy, primarily due to Moscow's support to the DPRK. These days, the Russian Pacific fleet is a shadow of its former self and does not represent a top tier threat to the ROK.

The growth of Chinese maritime power has undoubtedly become a source of concern for the ROK, as has China's ongoing linkages with the DPRK. China therefore has moved to a prime position in the ROK threat calculus. That brings us to the DPRK which continues to be an existential threat to ROK security. DPRK nuclear and other Weapons of Mass Destruction (WMD), along with a profusion of delivery systems, are an obvious ongoing threat to the ROK. In a maritime context, the DPRK Navy also represents a constant and evolving threat. In March 2014, the Gorae class SSK 8.24 Yongung was launched with the capacity to launch a single Submarine-Launched Ballistic Missile (SLBM). The Gorae class appears to be a test unit for the development of the DPRK SLBM capability rather than an operational system.

The lead unit of the new Sinpo-C class submarine was completed in August 2020, and appears to be the operational SLBM system. The Sinpo-C, a conventional SSK, is estimated to have a displacement in the region of 3,000 tonnes and is thought to have an AIP capability able to carry either three or four SLBMs. The SLBM is thought to be the Pukguksong-3, which is believed to have a 1,900 km range; no information is available on the warhead, although a nuclear payload would not be unexpected.

Then there is the DPRK SSK threat to take into consideration. There are more than 40 Sang-O and Sang-O II class coastal submarines in service, plus the survivors of the Type 033 Romeo class, acquired and built between the 1970s and 1990s, although the latter are obsolete and far too noisy. Then there are at least 20 DPRK mini submarines to take into account as well. This SSK threat has to be considered, hence the ROK investment in Maritime Patrol Aircraft (MPA), surface ship and submarine-based ASW mission capabilities.

As far as the KSS-III was concerned, these DPRK developments led to the mission spectrum of the boat being significantly expanded. Initially KSS-III was envisaged as an SSK that had the ability to perform a mission akin to that of an SSN. The mission would be hunting down hostile SSKs, attacking surface targets as required and conducting land attack missions using indigenous cruise missiles.

Once it became clear that the DPRK was deploying an SLBM capability, the ROK had to respond and decided to field its own SLBM capability in the shape of the Hyunmoo-4.4. This is said to be a development of the land-based Hyunmoo-2B, with a range of 500 km and a warhead in the 1,000 kg category. In September 2021, the lead KSS-III unit, ROKS Dosan Ahn Chang-ho (SS 083), built by DSME and commissioned in August 2021, performed two Hyunmoo-4.4 launch tests on 7 and 15 September.

Credit: DSME

Jang Bogo-III (KSS-III) launch at the DSME yard at Okpo. The first two Jang Bogo-III Batch I units were built at DSME and the third is in build at HHI. These submarines have an SLBM capability carrying six Hyunmoo-4.4 SLBM in VLS cells.

To digress slightly, it should be noted that the ROK has a strong civil nuclear power capability. For example, it has exported nuclear power stations to the United Arab Emirates (UAE). Should the ROK Government be prepared to take the risk, there is no reason why they could not develop a nuclear weapons capability. Equally, given some external assistance, they could develop a submarine nuclear propulsion system as the basis for an SSN. As things stand though, the ROK has resisted pursuing the nuclear option.

The KSS-III is now referred to as the Jang Bogo-III class, but also by the name of the lead unit Dosan Ahn Chang-ho. The first three boats are referred to as Batch I units, with the second boat to be launched being ROKS Ahn Mu (SS 085) in November 2020 at DSME. The third boat, ROKS Shin Chae-ho (SS 086) was launched at HHI in December 2021. At the launch of ROKS Ahn Mu, the ROK Defense Acquisition Program Administration (DAPA) released details on the Batch I boats. They noted that the submarine has 76% local content; surface displacement is 3,358 tonnes and displacement submerged is 3,705 tonnes, Its length is given as 83.5 metres and a beam of 9.6 metres. They also stated that the SSK has six VLS cells for the launch of the Hyunmoo-4.4 SLBM. The second unit will commission this year and the third in 2024. The first Batch II unit, ROKS Lee Bong-chang (SS 087) is under construction at DSME, with likely commissioning in 2027, with the yard also awarded a contract to start work on an as yet unnamed second Batch II unit. Batch II submarines will have a larger displacement and length, with ten VLS cells for the Hyunmoo-4.4 SLBM. Local content in the Batch II boats has been increased to 80%, with the most significant local addition being the inclusion of lithium-ion (Li-ion) batteries. Compared to conventional SSK batteries, Li-ion batteries offer greater endurance, a significant increase in battery life and an increase in recharging cycles prior to replacement. Current planning calls for three Batch II units to be built, followed by three Batch III units. At this point, there is no information available on possible configuration differences on the Batch III boats.

The KSS-III design and its associated technology also provide the basis for export submarine designs offered by DSME, in the form of the DSME-2000 and the larger DSME-3000, with the number representing the displacement of the submarine. The initial export target for DSME is the highly competitive Indian Navy SSK requirement. With its mix of ROK and European technology, these advanced submarine designs could well be a very credible proposition in future SSK export markets. All told, the ROK has come a long way in SSK development terms since the 1980s. ■

The Republic of Korea's Naval Renaissance

David Saw

In the aftermath of the Korean War (1950-1953), small-scale maritime industry grew rapidly in the Republic of Korea (ROK) to meet the domestic demand for fishing vessels and similar smaller craft. It was not until the 1970s that the economic growth programmes of the ROK Government began to encourage domestic corporations to invest in shipbuilding.

The initial target market was merchant shipbuilding with ROK industry rapidly making a name for itself. At the outset, the ships they built were not considered the most sophisticated, but were seen as affordable when they began to take a market share in the sector. Later on, the level of sophistication increased, meaning they were now taken seriously, and were also seen as a threat to markets previously dominated by European or Japanese manufacturers.
The country's maritime industry continued to expand its capabilities and rapidly moved up the value chain, developing the capability to meet the most challenging requirements, to the point where ROK shipbuilders became a fixture on any listing of major merchant shipbuilding companies. Obtaining a leading position in this industry was one thing, but keeping a leading position in such a volatile industry was another. Merchant shipbuilding reflects the health, or otherwise, of the global economy. When the global economy is weak, merchant shipbuilding suffers, hence the periodic economic crises that have affected shipbuilders in the ROK, Europe and Japan. Nevertheless, the ROK remains a leader in terms of building merchant ships with cutting-edge technology, such as dual-fuel propulsion.

Credit: US Navy

ROKS Jeju (FF 958), an Ulsan class frigate, participating in a joint exercise with the US Navy in 2015. The first indigenous frigate class built in Korea, nine frigates were commissioned between 1981 and 1992.

Industry Awakens

In the 1970s, the ROK embarked on the Yulgok Plan, a programme designed to make the country more self-reliant in terms of defence equipment acquisition and sustainability. Up to this point, the ROK Navy (ROKN) had been primarily equipped with US Navy surplus units, with local yards producing small patrol craft for example. By the end of the 1970s, Korean shipbuilders would start to make a major contribution towards the modernisation of the ROKN, with the introduction of new classes of frigates and corvettes.

The ROKN would receive nine locally built Ulsan class frigates, which would be commissioned between 1981 and 1992; of this class, two are now museum ships, five are in reserve and two are still considered active by the ROKN. The Donghae corvette class saw four units built, all commissioned in 1993; two have since been scrapped, one was expended as a target, and one was transferred to the Colombian Navy. Then came the Pohang corvette class, with 24 units built and commissioned between 1984 and 1993. Less than five units remain active, with a number kept in reserve and two utilised as museum ships.
A significant feature about the Pohang class is that so many units have been transferred to foreign navies. The ROK does this to strengthen diplomatic and commercial relations, potentially opening the door to the future sale of ROK defence equipment. Both Colombia and Egypt have each received a single corvette, with Peru, the Philippines and Vietnam each receiving two vessels.
Even as the ROK naval industry was expanding its capabilities with the construction of units for the ROKN, it was also taking its first tentative steps into the naval export market. In the lead was the Korea Tacoma shipyard (later absorbed into Hanjin Heavy Industries, now part of HJ Shipbuilding and Construction). At the end of the 1970s, the yard sold four Mandau class FAC(M) units to Indonesia, equipped with a 57 mm and a 40 mm Bofors gun, 20 mm Rheinmetall cannon and MM38 Exocet anti-ship missiles. Three of this class remain in service. They then went on to sell two Musytari class offshore patrol vessels (OPVs) to Malaysia, with one built in the ROK and one in Malaysia. These units remain in service after being transferred to the Malaysian Maritime Enforcement Agency in 2006.
Later on, at the end of the 1980s, Korea Tacoma landed its most important contract to date, with India acquiring seven Sukhanya class OPVs. Three units were built in the ROK and commissioned between 1989 and 1991, with four units built in India. The Indian Navy still operates six of these OPVs, with a single unit sold to Sri Lanka, where it also remains in service.

In recent years, South Korean yards have won significant contracts globally for replenishment ships and tankers. Daewoo Shipbuilding & Marine Engineering (DSME) won a contract to build four 39,000 tonne replenishment tankers for Britain's Royal Fleet Auxiliary (RFA), based on the AEGIR design from BMT Defence Services in the UK. Subsequently, the Royal Norwegian Navy ordered a smaller displacement tanker version of the AEGIR design, also built by DSME. The Royal New Zealand Navy ordered a replenishment oiler from Hyundai Heavy Industries (HHI) in 2016, with HMNZS Aotearoa commissioned in 2020. Venezuela has the replenishment unit Ciudad Bolivar, acquired from the ROK in 2001.

The ROK naval industry is making significant strides in terms of exporting surface warfare units. At the end of the 1990s, DSME won a contract to build a frigate for Bangladesh to a modified Ulsan design. Then in 2013, DSME won a contract to build a DW3000 class frigate for the Royal Thai Navy (RTN); there was to be a second frigate purchased, but no contract was signed. However, it is in the Philippines that ROK industry has really made a breakthrough, with HHI winning numerous naval contracts. In 2016, HHI was awarded a contract to provide two Jose Rizal class frigates, the first of which was commissioned into the Philippine Navy in July 2020 and the second in March 2021.

HHI went on to win two other major Philippine Navy contracts against international competition. In December 2021, the company won the Corvette Acquisition Project with their HDC-3100 design, with a displacement of 3,100 tonnes and length of 116 metres. Two units will be acquired with first delivery in 2025. In June 2022, HHI was contracted for the Offshore Patrol Vessel Acquisition Project, with first delivery scheduled for 2025. The HHI solution is based on their HDP-2200 design OPV, with a displacement of 2,400 tonnes and a length of 94.4 m. In total, six units are due to be delivered.

Building the Future

The ability to win these export programmes comes from experience gained through meeting ROKN surface ship requirements. In the 1980s, frigates and corvettes represented the starting point for the naval industry, but the majority of the armament, electronics and other critical systems were sourced from foreign suppliers. Even then, licence production, offset requirements and technology transfers made an important contribution to ROK defence industrial development.

Credit: US Navy

ROKS Dae Joyeong (DDH 977) and ROKS Choi Young (DDH 981) are two Chungmugong Yi Sun-Shin (KDX-II) class destroyers of the Republic of Korea Navy (ROKN). The ROKN has six of these destroyers in service, three built at Hyundai Heavy Industries and three at Daewoo Shipbuilding & Marine Engineering (DSME).

Each successive generation of surface warfare systems produced in the ROK has led to further industrial capability development. For example, the three KDX-I Gwanggaeto the Great class destroyers, launched between 1996 and 1998 at DSME, and commissioned between 1998 and 2000, represented a major advance in ROK naval shipbuilding, allowing the ROKN to replace ex-US Navy destroyers as their major surface unit. As before, much of the equipment was imported, yet by the time these destroyers went through a mid-life update in 2020-2021, critical systems such as the combat management system was replaced by ROK-designed and built systems.

In the early 2000s, the ROKN embarked on the next stage of development with the introduction of the KDX-II Chungmugong Yi Sun-sin class destroyers, substantially larger and more capable than the previous KDX-I class. In total, six of these destroyers were built, three at DSME and three at HHI, with these ships commissioned between 2003 and 2008. The follow-on KDX-III Sejong the Great destroyer class was an even more formidable unit, again larger and more capable than the KDX-II and fitted with the Aegis Combat System, giving these units a national ballistic missile defence (BMD) capability, as well as a fleet air defence capability. HHI built two units and

Credit: US Navy

ROKS Sejong the Great (DDH 991) is the lead ship of the KDX-III destroyer class, three units are in service, and these are the most capable surface units available to the Republic of Korea Navy (ROKN). The first of three more KDX-III Batch II destroyers was launched in July 2022 at Hyundai Heavy Industries (HHI).

Credit: US Navy

The Republic of Korea Navy (ROKN) amphibious assault ship ROKS Marado (LPH 6112) departs Pearl Harbor during the RIMPAC 2022 exercise. Commissioned in 2021, ROKS Marado is the second of two Dokdo class LPH in ROKN service.

DSME one, with all units commissioned between 2008 and 2012. In 2019, HHI was awarded a contract for three KDX-III Batch II destroyers, with the lead ship ROKS King Jeongjo being launched on 28 July 2022 and due to be commissioned in 2024. Amongst other changes, the Batch II units have a larger displacement than Batch I units.

The other major surface warfare programme was based on the FFX frigate programme, with the objective being the replacement of existing Ulsan frigates and Pohang class corvettes. In 2010, HHI was awarded the first contract for what became known as the Incheon frigate class, HHI would go on to build three frigates, with STX Offshore and Shipbuilding (later K Shipbuilding) building three more. All units were commissioned between 2013 and 2016.

The next stage of the frigate programme was Batch II known as the Daegu class; these have an increased displacement over the previous Incheon class and incorporate more Korean content in terms of weapons and electronics. In total, eight units are to be acquired, four built by DSME and four by HHI. As of February 2023, five units are in commission with the ROKN, with two more units due to be commissioned this year and the final unit next year.

Batch III of the frigate programme covers six units, with lead ship ROKS Chungnam launched at HHI in April this year. Compared to the previous class, displacement in increased, as are anti-air warfare (AAW) capabilities. Surprisingly, the contract for the second frigate was won by a new player in terms of ROK naval shipbuilding, Samkang M+T (more recently renamed SK Oceanplant). Their bid was lower than those of HHI or DSME and it also appears that they won the contract for the build of the third and fourth Batch III frigates as well.

Future Prospects

The fact that SK Oceanplant was able to win a major share of the Batch III frigate programme was undoubtedly a major shock to HHI and DSME, and also to other ROK shipyards that intend to compete for ROKN and other ROK Government business. The maritime industry had three big players in the form of HHI, DSME and Samsung Heavy Industries. Then there was HJ Shipbuilding & Construction (formerly Hanjin Heavy Industries) which had built the two Dokdo class LPH for the ROKN and, finally, K Shipbuilding, which, as previously mentioned, had built three Incheon class frigates for the ROKN.

It seems clear that the Defense Acquisition Program Administration (DAPA) wishes to see more competition in shipbuilding. However, on the other hand the more established ROK shipbuilders, having experienced difficult business conditions in recent years are less than enthusiastic about expanded competition. For one major shipbuilder though, new possibilities beckon. DSME has been lurching from one crisis to another for a number of years, with Hanwha Group expressing an intention last year to purchase DSME, which remains the fourth largest shipbuilder in the world.

Hanwha will acquire 49.3% of DSME and will have full management control with their takeover cleared by competition authorities in the EU, the UK, China, Japan and Singapore, amongst others. At the end of April, the ROK Government's Fair Trade Commission (FTC) announced 'conditional approval' of the Hanwha takeover, meaning that the takeover can now proceed, although there will be reporting requirements to the FTC. According to South Korean news reports, once the takeover is complete, DSME will be rebranded as Hanwha Ocean. The Hanwha takeover will restore confidence in the shipbuilder and satisfy both DAPA and the ROKN over its long-term prospects.

Three Key Programmes

There are three key programmes underway that will define the future shape of the ROKN. In August 2020, the ROKN officially commenced a programme to acquire an aircraft carrier, with this effort subsequently receiving the CVX designator. The CVX was envisaged as operating 16 F-35B aircraft and eight helicopters, with the idea that the carrier would become operational in the first half of the 2030s. Now that appears to have changed, as DAPA and HHI are now said to be working towards the definition of a carrier with a displacement in excess of 50,000 tonnes and capable of operating the proposed naval variant of the Korea Aerospace industries (KAI) KF-21 Boromae fighter aircraft.

Inevitably, the change in the characteristics of the CVX will see a significant cost increase, while developing the KF-21N and accommodating it in the design of the carrier will require more time. Being reasonably optimistic, that could mean that the CVX will be ready in the 2035 time period. Budgeting for the CVX and its air group will be a key issue, as this will be a very expensive programme. Furthermore, there is very little point in having a single carrier, as a minimum of two will be required, further increasing the cost burden.

In 2019, there were the first reports of the ROKN working towards the development and acquisition of an 'Arsenal Ship'. In the ROKN, this is referred to as the joint firepower ship (JFS) and the intention is to have three units by the end of the current decade. DSME (soon to be Hanwha Ocean) has been selected as the responsible yard for the JFS programme, but at this stage there are still many issues to resolve. These include baseline design, desired operational characteristics, missile numbers and type. In parallel, DAPA is working

Credit: US Navy

ROKS Gwanggaeto the Great (DDH 971) was the lead ship of a class of three KDX-I destroyers commissioned into the Republic of Korea Navy (ROKN) between 1998 and 2000. They went through a mid-life update process in 2020-2021.

on the development of a new surface and submarine-launched ballistic missile (SLBM) to act as a deterrent to North Korea. Obviously, progress on the missile programme will have a bearing on the evolution of the JFS programme.

Finally, HHI is under contract to DAPA and the ROKN to work on the new KDDX class destroyer. By the end of this year, the KDDX design should be finalised, allowing for the contract award for the first of this destroyer class in 2024. In total, six KDDX are required, and if standard ROKN practice is followed, two batches of three destroyers will be built. The KDDX will be equipped with an indigenous area air defence system, with other major armament and electronics systems being of ROK design and manufacture. The arrival of the KDDX will see the eventual phasing out of the KDX-I class destroyers, but the capabilities of the KDDX are far beyond those necessary for a simple KDX-I replacement. The intention is to have KDX-III like capabilities, using indigenous systems in a hull form with a smaller displacement. ■

The Republic of Korea Defence Industry – Achieving Global Prominence

David Saw

Since August 2022, the Republic of Korea (ROK) defence industry has clearly demonstrated that it has become a global player in defence industrial terms. The decision by Poland, a NATO member, in August 2022 to invest in a vast quantity of South Korean defence equipment ranging from advanced jet trainers to tanks, to self-propelled artillery and multiple rocket systems, is further proof that their industry is competitive globally and at the highest level.

Today the South Korean defence industry can justly point to its success in Europe, one of the most sophisticated and competitive global defence marketplaces, to demonstrate the variety of defence solutions it has on offer. More than that, South Korean industry can also point to the fact that it has a global footprint. Their customers can be found in Australia, Southeast Asia, India, the Middle East, Africa and South America.

In March this year, the Stockholm International Peace Research Institute (SIPRI) published a report entitled "Trends in International Arms Transfers, 2022". The SIPRI report classifies the ROK as ninth on a list of the top 25 largest exporters of major arms. According to SIPRI, between 2013 and 2017 the ROK had a market share in global defence exports of 1.3%. Between 2018 and 2022, SIPRI classify the ROK defence export market share as growing to 2.4%. This makes the growth in market share percentage between 2013-2017 and 2018-2022, a massive 74%! No country in the top 15 defence exporters increased their market share to such an extent according to SIPRI figures. Even more significant is that the SIPRI figures did not include the major contracts signed with Poland; had that been the case, then the position of the ROK in the league of global defence exporters would have undoubtedly been higher.

There was a time when the ROK authorities would point to the Israeli defence industry as their inspiration and comment that their ambition was to achieve a similar market share to that of Israel. In 2008, the ROK Defense Acquisition Program Administration (DAPA) suggested that the ROK and Israel would increasingly be regarded as competitors in defence export markets. This was at a moment when the ROK industry would reach USD 1 Bn in export sales for the first time, up from sales of USD 850 M in 2007. At that point in time, the capabilities of the Israeli defence industry far outstripped those of the ROK, indeed the ROK was a significant customer of Israeli defence technology. However, according to the SIPRI report on arms transfers, the South Korean defence industry has outstripped the Israeli industry in terms of export performance. Between 2013 and 2017, the Israeli share of global defence exports was 2.6%, but between 2018 and 2022, it had declined to 2.3%, a percentage decline of 15% according to the report. The SIPRI data has Israel as the tenth largest defence exporting country, with the ROK in ninth place.

In many respects, given that the ROK has been so successful in increasing its defence exports should not be a surprise. In terms of gross domestic product (GDP), the World Bank lists the ROK as the tenth largest economy in the world. Once seen as nothing more than a producer of low cost/low sophistication products, the scope and capabilities of the South Korean economy have been totally transformed. Brands such as KIA and Hyundai are now major players in the automotive sector. Likewise, Hyundai Heavy Industries (HHI) and Daewoo Shipbuilding & Marine Engineering (DSME) are dominant players at the high end of merchant shipbuilding. The ROK is a major producer of semiconductors and in Samsung, the country has a major player in consumer electronics and telephony. Moreover, the ROK has sold nuclear power stations to the United Arab Emirates (UAE) and even has a space programme focused on satellite launches. Clearly, the ROK is a highly sophisticated and diversified economy.

Credit: Polish MoD

One of the first batch of Hyundai Rotem K2 tanks supplied to Poland on a Polish Army training area in late March 2023. The decision of Poland to order 180 K2 tanks and then to build as many as 820 K2PL tanks in Poland is a major breakthrough for the Korean armoured vehicle industry.

Industrial Genesis

The fact is that today's highly sophisticated and diversified South Korean economy is an incredible achievement. Looking back to July 1953 and the Armistice that ended the Korean War (1950-1953), the territory

Credit: KAI

The first Korean aircraft to be exported was the KT-1 turboprop trainer. Export customers include Peru (shown here), Indonesia, Turkey and Senegal. The Republic of Korea Air Force (ROKAF) acquired 105 KT-1 aircraft, with export customers purchasing an additional 71.

of the ROK was essentially a wasteland. There was hardly any infrastructure left, although to be fair, there was not much infrastructure to start with in the south of the Korean peninsula. In the Japanese colonial era (1910-1945), the economic centre of Korea was in the north of the peninsula, within the territory of today's Democratic People's Republic of Korea (DPRK). It was here that the raw materials and the associated extractive industries, along with heavy industry, were located. In the south (ROK today), agriculture was the most important economic activity.

Even though DPRK territory had been devastated by the war, post-1953, economic aid and assistance from the Soviet bloc and China saw the DPRK recover quickly. The situation was totally different in the ROK, where a considerable amount of foreign aid was received, though much of this was wasted by the Syngman Rhee regime (first ROK president), arguably because his administration had no vision of the sort of economic structure that the ROK would need. Rhee had no option but to resign in April 1960, resulting in a period of chaos and in May 1961, there was a military coup led by General Park Chung Hee.

Park would become the third President of the ROK after he won the 1963 election. He would remain the dominant figure in South Korean politics until his assassination in October 1979. Undoubtedly, Park was a dictator, and his regime took a brutal line as regards dissent, yet it was the Park era that triggered the country's economic transformation and laid the foundation for what the ROK is today. The Park government encouraged foreign direct investment (FDI) which received a favourable response by both US and Japanese companies. The government also wanted to develop South Korean industry through the establishment of national champions. This led to the development of the 'Chaebol,' family-run conglomerates which would establish a large number of subsidiaries. Examples of Chaebol are Hyundai, Samsung, LG Group, Hanwha, Doosan and Hanjin.

The Park government would also play a critical role in the development of the South Korean defence industry, with the catalyst for this being a desire to upgrade the country's military capabilities and reduce dependence on the US. Equally as important was the belief that the acquisition of advanced defence technologies would then be applicable to the technological development of the broader national economy. This eventually led to the 'Yulgok Plan', which essentially saw the establishment of the defence industry in the 1970s.

In August 1970, the Agency for Defense Development (ADD) was established; its mission was to perform R&D related to defence and other high technology applications. In addition, the ADD was tasked with progressing the development of the national defence industry. The Chaebol would inevitably be drawn into helping to build the defence industry, but so would other South Korean companies. For example, the Poongsan Corporation was established in October 1968, and by the end of 1969 it had completed the Bupyung Brass Mill. In 1973, it had become an important defence player, with the completion of the Angang Ammunition Plant. Poongsan remains a key defence supplier to this day, being the primary ammunition supplier to the country's military.

Today and Tomorrow

From its roots in the 1970s, the South Korean defence industry would gradually evolve its capabilities in a systematic manner to the point where it could develop and produce highly sophisticated equipment for indigenous requirements and for export. An excellent example of this is how the aerospace segment developed from the 1980s onwards in terms of combat aircraft. It began with the signature of a contract for the local production of the Northrop F-5E/F in 1980 for the Republic of Korea Air Force (ROKAF). In total, 68 aircraft were delivered to ROKAF between 1982 and 1986. By the end of the 1980s, the ROK started work on two indigenous programmes, with the ADD leading the programmes and working with local industry. The first of these programmes was the KTX-1 turboprop trainer and the second was the KTX-2 advanced jet trainer. Both

Credit: KAI

The T-50/FA-50 family of advanced jet trainers and light combat aircraft has been a major success story for aerospace in Korea. Export customers include Indonesia (shown here), Iraq, Philippines, Thailand, Poland and Malaysia. Export sales amount to 138 aircraft, with Korea having 140 aircraft in service and 20 on order.

of these were logical programmes as they would replace large numbers of elderly US-supplied aircraft.
The KTX-1 conducted its maiden flight in 1991, with ROKAF ordering 85 KT-1 trainers and the 20 KA-1 light attack aircraft in 1999. Indonesia became the first export customer, eventually purchasing 17 aircraft; Turkey acquired 40 KT-1T, Peru 10 KT-1P and KA-1P aircraft, and Senegal acquired four KA-1S variants. In the case of Turkey and Peru, local assembly of the KT-1 was part of the contract. The KT-1/KA-1 would be the first military aircraft exported by the ROK.

Credit: KAI

The first KF-21 prototype flew in July 2022 and by the middle of this year six prototypes will be flying, with the test programme to continue to 2026. The Republic of Korea Air Force (ROKAF) is to acquire 120 KF-21, the Republic of Korea Navy (ROKN) is likely to acquire the aircraft for its new carrier and Indonesia is a partner in the programme.

The next stage in aircraft development would come through the medium of the Korean Fighter Program (KFP). In December 1989, the ROK announced it would acquire 120 F/A-18 aircraft for the KFP requirement. For various reasons, this acquisition never happened, instead the ROK decided on the Peace Bridge 2 programme under which they would acquire 80 F-16C Block 52 and 40 F-16D Block 52 aircraft. Lockheed Martin supplied 12 aircraft directly, with 36 aircraft assembled from kits in the ROK and the remaining 72 aircraft produced in the ROK. The first ROK-produced F-16C/D was delivered in June 1997 and the Peace Bridge II programme was complete in 2000. As a part of KFP, Lockheed Martin also provided assistance on the development of the KTX-2 programme.
At the end of the 1990s, the impact of the Asian financial crisis was also felt in the ROK. As a part of their recovery efforts, in 1999 the government helped to create Korea Aerospace Industries (KAI) as the national aerospace champion. KAI was built on the integration of the aerospace activities of Samsung, Hyundai and Daewoo. To sustain KAI, an order was placed for 15 F-16C Block 52 and five F-16D Block 52 aircraft under the Peace Bridge III programme, with deliveries taking place in 2003 to 2004.
In the meantime, the KTX-2 programme had reached its critical mass in 2002 with the first flight of the newly designated T-50 advanced jet trainer. The primary customer was ROKAF with the objective to replace elderly trainers such as the T-37 and the T-38, as well as the A-37 light attack aircraft. Four variants were developed for ROKAF: the T-50 advanced jet trainer; the T-50B version for the ROKAF Black Eagles aerobatic team; the TA-50 fighter lead-in trainer/light attack aircraft; and the FA-50 dedicated combat variant. ROKAF would order some 140 aircraft, with 20 remaining on order.
The aircraft would also prove highly successful in the export marketplace with Indonesia the first export customer, ordering 16 T-50i aircraft and then a second batch of six in 2021. Other customers included Iraq with 24 T-50IQ aircraft ordered, and the Philippines, with 12 FA-50PH aircraft. Thailand acquired an initial batch of 12 T-50TH and then ordered two more, all of which are combat capable. More recently, Poland ordered 12 FA-50 Block 10 aircraft due to be delivered later this year and 36 FA-50PL (based on the FA-50 Block 20) scheduled for delivery between 2025 and 2028. Lastly, in February it was announced that Malaysia had ordered 18 FA-50s for delivery from 2026.
In total, these acquisitions amount to some 298 T-50/FA-50 aircraft in service or on order, with the number of export aircraft roughly equivalent to aircraft ordered by the ROKAF. Obviously, there was dissatisfaction stemming from working with Lockheed Martin, which meant they were unable to win the US Air Force T-X trainer programme. However, the T-50/FA-50 has, and continues to be a successful programme for KAI and the ROK.
The next stage in the evolution of KAI and ROK combat aircraft is the KF-21 Boromae. The design, development and production of an advanced combat aircraft was the next logical step in the evolution of the ROK aerospace industry. The ROKAF requirement was for an aircraft to replace the last F-4E Phantom and F-5E/F aircraft in service; in total, the ROKAF envisages buying 120 KF-21 aircraft. With the apparent decision by the Republic of Korea Navy (ROKN) to increase the displacement of its future CVX aircraft carrier to accommodate the KF-21N, the naval variant of the aircraft, the number of KF-21 aircraft increase significantly, especially since the ROK is unlikely to stop at one carrier!
In an astute move, the ROK decided to find an international partner for the KF-21 programme, leading to Indonesia taking a 20% stake in the programme. Indonesia has had problems financing its workshare, but ultimately it is highly likely to procure in the region of 40 KF-21 for its air force. Reportedly, Poland has expressed an interest in the KF-21 and other T-50/FA-50 customers represent a strong potential market. The first KF-21 prototype flew on 19 July 2022, the second in November and the third in January 2023, at which point the KF-21 had made its first supersonic flight. The first two-seat prototype flew in February this year and two more prototypes will join the test programme by the middle of this year. The flight test programme is due to be completed in 2026.
Mention should also be made of another KAI programme that involves international collaboration. This is the MC-X transport aircraft programme, envisaged as a C-130 replacement capability. In January, a Memorandum of Understanding (MoU) was signed with the UAE covering the joint development of a 'multi-mission cargo aircraft,' the MC-X. The aircraft is due to be ready to enter service in the 2030s.
The story of how KAI became a global player is just one element within the broader theme of how the ROK became a major defence exporter. Mention should also be made of the Hyundai Rotem K2 tank programme, which achieved its first export order from Poland last year and whose technology provides the basis for the Turkish Altay tank programme. We could also mention submarine sales to Indonesia and frigate sales to the Philippines and Thailand. Suffice to say, the South Korean defence industry truly is a global player and fully intends to expand its market share. ■

Scandinavian Naval Procurement – Status Report

Conrad Waters

On 4 April 2023, Finland completed the final formalities needed to join NATO and became the alliance's 31st member. When considered alongside Sweden's pending application for membership, this historic moment marks another milestone in the broader Scandinavian region's strategic realignment that has followed the return of Russian 'adventurism'. This process of change is also evidenced in Scandinavia's accelerating process of naval renewal, which is steadily adapting to new realities in the Baltic and Norwegian Seas. However, maritime reorientation will inevitably be incremental in nature and take time to achieve. This article provides a status report on the naval programmes that are currently underway.

Finland

The lengthy timelines involved in naval acquisitions are visibly demonstrated by Finland's current flagship naval project, known as 'Squadron 2020'. This was formally launched in 2015 after several years of preliminary research and development. Its intention was to replace seven of the fleet's existing major combatants with a quartet of flexible, multi-role corvettes. These will be named the Pohjanmaa class after one of the vessels they will replace. The new construction was planned to run alongside a mid-life upgrade for the Finnish Navy's four existing Hamina class fast attack craft, which will share much equipment with the corvettes.

It is fair to say that implementation of the 'Squadron 2020' concept has not progressed as smoothly as was initially hoped. This is likely due to the challenges involved in developing an entirely new design to a demanding, multi-role requirement, as well as the need to refresh warship construction expertise at builder Rauma Marine Constructions (RMC) after a considerable gap. A contract for the class's assembly was signed with RMC in 2019 after some delay. This envisaged fabrication starting in 2022, the first corvette commencing trials in 2024 and all four ships being delivered by 2028.

Credit: Finnish Defence Forces

Finland's Pohjanmaa class corvette design has evolved significantly since these early graphics were released.

Although good progress was achieved in making key equipment selections for the new corvettes, it became increasingly apparent that there were problems in finalising detailed design and making a start on construction.

On 31 March 2023, the Finnish Navy released an update on the programme's sta-

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Credit: Saab AB

Acquisition of the A26 Blekinge class submarines currently dominates Swedish naval procurement.

tus. Reporting that the corvettes' design was nearing completion, it also announced a slight increase in length (119 m) and beam (16 m) over previous parameters. Displacement will be 4,300 tonnes. These changes were essentially adopted to improve stability and to add a margin to allow for increases in payload over the ships' service lives. With conclusion of the design process imminent, the navy was also able to provide an update in planned assembly. It is now intended to start fabrication in the autumn of 2023 and commence sea trials of the lead ship in 2026. The entire programme will be completed by the end of 2029. In effect, this amounts to a delay of around two years compared with previous plans. The programme is also experiencing material increases in its projected cost over an original estimate of EUR 1.3 Bn.

Despite these problems, the Pohjanmaa class will undoubtedly mark a step change in Finland's naval capabilities when they arrive at the end of the decade. In particular, they will make a significant contribution to the concept of 'unified naval striking power' articulated in the current 'Merivoimat 2032' (Navy 2032) operational plan. Notable equipment selections include IAI's 'Gabriel V' surface-to-surface and Raytheon's Evolved SeaSparrow Missile (ESSM) surface-to-air weapons. These provide a marked uplift in the capabilities installed aboard previous-generation ships. Importantly, the new vessels will also be larger and have improved sea-keeping qualities compared with their predecessors. This will enhance the navy's capacity to contribute to a wider range of NATO operations.

Meanwhile, much better progress has been achieved with the Hamina class mid-life modernisation, which has a strong anti-submarine warfare (ASW) emphasis. Work on FNS Pori, the fourth and final vessel to be upgraded under the project, was completed by lead-contractor Patria in September 2022. In addition to the 'Gabriel V', Saab's 9LV combat management system and Torped 47 ASW torpedo will be amongst systems shared with the corvettes. This will streamline logistical and training requirements.

Although there has been public speculation about Finland regaining a submarine arm – a capacity lost in the aftermath of the Second World War – this looks unlikely in the foreseeable future given the significant effort that will be required to bring 'Squadron 2020' into reality. Instead, other procurement is likely to be focused on less prestigious but still vital capabilities. For example, deliveries of a new series of 22-tonne 'Üto' class fast landing craft are currently underway from local builder Marine Alutech. Plans for replacement inshore minehunters are also well-advanced.

Sweden

Whilst the prospect of a Finnish submarine flotilla seems remote for the foreseeable future, the renewal of Sweden's underwater assets is currently the main focus of its own naval procurement plans. In similar fashion to 'Squadron 2020', these have a lengthy history that can be traced as far back as the 'U-båt 2000' (Submarine 2000) studies of the immediate post-Cold War era. The programme finally took tangible shape in 2015 when the Swedish Defence Materiel Administration (FMV) signed two linked contracts with Saab covering the modernisation of existing submarines and the construction of new boats.

The modernisation agreement initially focused on mid-life upgrades for two of the three existing A19 Gotland class. As well as ensuring the maintenance of an effective Swedish underwater arm, this was intended to de-risk the project for the new boats by overhauling the country's neglected submarine infrastructure and 'proving' much of the technology that would be used in their design. The SEK 2 Bn (EUR 180 M) upgrade appears to have gone largely to plan, being extended to cover the third member of the A19 class as a result of Sweden's current 'Totalförsvaret 2021-2025 (Total Defence 2021–2025) regime. A SEK 1 Bn (EUR 90 M) contract to undertake the work was signed with Saab in March 2022.

The contract for the new submarines is a much larger endeavour, amounting to SEK 7.6 Bn (EUR 670 M) when initially signed in 2015. It involved the construction of two A26 Blekinge class boats at the Saab Kockums shipyard in Karlskrona. Finalising the design proved to be problematic and FMV were obliged to contribute an additional SEK 5.2 Bn (EUR 460 M) in August 2021 to enable the project to proceed. A keel-laying ceremony for the first unit was subsequently held in June 2022. Current plans envisage the new submarines being delivered in 2027 and 2028, two years later than envisaged back in 2015. Although the new class has not got off to an entirely smooth start, it has provided Saab with the basis to develop a series of export designs, leaving it as a strong contender for the Dutch Walrus class replacement. Saab is also reportedly working on a 'U-båt 2030' concept to meet the need for an eventual replacement of the A19 design. The Swedish Navy reportedly hope to secure agreement to increase submarine numbers to a total of six boats by the 2030s, opening up the prospect of an extended production run.

Given the considerable effort being expended on re-equipping the submarine flotilla, current surface combatant programmes are largely focused on modernisation rather than construction of new ships. The mid-life modernisation of the navy's two Gävle class corvettes was completed with the return of HSwMS Sundsvall to the fleet in December 2022 after four years refurbishment at Karlskrona. This has allowed attention to turn to similar plans for the five-strong Visby class. FMV contracted Saab to commence project definition for the upgrade in early 2021. However, physi-

Credit: Saab Kockums/YPS Peter Neumann

The Swedish Navy will soon commence mid-life upgrades for its five-strong Visby class.

cal work has yet to commence. Overall objectives are to bring existing systems to the latest standard and add an anti-air warfare capability, which is currently lacking from the class. Project definition work is also underway on a follow-on YSF 2030 programme that will eventually lead to orders for four new larger surface combatants, two of which should be delivered before the end of the decade. The planned new vessels have been referred to as 'Visby Generation 2' corvettes. The intention is that they should make considerable use of the technology adopted for their predecessors' mid-life modernisation. However, recent press speculation suggests that much larger, frigate-like ships equipped for an area air-defence role are now being considered. In similar fashion to Finland's aspirations for their new Pohjanmaa class, it is hoped that the vessels will provide an enhanced capacity to contribute to future NATO maritime operations.

The approach being taken to modernising the navy's surface combatants is also reflected in that being adopted for the rest of the surface fleet. In the short-term, the effectiveness of the mine countermeasures (MCM) force will be assured by implementation of a life extension for the five existing members of the Koster class. This will ultimately be followed by acquisition of new MCM vessels a decade or more from now. In December 2022, Saab announced that it had received a SEK 350 M (EUR 31 M) contract to commence work modernising two Koster class vessels. The award also included a SEK 270 M (EUR 24 M) option for the upgrade of the remaining trio.

In the short term, the navy will benefit from the imminent delivery of the intelligence gathering ship HSwMS Artemis. Completion of the vessel was delayed by financial problems at the Polish shipyard that was sub-contracted to build the hull, requiring Saab's intervention. However, sea trials finally commenced in November 2022. Longer term projects include at least one new logistic support ship, as well as replacements for the renowned CB-90 series of assault craft. It also seems likely that dissatisfaction with the performance of the air force's maritime-roled NH-90 helicopters will result in their premature retirement. If so, Sikorsky's MH-60R Seahawk seems to be the most likely replacement.

Credit: Saab AB

Saab was awarded a SEK 350 M contract to commence work modernising two Koster class mine countermeasures vessels in December 2022.

Norway

Just as is the case for Sweden, Norway's current naval procurement is driven by the need to renew its submarine flotilla. The replacement of the Royal Norwegian Navy's existing six Type 210 Ula class submarines is being taken forward in conjunction with the German Navy under a EUR 5.5 Bn contract signed with tkMS in July 2021. The programme envisages the construction of six boats – four for Norway and an initial two for Germany – to a Type 212CD (Common Design) iteration of the

Credit: Forsvaret/Thomas Haraldsen

The Norwegian Type 210 submarine KNM Utvær pictured during the Arctic Dolphin 2023 exercise. Norway is replacing its Type 210 boats with the tkMS Type 212CD design.

existing Type 212A class. Work on the lead submarine, which is allocated to Norway, is anticipated to commence in 2023 prior to launch in 2027 and delivery in 2029. With subsequent deliveries extending into the middle of the 2030s, the Type 212CD programme will inevitably dominate Norway's naval acquisition spending for the foreseeable future. Although all the boats will be constructed in Germany, the acquisition will still be of significant benefit to Norwegian industry. Notably, Kongsberg has been contracted to provide a number of sonar systems for the new submarines and is developing their combat management system through the kta naval systems joint venture with Atlas Elektronik. Additionally, Germany has agreed to adopt Kongsberg's Naval Strike Missile as part of the broader industrial framework support in the deal.

Turning to Norway's surface fleet, the most immediate priority is the mid-life upgrade of the six Skjold class fast attack craft, referred to locally as coastal corvettes. In September 2020, Umoe Mandal (the class's builders) and Kongsberg announced that they would work in partnership to implement the project. Subsequently, in June 2022, Kongsberg announced that the Norwegian Defence Materiel Agency had awarded it a NOK 267 M (EUR 23 M) contract to upgrade the vessels' combat system. Once completed, the upgrade should allow the corvettes to serve well into the 2030s.

In the medium term, Norway will also need to make a decision on the future of its remaining quartet of Fridtjof Nansen class frigates (a fifth ship, KNM Helge Ingstad, was declared a constructive total loss after a collision and beaching in 2018). Although it appears a limited programme of ongoing improvement is planned, there has been speculation that the Royal Norwegian Navy is concerned about the class's suitability

Selected Scandinavian Naval Acquisition Programmes

Programme	Warship Type	Number	Programme Type	Status	Industry Lead
Finland					
Pohjanmaa (Squadron 2020)	Corvette	4	New-build	Contracted	Rauma Marine Constructions
Sweden					
A19 Gotland Mid-life Upgrade	Submarine	3	Modernisation	In Progress	Saab
A26 Blekinge	Submarine	2	New-build	In Progress	Saab
Koster Mid-life Upgrade	MCMV	Up to 5	Modernisation	Contracted	Saab
UB30	Submarine	Up to 4	New-build	Planned	Saab
Visby Mid-life Upgrade	Corvette	5	Modernisation	Planned	Saab
YSF 2030	Surface Combatant	4	New-build	Planned	Saab
Norway					
Type 212CD	Submarine	4 [1]	New-build	Contracted	tkMS
Skjold Mid-life Upgrade	FAC	6	Modernisation	Contracted	Umoe Mandal/ Kongsberg

Note [1]: Plus at least two additional Type 212CD submarines for the German Navy

Credit: Forsvaret/Stian Lysberg Solum

The Thetis class patrol frigate KDM Triton. Replacement of the four vessels of the class is likely to be a priority for Denmark's upcoming Defence Agreement.

for extensive modernisation given the demanding nature of their primary operating theatre close to Russian's 'bastion' in the High North. Any replacement would need to be a 'high end' ASW vessel, most likely based on an existing allied design. Participation in the British Type 26 or US Navy Constellation (FFG-62) class programmes would appear to offer potential routes forward. Interestingly, Umoe Mandal already provides parts of the superstructure for the Type 26 design.

Norway is also in the course of acquiring new naval aviation assets that will further enhance its overall ASW potential. Notably, the government's June 2022 decision to terminate its acquisition of the NH90 helicopter and seek reimbursement of the NOK 5 Bn paid under the contract resulted in an urgent need to acquire a replacement shipboard rotorcraft. In March 2023, it was announced that six MH-60R Seahawk would be purchased from Lockheed Martin to fill the gap at a cost of NOK 12 Bn (EUR 1 Bn). Deliveries are scheduled for between 2025 and 2027. Training Norwegian air crew on the new helicopters will be facilitated by fellow Scandinavian NATO partner Denmark, which has operated the MH-60R since 2016. The Royal Norwegian Air Force has already taken possession of five Boeing P-8A Poseidon maritime patrol aircraft under a contract valued at approximately NOK 10 Bn (EUR 860 M) that was signed in November 2017. They were all delivered between 2021 and 2022 and will replace the country's existing inventory of P-3 Orion and DA-20 Falcon types.

Denmark

Of all the Scandinavian countries considered in this report, Denmark's future naval procurement plans are the least advanced. However, it appears that a major new phase of investment in surface warships is imminent. In August 2022, the Danish Ministry of Defence stated that an investment of up to DKK 40 Bn (EUR 5.4 Bn) was envisaged in the years ahead as part of an announcement launching a new national partnership in the maritime sector. Stating that "Denmark must be capable of building its own warships", the announcement laid out aspirations to rebuild the skills to design, construct and maintain the new fleet. The partnership follows a public-private sector model encompassing representatives from government agencies, industry, finance and the trade unions.

Further clarity on the likely shape of the new construction programme is likely to emerge after conclusion of political negotiations to replace Denmark's current 2018-2023 Defence Agreement. Recent ministerial statements suggest that security in the Arctic and North Atlantic are likely to be key areas of focus in the replacement document. This inevitably bolsters expectations for a renewed phase of significant naval investment. A likely priority is the replacement of the existing four Thetis class patrol frigates. Optimised for deployments in Danish waters around Greenland and the Faroe Islands, these vessels first entered service in the early 1990s. Accordingly, they are now approaching life-expiry. Recent press speculation suggest that they will be replaced by a new frigate class, probably on a like-for-like numerical basis. Any programme will likely require considerable investment in industrial infrastructure given the 2012 closure of the giant Odense Steel Shipyard that assembled the previous Absalon and Iver Huitfeldt classes. In the meantime, the two Absalon class frigates are to receive upgrades to their ASW capabilities under a programme that is expected to be concluded in 2026.

Conclusion

This brief overview of Scandinavian naval procurement highlights the considerable efforts that are being made to rebuild the region's maritime capabilities after a considerable period of post-Cold War neglect. However, it is clear that this endeavour will not be a straightforward one. Many of the programmes discussed date from many years before Russia's 2022 invasion of Ukraine. However, it is unlikely to be much before the end of the current decade before the capabilities that they promise will be delivered. The further enhancements that have been driven by the more recent decline in East-West relations are even further away on the horizon. A notable feature of current programmes is the extent of the challenge posed by the need to rebuild the naval industrial base. The situation is a further illustration of the difficulties of regaining lost capacity once it has been abandoned. ■

Sweden's Path to Transformation and Integration with NATO

General Micael Bydén

The Swedish Armed Forces have undergone significant transformations over the past year and a half. These transformations have been propelled by several factors, most notably the full-scale Russian invasion of Ukraine in February 2022, Russia's continuous menacing rhetoric and security demands towards the West, the substantial assistance Sweden provides to Ukraine, and our application in May 2022 to join NATO. In this article, I provide an overview of how these factors are changing the present and, more importantly, shaping the future of the Swedish Armed Forces.

Credit: Försvarsmakten

General Micael Bydén has been the Supreme Commander of the Swedish Armed Forces since 11 September 2015. Prior to this, Bydén served as the Chief of the Air Force.

The unprovoked armed Russian aggression in Ukraine, which commenced on February 24 last year, reintroduced large-scale warfare to Europe and the inevitable suffering, death, and destruction it entails.

Since day one, the world has witnessed remarkable Ukrainian resistance. On numerous occasions, I have expressed my professional admiration for the skill, discipline, and endurance of the Ukrainian Armed Forces, and how profoundly impressed I am by the courage and strong sense of duty exhibited by the entire Ukrainian population.

The Russian aggression in Ukraine has served as a stark reminder of the importance of standing up for what is worth defending. Russia's disregard for human suffering, international law, and its long-term ambition to break Ukrainian resistance necessitate a robust response from Sweden and the Western community.

Regarding our continuous, unwavering support for Ukraine, Sweden has been an integral part of the unified response from the EU and NATO, as well as from numerous partner countries worldwide, since the onset of the Russian invasion

We have provided substantial aid, including heavy weapons and training, to the Ukrainian Armed Forces, and we will continue to do so. I take great pride in the pivotal role my organisation has played, and will continue to play, in the efforts to provide Ukraine with this support.

The significantly deteriorated security situation in Europe has led the Swedish Armed Forces to continually adapt and strengthen their readiness and defence posture. Regular joint activities have been conducted with key partners.

A notable example is the capstone exercise, AURORA 23, which we conducted this spring. It stands as the largest national exercise of its kind in over 25 years, encompassing air, ground, and sea operations. Swedish soldiers and seamen trained alongside colleagues from 14 partner countries.

In May 2022, Sweden submitted its application for NATO membership. From a military strategic standpoint, it was the correct course of action, something I made very clear in my military advice to the government during the intense national consultations preceding the decision. In an increasingly uncertain world, strength lies in unity.

Credit: SAAB

SAAB's Next-generation Light Anti-tank Weapon (NLAW) was noted to have performed well against Russian armour, which was employed at scale during the initial phase of the invasion.

Russia has unequivocally demonstrated, through its actions in Georgia, Syria, and in Ukraine since 2014, its willingness to employ military force to achieve its objectives. Moreover, the threat posed by terrorist groups, a threat that transcends borders, persists.

Together, we can confront these challenges. Sweden's future inclusion in NATO will mark a historic moment, as it will be the first time since 1814 that we join a military alliance. By acting alongside our allies, our objective will be to deter further acts of aggression by Russia in Europe.

Naturally, Sweden will contribute to NATO operations both within NATO territory and out of area. We wholeheartedly embrace the 360° perspective, including continued contributions to NATO Crisis Management Operations.

Considerable efforts are currently underway within the Swedish Armed Forces to gradually integrate Sweden into NATO on a military level. It is a process that demands hard work and prudent choices, and it is progressing remarkably well.

To initiate our NATO integration, a set of prioritised capabilities has been identified. Three of the most crucial priorities include joining the collective integrated air and missile defence, establishing interoperable communication and information systems between Sweden and NATO, and developing robust Host Nation Support capabilities.

Credit: BAE Systems

The CV90 family is in wide use with many European NATO member states, as well as Switzerland.

Thanks to the hard work being conducted in the military integration process, Sweden will be prepared to shoulder the responsibilities that come with NATO membership. We will contribute to the core responsibilities of the alliance: deterrence and defence, preventing crises and handling the crises that arise, as well as security cooperation.

As President of the European Union during the first half of 2023, Sweden has been fully committed to the EU and its priorities of security, resilience, prosperity, democratic values, and the rule of law. The Russian invasion of Ukraine has significantly influenced the Presidency, with support for Ukraine and intensifying collective pressure on Russia through sanctions ranking as top priorities. The current security environment underscores the need to strengthen the EU as a more assertive actor in security and defence, assuming greater responsibility for its own security.

Furthermore, maintaining European and transatlantic unity is crucial as we

Credit: BAE Systems

The Archer from BAE Systems Bofors is a modern and highly capable example of a self-propelled howitzer.

Credit: SAAB

The Ground-Launched Small Diameter Bomb (GLSDB) was co-developed by Boeing and SAAB. The weapon is now in use with Ukraine, providing its armed forces with another critical long-range precision strike option.

confront the common challenges posed by Russia's use of military force and the persistent threat of terrorist groups. Strengthening partnerships, particularly EU-NATO cooperation and strategic alliances with key nations, is pivotal for collective defence and security in Europe.

Joining NATO does not entail outsourcing the responsibility for our national defence. Quite the contrary. To fulfil Article III of the Washington treaty in a credible way is a top priority for Sweden.

Ensuring strong national defence and resilience within our society will be a significant contribution to NATO's deterrence. That is what individually, and together with allies, deters an aggressor from attacking us.

As part of this commitment, we are making substantial investments in bolstering both our national military defence and civil defence. The Swedish Armed Forces have experienced substantial growth since 2015, with further aspirations to reach a defence spending level of 2% of GDP as soon as possible.

With this growth comes great responsibility, and I will play my part in ensuring that every Swedish krona invested in defence yields a heightened operational capacity.

Accelerated growth requires close collaboration with relevant agencies and industries. By working together, we can deliver a stronger national defence, a more secure neighbourhood, and ultimately, a stronger NATO.

Credit: SAAB

The latest variant of the Gripen family, the Gripen E, shown here in Winter colours.

As General Cavoli, SACEUR, emphasised in his speech at the Sälen Security Conference in early 2023: "A healthy and elastic defence industrial base is just as important to NATO's deterrence and defence as military forces standing ready." This fact is clearly underscored by the events unfolding in the war in Ukraine.

The unpredictable and increasingly complex security situation demands continual adaptation of readiness and the upholding of adequate and credible defence capabilities, both individually and in collaboration with allies. This imperative holds true in the present and will continue to be of utmost importance in the years to come. The Swedish Armed Forces must be prepared to defend Sweden today, in ten years, and in fifty years.

Enhancing military capability is a time-consuming endeavor that calls for concerted effort and with a constant glance at the future. Embracing new technologies is pivotal; they must be adopted, integrated, and mastered. In this regard, our close cooperation with The Swedish Defence Material Administration (FMV), the Swedish Defence Research Agency (FOI), and the strong Swedish defence industry remains indispensable.

These are among the critical topics presently under discussion in the Swedish Defence Commission, a forum for consultations between the Government and representatives of political parties with the aim of achieving broad consensus on Sweden's long-term defence and security policies.

Given the many changes and challenges facing Sweden, many of which I have described above, the Commission has recently recommended advancing the adoption of the next Swedish defence bill by one year, to 2025 instead of 2026. The next defence bill will set the frames for the development of the Swedish total defence up until 2030 with an outlook up to 2035.

A final remark – the Russian invasion of Ukraine will go down in history as an example of the worst actions the human race is capable of. Simultaneously, dark and challenging times can also unite us. And there are flickers of hope, particularly when we witness the steadfast Ukrainian resistance and their remarkable courage. This serves as a great source of hope, as does the strong and unified Western response to the Russian challenge. ■

The FMV – Pushing Forward Sweden's Defence Procurement Projects

Credit: FMV

Lieutenant General Göran Mårtensson.

With Europe exposed to war on its doorstep once again, and the NATO alliance continuing to face some internal political opposition with regard to the accession of its newest candidates, the modern European security environment is a challenging one to say the least. In May 2023, ESD interviewed Lieutenant General Göran Mårtensson, Director General of the FMV, the Swedish Defence Materiel Administration. The interview was conducted by Mark Cazalet.

ESD: Can you briefly elaborate on the role, organisation and duties of the FMV?
Mårtensson: The Swedish Defence Material Administration, FMV, is a governmental agency acting under the Ministry of Defence. FMV procures equipment and logistics services for the Swedish Armed Forces. Our technical, commercial, military and legal expertise, as well as our expertise in project management, ensures that we deliver sustainable solutions over time. As Sweden is strengthening its military capacity FMV are seeing an increase in operations. Last year, 2022, orders to the industry doubled compared to the previous year and amounted to SEK 36.4 billion. With the political ambition to increase Sweden's defence spending to 2% of GDP, the FMV's turnover will increase from today's SEK 28 Bn to approximately SEK 50 Bn in 2026.

ESD: With respect to Research and Development, what share of these efforts is typically undertaken by the FMV with respect to new domestic requirements?
Mårtensson: At present, the Swedish Armed Forces and FMV are strongly focused on the procurement of what is needed today, but we must not underestimate the importance of R&D and more long-term capability needs. The FMV is responsible for technology development while the Swedish Defence Research Agency (FOI) conducts the more research-oriented tasks. In a difference to the FOI, the FMV does not perform the R&D itself but procures it from industry, institutes and academia. Due to the current international situation and the Swedish NATO membership application, we see a significant increase in the R&D funding in the coming decade and the process of planning and prioritising how to use the growing funds is ongoing. It is important to adequately balance strengthening our R&D in classical technology areas with the exploration of new technologies that may affect our military capability disruptively. This requires efficient ways to integrate the fast civil technology development in our materiel development. The current international situation also leads to a renewed emphasis on access to materials and technologies where the supply chains need to be under control. This perspective will impact both what R&D we do and how we do it in the coming years.

ESD: What are the key requirements for developing Sweden's military potential that still lie ahead?
Mårtensson: Within FMV's area of responsibility, we see several important factors for developing the Swedish Armed Forces capabilities according to the current political direction. Replacement of equipment sent to Ukraine must be done urgently. We must be given the conditions to place orders for equipment early in order to be able to get deliveries on time. We need to take into account the industry's production capacity and ability to deliver materials. We need to have fewer specific national requirements when we procure equipment, alone or in cooperation with other countries. In conclusion, the time factor must have a greater impact when we acquire equipment.

Credit: BAE Systems

Sweden's CV90-based Granatkastarpansarbandvagn 90 (Grkpbv 90), armed with two muzzle-loaded 120 mm Mortars.

ESD: Which of your current procurement programmes are being carried out in partnership with other national or multinational procurement organisations?

Mårtensson: FMV has a large number of projects carried out in partnership with other countries.

- Sweden is lead nation for the joint procurement of the BvS10 from BAE Systems within the CATV (Collaborative All-Terrain Vehicle) programme, which includes Germany and the United Kingdom.
- FMV recently placed an order for 20 armoured vehicles from Finnish Patria within the framework of the CAVS project, Common Armoured Vehicle System, which is a collaboration between Sweden, Finland, Latvia and Germany.
- On 18 April, Sweden and France signed a framework agreement to cooperate on a new anti-tank system, Akeron MP.
- Together with Denmark, Finland and Norway, Sweden is procuring a new combat uniform system within the NCU project (Nordic Combat Uniform) which is part of NORDEFCO.
- Sweden has a cooperation (LoI) with the Netherlands in the area of very long range radars (Ballistic Missile Defence radars). The cooperation includes amongst other things security of supply, education, future industrial cooperation and joint development of BMD radars.

Credit: SAAB

CG render of an RBS15 Gungnir anti-ship missile.

ESD: How has Swedish domestic industry had to adapt or develop to meet key domestic requirements over the past decade?

Mårtensson: Swedish defence industrial capabilities and capacity is an integral part of the Swedish defence. The state has no shareholder interest in defence industry but due to defence procurements and cooperation related to specific national security requirements the industry has adapted its portfolios over the years. Developing cutting edge technology as a result of domestic orders the industry has done very well exporting a wide variety of products on the global market as well. From grenade launchers, to armoured vehicles and aero fighters. Sweden proud itself as being one of the few countries in the world with an industry that produces aero fighters, military vehicles and submarines by themselves.

Credit: Austrian MoD

A Bv410 in use with the Austrian 6th Mountain Brigade. The Bv410 is to form the basis of the Collaborative All-Terrain Vehicle (CATV) programme.

Growing both organically and through mergers and acquisitions, the industry has been able to expand enough to meet the Swedish defence requirements of having suppliers that can take full system responsibility for those platforms that are coupled with national security requirements. There is also an aspect of security of supply here that cannot be understated.

ESD: To what extent has Sweden's domestic industry been supported through government policy, for instance through skills development programmes?
Mårtensson: I think that the word 'support' is the wrong word here. Sweden treats regulations regarding unauthorised state aid very seriously. Although single source procurements within the limits of procurement regulations occur we are very careful to not give any national tenderers any improper advantages. That said, Sweden, as other countries with a vital national defence industry, has a need to utilise the industry´s prowess to foster innovation. Defence innovation is one of the foundations of future capabilities. We do this in a number of ways. One being through national procurement programs of larger platforms with specific national security requirements discussed in the previous questions. In addition, commonly, FMV orders studies and research as a mean to foster both new ideas and prototypes of new technologies. Both from industry and state actors such as the Swedish Defence Research Agency (FOI). The years of budget restraints within defence sculpted a structure in which the Swedish defence saw great value in maintaining a defence industry capable of producing necessary capabilities even during challenging economic conditions. Resulting in cost-effective materiel that still had a satisfactory technological edge. The industry, of course, should be lauded for being able to find solutions that fit both technological and economic prerequisites.

ESD: How have Swedish defence modernisation priorities been impacted by the war in Ukraine and the country's progress toward NATO accession? As Sweden joins the alliance, do you expect any major changes to procurement priorities? For instance, more equipment aimed at providing coverage of the Baltic Sea or support for Arctic operations.
Mårtensson: Political work is currently underway to develop a new political direction for Sweden's military and civil defence. The new focus will be brought forward in time as a result of Russia's war against Ukraine. At the same time, the defence authorities are implementing the direction of the latest defence decision from 2020, before Sweden's application to NATO. Swedish membership in NATO will have an impact on the Swedish Armed Forces and its capabilities, but to what extent is too early to say. However, the government has said that Sweden will join the European Sky Shield Initiative. It is assumed to have an impact on the development of future capabilities.

ESD: Ukraine has served as a great reminder of the importance of maintaining a reliable supply of ammunition. Have Sweden's recent procurement priorities or practices been impacted by this lesson?
Mårtensson: The ongoing war have foremost made us change our mindset from 'just in time delivery' to a much more long-term view on sustainment of delivery. To do this we have, as an example, added economy and reviewed the way that we form our contracts.

ESD: With Sweden seemingly deciding not to pursue the Tempest programme, what are the country's future plans with respect to developing a sixth-generation fighter capability? Given Sweden's fighter aircraft design heritage, is flying solo an option the FMV is considering?
Mårtensson: Sweden will, pending governmental decision, launch a national combat air project with the purpose of creating a decision roadmap for future combat air solutions. The outcome will then be subject to a decision by the Swedish government. Those solutions can be the following:
a) Continued national development
b) International cooperation
c) Acquisition of an already developed system

Credit: SAAB

Gripen E fighter in flight.

Swedish Defence-Industrial Capabilities Shine Bright

Robert Limmergård and Jonathan Lindqvist

The Swedish Security and Defence Industry Association (SOFF) represents enterprises with security and defence equipment and services in Sweden. SOFF currently has 180 member companies of which 100 SME's – ranging from one-man businesses to major national defence contractors. Whereas the enterprises have approximately 30,000 employees, the subcontractor level employs even more people.

The SOFF cooperates with corresponding organisations in other countries and are a member of ASD (AeroSpace and Defence Association in Europe), NIAG/PfP (NATO Industrial Advisory Group/Partnership for Peace) while having several collaboration agreements with associations in other countries.
The purpose of the SOFF is to create the best possible preconditions for member companies to operate in Sweden and enhance their market accessibility and capacity to trade. In essence this entails two courses of action: long-term effort in addressing market access and trading conditions; working with upcoming promotional processes and activities.
In the short run, the SOFF's most important issue is ensuring a level playing field for enterprises in Sweden to export and collaborate on the international market. Included is reinforcing the understanding of the contribution made and importance the enterprises have for Sweden's defence capability, whilst enhancing research and innovation activities.

Credit: SOFF

Robert Limmergård, the General Secretary of SOFF.

Introduction

For several years, Europe has experienced a deteriorating security situation in its eastern neighbourhood. Russian aggression towards Ukraine and the Western states has increased dramatically, reaching its culmination when launching a full-scale military invasion of Ukraine in February 2022. Europe is once again experiencing war within its vicinity and states are drastically ramping up their defence expenditure. Sweden, with its proximity to the conflict, is responding with rapid decisions for increasing its defence expenditure and applying for NATO membership. Consequently, the defence-industrial base constitutes an increasingly important component of Sweden's – and its international allies' – defensive capability against aggressors.

In the context of Sweden's political interests and exports, Sweden has since the outbreak of the Ukrainian war in 2022, assisted Ukraine with various forms of military material support. The Swedish defence industrial base shows its widespread support through exporting systems and capabilities that have great operational impact. With world-class defence equipment, the Swedish defence industry is a key player in the international are-

Key facts

2021 Statistics

Turnover:	SEK 48 Bn
Export Value:	70% of Turnover
R&D Value:	15.4% of Turnover
Companies, authorities, private persons (manufacturing or supply license):	331
Five biggest enterprises (invoiced military equipment within and outside the country):	Saab AB (SEK 19.4 Bn); Saab Dynamics AB (SEK 3.5 Bn); Saab Kockums AB (SEK 2.3 Bn); FMV (SEK 1.67 Bn); BAE Systems Hägglunds AB (SEK 1.57 Bn).
Export Value to Major Countries	United Arab Emirates (SEK 7.5 Bn); USA (SEK 2.94 Bn); Brazil (SEK 2.2 Bn).

Credit: SAAB

The NLAW has proven itself to be a highly-effective anti-armour weapon in Ukraine.

na, as well as something one can count on in demanding times. Moreover, in comparison to other countries, another central aspect that makes the Swedish defence-industrial base stand out is the lack of government-owned companies. Thus, advanced military equipment is developed through competent and competitive domestic market. Accordingly, this article continues with delving into Sweden's defence industrial base.

Export

The fundamental aspects of the Swedish defence industry emerged during the Cold War with the ambition to be independent from foreign suppliers, making domestic defence industry vital for national defence policy. After its end, there has been an increased need for material cooperation with like-minded allies. Contemporary perspectives on export of defence products are different, and Sweden is nowadays dependent on deliveries of components and systems from other countries.

Furthermore, exports within the defence industry are separated and different from the civilian market for goods. Exports of defence equipment have a close political connection while being qualitatively controlled and regulated. Moreover, there is also a close connection to Sweden's defence, foreign, and security policy. In that sense, it acts as a focal point between politics, law, trade, and industry.

While exporting has a direct effect on Sweden's defence capability, it simultaneously creates trading partners that ensure security of supply, and enterprises develop new competence and skills through international cooperative projects.

As a token of its importance, the latest data indicates that invoiced and delivered military equipment within and outside Sweden has steadily increased over the years between 2017-2021. Despite the large number of supplying and manufacturing enterprises, only a handful account for most sales. The Saab group being the largest enterprise, with its export of fighter jets (JAS 39 Gripen), missiles, and ground combat weapons (NLAW, AT4, Carl-Gustaf M4), and naval surface/underwater vessels (Submarines, Visby-class corvette, Combat boat CB90). BAE Systems Hägglunds with armoured vehicles (CV90) and Bofors with artillery systems (Archer) are also key enterprises for Swedish exports.

The major export market is within the Nordic countries. This is followed by other parts of Europe, however Asia and the Middle East, as well as north America are becoming increasingly important. Accordingly, the Swedish defence industry possess and manufactures advanced technological capabilities that are internationally recognised and highly coveted.

Research and Development

Innovation starts with ideas and knowledge. To support it, Sweden has the most PhDs in the world per capita, in technical and natural-science subjects and the second-most who work in this area. Sweden also tends to score well in international comparative surveys on innovation. For the defence industry, this emphasises the importance of engagement with the commercial sector. In this regard, Sweden has a rather unique industrial landscape.

No other country of a similar size, possibly with the exceptions of Switzerland and Israel, has so many large high-tech multinational companies. ABB, Atlas Copco, Electrolux, Ericsson, Saab, Scania, Securitas, SKF and Volvo are cases in point. The resource limitations that come from being a small country has led us to work very closely within the Triple Helix model where industry, academia and government agencies work hand in hand on cost-efficient innovation models. Within this Triple Helix, there is intensive collaboration on the technologies connected to artificial intelligence, robotics, Big Data and the Internet of Things.

Credit: SAAB

Top view of a Brazilian Air Force Gripen E Fighter.

Credit: SAAB

GlobalEye airborne early warning & control (AEW&C) Aircraft, equipped with SAAB's Erieye Extended Range (ER) Radar.

Credit: BAE Systems

The CV90 Mk IV is the most recent major family variant to emerge from BAE Systems Hägglunds' CV90 infantry fighting vehicle family. The family has been in a state of continuous evolution ever since its inception.

The Swedish defence industry covers multifaceted system platforms in all domains. Besides providing technological advanced capabilities of fighter jets, naval vessels, submarines, and land platforms, numerous subsystems are also provided. This entails IT systems, intelligent ammunition, sensors, cryptography, as well as niche products and services. Consequently, the defence-industrial base is exceptionally research-intensive, with Sweden a world leader in certain areas. Some of the aforementioned areas – such as fighter jets, naval underwater vessels, sensors, and cryptography – are of particular importance in relation to vital national security interests for Sweden. The purpose of this is ultimately to maintain freedom of action in its security policy and avoid dependence on other countries in strategically important areas for Sweden.

Furthermore, aligned with the year 2021 statistics, 15.4% of the combined annual turnover of SEK 48 Bn is reinvested into R&D, qualifying the defence-industrial base as one of the most research-intensive technology sectors.

Through having a research-intensive defence-industrial approach, Sweden not only has state-of-the-art advanced technological capabilities within its Armed Forces, but also has a competitive technological level on the international arena. Therefore, Sweden continuously remains an interesting and highly skilled country for bilateral and multilateral cooperation on various projects. Simultaneously, it provides better opportunities for Sweden to influence international export control cooperation.

International Cooperation

After a gradual departure from a closed domestic focus during the Cold War, to utilising an open and international approach as of today, large part of Sweden's defence capability rests upon bilateral and multilateral cooperation with like-minded partners. This is one reason why the defence industry market is highly internationalised with a great scope of internationally-owned enterprises.

Moreover, cost-efficiency has been a critical mission from the very start for the Swedish security and defence industrial base. It has for many decades been used to working with a relatively small client in the Swedish Armed Forces. This has created a system with exceptionally integrated project teams from industry, government agencies and academia which have strived to find efficient and cost-effective solutions. Innovative thinking, highly skilled engineers, a strong science and technology base, as well as expanding international cooperation have assured the accomplishment of Sweden's industrial base.

Furthermore, Sweden has long-lasting bilateral defence cooperation with Finland, but also through the Nordic cooperation, NORDEFCO. Other close partners are the Baltic states, the US, the UK, France, and Germany.

Multilateral cooperation is grounded in various initiatives within the EU, such as EDF (European Defence Fund), CARD (Coordinated Annual Review on Defence), and PESCO (Permanent Structured Cooperation). Other cooperations includes JEF (Joint Expeditionary Force), NATO/PfP, and OSCE (Organization for Security and Co-operation in Europe). Going forward, cooperation within NATO is expected to further increase since Sweden applied for NATO membership in May 2022.

Technology Contributions

The Swedish defence industry excels in multiple domains and offers advanced technological contributions. What follows are some examples of prominent products provided by the major enterprises of the defence industrial base.

In the air domain, the Gripen series of fighter jets excels in various roles, with its latest model being the Gripen E. With emphasis on advanced Human Machine Collaboration and AI, Gripen E is designed to achieve air superiority in highly contested environments and defeat any adversary. Besides having a key part in Sweden's Airforce, Brazil; Thailand; Hungary; and Czech Republic are partners who have adopted the Gripen series into their armed forces. Moreover, GlobalEye AEW&C (Airborne Early Warning & Control) is a prominent air surveillance system and the only one on the market providing real time long-range air, sea, and land surveillance from a single platform.

In the naval domain, Sweden stands out with its Visby class corvettes that are world leading in signature reduction across the whole spectrum, while having both speed and fighting power. Submarines are also a leading technology on the market whereof seven classes have been delivered across three continents.

In the land domain, prominent weapon systems provided are RBS 70 NG (ground-based air defence missile system), AT4, NLAW, and Carl-Gustaf system. Moreover, recognised ground vehicles include the CV90 infantry fighting vehicle, and the Archer, a mobile artillery system that can fire six rounds, displace, and move 500 m in less than two minutes.

Sweden also has key competences in fields such as 5G/6G; artificial intelligence and machine learning (technologies can be used for predictive analytics, autonomous systems, and data processing); cybersecurity; autonomous systems (such as for drones or unmanned ground vehicles); hypersonic propulsion; directed energy (lasers and high-powered microwaves); quantum computing (for decrypting codes and modelling complex systems); graphene (for decreased signature, visual information). In addition to all the above, the Swedish defence industry also consists of high-tech SMEs that produce and delivers highly-specialised products across various domains.

Credit: SAAB

Blekinge-class (A26) Submarine, presently under construction for the Swedish Navy.

Looking Ahead

The security situation today has deteriorated dramatically internationally. From Sweden's perspective, Russia's willingness to use military force is of great concern. Consequently, focusing on national defence capabilities is once again a major priority, and thus increasing its defence expenditures while applying for NATO membership. The Swedish defence industry has always been, and will continue to be, a key actor to provide highly advanced defence systems and capabilities that can withstand any aggressor. This is enabled by having an internationalised, competitive, and co-operative market, allowing enterprises to develop state-of-the art military equipment, while being a reliable partner and supplier for customers around the world. ■

The German Navy Turns 175

Irina Haesler

With the German Navy celebrating its 175th anniversary on 14 June 2023, it is worth taking the opportunity to reflect on the Navy's continuing role in Germany's security and prosperity. In this vein, Irina Haesler of the German Shipowner's Association (VDR) examines the relationship between Germany's Navy and its merchant shipping, making the case for increased cooperation between the two.

"A good Navy is not a provocation to war. It is the surest guarantee of peace." These famous words spoken by US President Theodore Roosevelt to the US Congress on 2 December 1902 could not be more relevant today. Peace is the basic prerequisite for our present and future prosperity. Guaranteeing this permanently and sustainably requires freedom and security. When it comes to the maritime dimension of German security, there is no way around the German Navy. For it is the German Navy that secures sea routes and literally 'clears the way' for the German merchant fleet so that it can fulfil its obligations, and reliably bring goods or raw materials to their destinations.

After all, shipping dominates global trade flows, accounting for 90% of all goods transported with an annual volume of 11 billion tonnes of goods, worth USD 15 Tn. Germany is one of the most important shipping nations in the world. It is from here that the world's largest container ship fleet and the seventh-largest merchant fleet in the world are currently operated. In terms of the container ship fleet, Germany ranks ahead of China in terms of the number of container ships operated. German merchant shipping is urgently dependent on a strong navy. Only with a sufficient presence and sufficient resources is it possible for the navy to be active worldwide in order to protect the sea routes essential for merchant shipping. A strong navy is therefore in the best interests of German shipowners. In Germany, shipping has a relatively unique character – more than three quarters of the resident shipping companies own only 10 or fewer ships. Many of these companies are family-run and deeply rooted in the location. These companies were the backbone of the sector during the shipping crisis that lasted more than 10 years. A sector that had previously been significantly weakened has fortunately been able to regain stability in the last two years and align itself to face the future. As the world's third-largest import

Credit: Bundeswehr/Nico Theska

The Emden (F266) during her commissioning ceremony on 4 May 2023. The Emden is the second vessel of the second construction batch of the Braunschweig class (Type 130) corvettes.

Author

Irina Haesler is a lawyer and became a member of the executive board of the German Shipowners' Association (VDR) in September 2022. Since 2013 she has been based in Brussels, and responsible for working on the VDR's EU and security policies.

Credit: Damen

CG render of Germany's F126 future frigate class, set to replace the Brandenburg class in German Navy service.

and export country, the merchant fleet plays a key role in supplying the population with imports and in Germany's economic success through exports by sea. This leading role must now be further expanded. The German navy and merchant fleet are thus undoubtedly closely related. Together they play a decisive role in shaping the maritime dimension that is so important for Germany.

Russia's invasion of Ukraine on 24 February 2022 violated international law, and has confronted us all with a new reality, disrupting the geopolitical order and leading to a re-examination of security issues. Threat scenarios that were thought to be over since the end of the Cold War must now be reassessed and Germany must develop its new leadership role in Europe and the world. Maritime sovereignty is the core of a new national resilience strategy. The goal of maritime sovereignty is to ensure that Germany is supplied and secured with goods and energy as sustainably as possible, even in the event of a crisis. Maritime sovereignty must therefore not be reactive – structures and processes must be created proactively and for the long term. For Germany, the best preparation for changing supply needs and future crises is to further strengthen its merchant fleet and its leading role as a maritime nation. This requires strengthening both the navy and merchant shipping. Together, these not only provide Germany with access to secure sea routes and thus a reliable connection to international trade, but the transition to clean energy also depends significantly on functioning global supply chains in the procurement of raw materials needed for the energy transition, such as nickel, aluminium, palladium or rare earths. In order to avoid dependency on certain countries and regions, diversification of supply chains is necessary. Due to their international orientation, German shipping companies can serve these at any time. Maritime resilience undoubtedly requires transformative approaches in a constantly changing environment in the future. However, this also requires shipping companies to have a reliable shipping policy which factors in their location to deal with these challenges accordingly.

Climate change also entails changes in the security sector for Germany. The shift in agricultural patterns and migratory movements due to rising temperatures will also shift logistics chains and thus shipping routes globally in the long term. International trade routes are and always have been seismographs for disturbances. This applies to criminal activities at sea, wars, but also in future will apply especially to natural disasters. This makes it all the more important for the German government further intensify its efforts to combat climate change at the international level within the framework of the International Maritime Organisation. Maritime shipping is already the most efficient means of transporting goods internationally, and the industry has also set itself the declared goal of operating its ships in a climate-neutral manner by 2050 at the latest.

There is no doubt that strengthening the maritime dimension is a necessary condition for Germany's strategic autonomy. In this context, it is important that merchant shipping is recognised and involved at the national level as an important partner within the framework of a national security strategy – we are dependent on the support of the German Navy in this regard. The creation of a forum for exchange between the navy, merchant shipping and the federal government on maritime security issues would be an important step.

Addressing maritime issues appropriately is not only in Germany's security policy and economic interest, but also in its ecological interest. Overall, the German government needs to make a clear commitment to the political and strategic importance of merchant shipping and the navy for Germany.

"When you are asked if you can do a job, tell 'em: 'Certainly I can!'" These words of Roosevelt should also be a challenge and an incentive for us. The German Shipowners' Association congratulates the German Navy on its 175th anniversary and looks forward to further cooperation. ■

Romania's Ongoing Military Transition

David Saw

The end of the Warsaw Pact and the collapse of the Soviet Union opened the way towards a new future for Eastern Europe, but the path was not the same for every country. Different circumstances led to different results and that influenced the nature of the transitional process and the time necessary to rejoin the European mainstream. In the case of Romania, the revolution of December 1989 and the demise of the Ceausescu regime, was the starting point for this transition.

The National Salvation Front (FSN) came to power following the revolution and they would go on to win the first post-Communist election in May 1990 and this would eventually be followed by the drafting of a new democratic constitution. Romania had embarked on an immense process of change in terms of politics, economics and society and it would take time for these changes to take effect. As with elsewhere in Eastern Europe, the establishment of respect for the rule of law across society and successfully battling against corruption were key challenges. In terms of external relations, achieving NATO membership in 2004 and EU membership in 2007 demonstrated Romania's political progress.

The Romanian Armed Forces are another national institution that has transformed itself since the 1990s. The starting point was accepting the fact that the military was far larger in size than necessary and financially unsustainable. On top of that, a large proportion of legacy equipment was unusable. For Romania was to meet its long-term goal of NATO membership, military reform was needed. As Romania's economy improved it became possible to increase defence expenditure, restructure the military establishment and reorganise the military from a conscript to a professional force.

Security Challenge

The evolution of Romanian military capabilities had to be gradual, the inescapable fact was that there was insufficient funding available for a rapid military transformation. Romania did benefit from the transfer of equipment from surplus stocks in Europe, for example Gepard self-propelled anti-aircraft guns (SPAAGs) from Germany and I-Hawk PIP surface-to-air missile (SAM) systems from the Netherlands. Also acquired were two Type 22 frigates from Britain, which were modernised before delivery to Romania and commissioned in 2004/2005.

Credit: Romanian MoD

The Romanian MLI-84M IFV is an indigenous development of the BMP-1, this modernised variant is equipped with an OWS mounting a 25 mm cannon and anti-tank missiles. There is interest in the acquisition of a new IFV to replace the MLI-84.

Romania also looked to use its defence industry to modernise legacy equipment, much of which had been produced locally. This was a cost-effective solution to modernisation and also had the benefit of sustaining local industrial capability. Romanian industry had capabilities in air, land and sea systems, with the potential to further develop to support national defence requirements. This would provide a capability to sustain in-service equipment and, where suitable, produce new equipment and systems to meet national needs.

Obviously how Romania intended to develop its defensive capabilities was based on an appreciation of the strategic situation in the Black Sea region and the surrounding territories. The assumption had been that there was a measure of strategic stability, an assumption which proved incorrect as in February/March 2014 Russia annexed Crimea and by April 2014, the War in Donbas commenced. In response, Romania would embark on a number of major defence acquisitions over the next few years.

The Romanian Air Force (FAR) had been attempting to acquire a replacement for its MiG-21 Lancer aircraft for some considerable time, but funding proved difficult. In 2015 a new possibility emerged as Portugal had surplus F-16A/B aircraft, this resulted in the Peace Carpathian I programme under which nine F-16A Block 20MLU and three F-16B Block 20MLU were supplied to the FAR in 2016/2017. Then in early 2020, FAR was able to acquire another five F-16A Block 20 aircraft from Portugal, under the Peace Carpathian II programme, with deliveries complete by early 2021.

Credit: Romanian MoD

One of three F-16B Block 20 MLU aircraft acquired under the Peace Carpathian I programme by the Romanian Air Force. Romania acquired 17 F-16A/Bs from Portugal and under the Peace Carpathian III programme it will acquire 32 F-16s from Norway.

The FAR was acquiring combat aircraft at very affordable prices, but more aircraft were required. By the end of 2021 this led FAR to Norway, who were retiring their F-16A/B fleet. In a contract worth EUR 454 M (Peace Carpathian III), the FAR was to acquire up to 32 F-16A/B MLU aircraft and associated support and training, with deliveries between 2022 and 2024. Separately, a contract covering F-16 modernisation and logistics support for the existing fleet was signed with the US.

In 2017 a major Foreign Military Sales (FMS) contract was announced between the US and Romania, this was valued at USD 1.25 Bn and covered the supply of 54 M142 HIMARS launchers, GMLRS and ATACMS missiles, as well as supporting equipment, with first deliveries in 2021. Another major FMS contract with the US

Credit: Romanian MoD

The TR-85 tank was designed and built in Romania, along with Soviet-era T-55s it provides the bulk of Romania's heavy armour capability. Romania now intends to acquire a battalion of 54 M1 Abrams tanks to modernise its armoured force.

was valued at USD 3.9 Bn, covering the supply of seven PATRIOT Configuration 3+ fire units, plus associated MIM-104E PAC-2 GEM-T and PAC-3 MSE missiles. More recently, a contract valued at USD 300 M for two Coastal Defence Systems (CDS), using the Kongsberg Naval Strike Missile (NSM), was placed with the US with Raytheon as prime contractor.

Future Needs

These contracts represent just some of the major programmes actioned by Romania after the Crimean annexation and War in the Donbas. Although substantial sums had been spent, there were still major capability gaps that needed to be filled. Filling those gaps became even more pressing after the Russian invasion of the Ukraine in February 2022 and the fact that this conflict still continues more than a year later, which in turn continues to present Romania with major security challenges.

For the Romanian Land Forces, the acquisition of the GDELS Piranha 5 is a key modernisation programme. The initial contract covered 227 vehicles, with a joint venture agreement between Uzina Mecanică București (UMB) and GDELS covering local production of the Piranha 5 being signed in March 2022. In February 2023 it was reported that Romania would acquire an additional 150 Piranha 5 vehicles.

Currently the Land Forces operate the indigenous TR-85 and old Soviet T-55 tanks, clearly an unsatisfactory state of affairs. The resolution to this problem appears to be the acquisition of a tank battalion of M1 Abrams amounting to 54 tanks as a starting point. As a part of growing defence links with the Republic of Korea (ROK), Romania has investigated a number of ROK defence products, including the K2 tank, although an Abrams purchase would seem to block this acquisition.

Where the ROK could benefit is in terms of tube artillery, Romania's legacy fleet is weak in this area and the Hanwha K9 155/52 mm self-propelled gun is a possible solution, and there is also interest in ammunition and ammunition technology transfer. Nexter's CAESAR system would also be a likely contender for a tube artillery and associated ammunition requirement. There is also a potential requirement for a tracked IFV replacement and improved air defence capabilities in the VSHORAD/SHORAD sector. Also important are growing defence ties with Turkey, including Romarm signing a memorandum of understanding (MoU) with Aselsan on smart munitions technology transfer, and a potential order for Bayraktar TB2 UAVs.

Turning to the Romanian Navy (FNR), back in 2019 Naval Group and its local partner Santierul Naval Constanta (SNC) announced they had been selected to provide four Gowind multi-mission corvettes, modernise the two FNR Type 22 frigates and build a maintenance facility and a training centre. A binding contract was never signed, however, in June 2022, Romania and France did sign a Naval Cooperation Agreement and it has been suggested that this could lead to the Gowind programme being signed in the near-term.

Another potentially significant programme for the FNR is a submarine acquisition, they currently have a single Project 877 Kilo class that is essentially inoperable. The naval agreement with France would seem to put Naval Group in the lead for any future FNR submarine programme.

Despite the current uncertain strategic situation in the Black Sea region, the positive state of the Romanian economy and future economic growth projections, indicate that Romania can continue to build its defensive capabilities. The continuing conflict in the Ukraine means that Romania has little choice but to look to its defences. ■

Lessons Learned from Ukraine: Logistics

Manuela Tudosia

There are many lessons to be learnt from the logistics of the war in Ukraine. Quite a few relate to how we need to adapt to modern warfare and how to prepare our economies for a complex landscape of challenges. For starters, the equipment providers often lacked direct access to the battlefield to train personnel, and organise storage, maintenance and repair. Secondly, the equipment used by Ukraine reflects disparate industrial bases and equipment logistics processes. In the face of these challenges, the pace at which Ukrainian forces have had to integrate a diverse array of equipment and support processes has been extremely fast. While this was fairly ad-hoc at the start of the conflict, it has become increasingly efficient.

NATO's website succinctly summarises logistics as relating to "having the right thing, at the right place, at the right time," and serving as a "bridge between deployed forces and the industrial base". Yet despite its importance, the topic often receives less attention than other areas until times of crisis arise. A common characterisation of its practitioners, taken from a text known as the 'Logistician's Lament', which is most commonly attributed to an unknown author goes as follows: "Logisticians are a sad, embittered race of people, very much in demand in war, who sink resentfully into obscurity in peace." This obscurity was probably the case for thousands of logisticians who, during the 'peace dividend', and behind the obscurity of their desk, carefully planned and implemented maintenance and sustainment of the bulk of equipment that is now used in Ukraine. Today, these same logisticians are probably unsurprised by many of the 'lessons learned' from the ensuing war.

Author

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

Credit: Ukraine Security Service (SSU)

On Saturday, 8 October 2022, a blast destroyed part of the Crimea (Kerch) Bridge opened in 2018 to connect Russia to the Crimean Peninsula. It was not clear whether the blast was a deliberate attack by the Ukrainian forces or an accident.

The Tip of the Iceberg

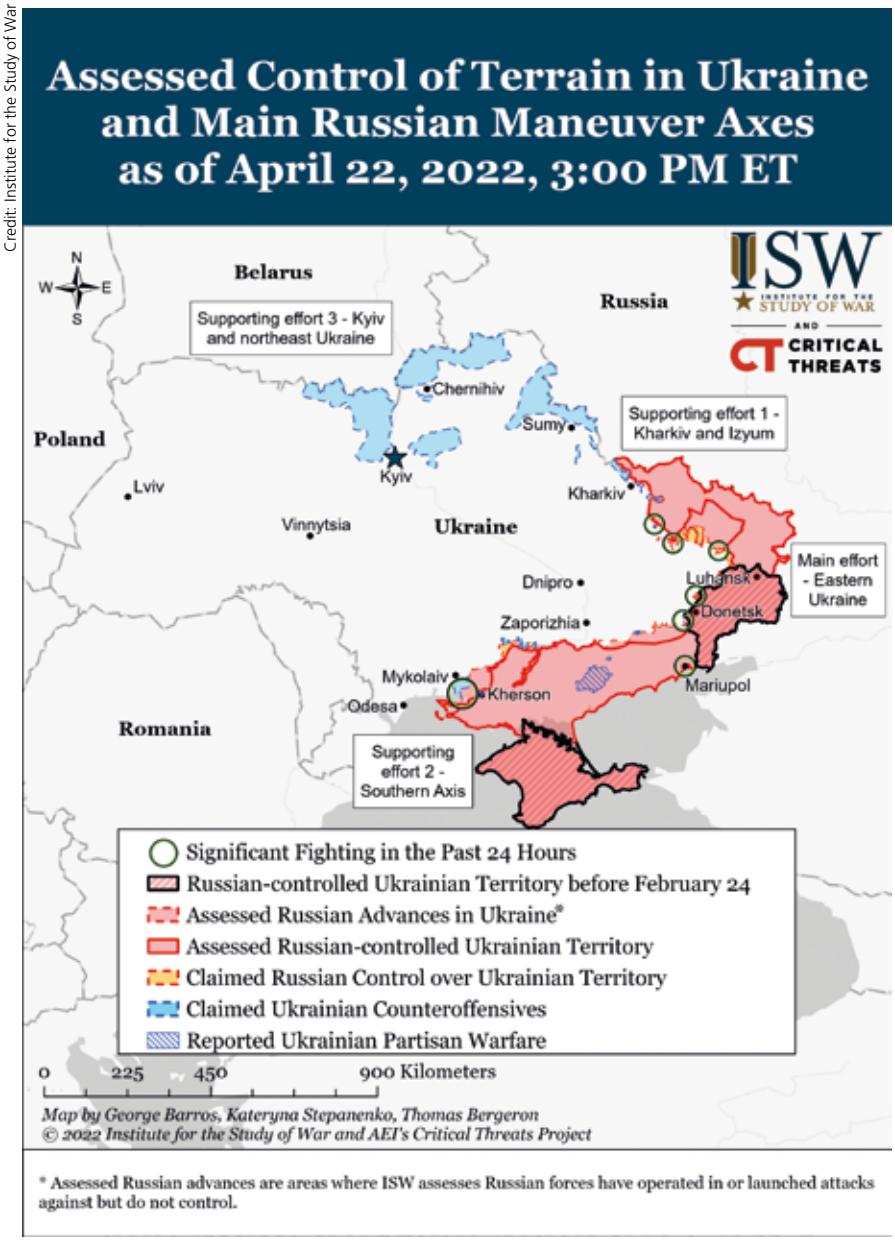
After the Russian invasion of Ukraine, public attention was focused on tactics used by both parties to enable their own movement of forces and equipment while disrupting those of the adversary. The invasion and annexation of the Crimean Peninsula in 2014, which hosts several Russian military bases, had already given Russia significant advantage, with Sevastopol allowing control of shipping routes. Before and during the current conflict, Russia sought to build land connections with Ukraine, important for movement and for sustainment. The opening of the Kerch bridge in 2018, which linked Russia to Crimea by both road and rail, was another advantage which existed before Russia's 2022 invasion. The fight to control the Donbas Region, the battles of Kherson, of Mariupol, or of Zaporizhzhia are also believed by analysts to have been strategic efforts for Russia to establish a 'land corridor' linking the Crimean Peninsula to the two rebel regions of Donetsk and Luhansk, and ultimately to Russia. Control of these strategic locations provided access to critical infrastructure – railways, water, energy - as well as to key industrial resources. Control of other critical infrastructure assets, or even of 'vulnerabilities' like the Chernobyl powerplant, were meant to disrupt Ukraine's supply routes and access to critical infrastructure necessary for the sustainment of forces and of population.

In retaliation, Ukrainian Railways terminated relations with Russian Railways and destroyed the railway line between the two countries. Russia encountered several logistics challenges along the way. The 64 km long traffic jam caused by a military convoy near Kyiv in March 2022 was the beginning. Its logistics vehicles were frequently targeted, leading to Russian combat vehicles running out of fuel and having to be abandoned. Despite these problems, for over a year now both parties seem to persist in their military efforts, in the face of expectations.

Ukraine's highly competent defensive response led Russia to face a number of difficult choices, after having lost a lot of equipment in the first two months when it was understood to have planned for a rapid military operation with little resistance from the Ukrainian side. Although Ukraine's armed forces have performed well, they have often needed significant materiel support from abroad to even maintain parity with Russia in various sectors, let alone achieve operational superiority. However, the intensity of the conflict is such that it has led to stocks of many crucial supplies running low, notably including artillery ammunition.

It is easy to understand that providing materiel support to Ukraine was and still is a mighty task that goes beyond simply moving equipment from point A to point B. It involves human resources and training of personnel, positioning and protecting stockpiles, as well as the capacity to maintain and repair the equipment received. These challenges cover the entire spectrum of logistics.

Credit: Institute for the Study of War



Assessed control of terrain in Ukraine and main Russian Manoeuvre Axes as of April 22, 2022, 15:00 ET. The map illustrates the strategic importance of securing a 'land corridor' between the Crimean Peninsula and the two rebel regions of Donetsk and Luhansk.

A Variety of Suppliers and Equipment

According to the Wikipedia 'List of military aid to Ukraine during the Russo-Ukrainian War', approximately 45 countries have provided equipment and other forms of aid to Ukraine, as well as to the European Union, private companies and other parties. The level of coordination required must be daunting, as it involves all levels, not just the political level. Nonetheless, it was pivotal in establishing a structured approach and gradually overcoming initial maintenance and training limitations.

Since the start of the Russian invasion, Ukraine welcomed all support but insisted on "urgent requirements", dictated by the reality on the ground. From this perspective, decision-making process and coordination was probably perceived as relatively slow by Ukraine, since it often urged EU and NATO countries to move faster in fulfilling their promises.

The supply of ammunition and of Western tanks are the best-known examples of how reality on the ground dictates certain urgent requests, and the time needed to implement these requests, both politically and operationally. After months-long insistence by Ukraine, at the beginning of the year, several western countries announced that they would provide Ukraine with main battle tanks (MBTs). Quoting President Joe Biden, tanks were requested because "They need to be able to counter Russia's evolving tactics and strategy on the battlefield in the very near term. They need to improve their ability to manoeuvre in open terrain. And, they need an enduring capability to deter and defend against Russian aggression over the long term."

As such, in January 2023, the US has announced it would provide 31 M1A1 Abrams tanks to equip an entire tank battalion, together with training on logistics and maintenance. Added to these, the UK committed to send 14 Challenger 2 tanks, with training of Ukrainian tank crews reportedly completed in March. France agreed to send AMX-10 RC fire support vehicles to the Ukrainian forces, although Ukraine's initial request was for Leclerc tanks. After some tergiversation, Germany also approved the export of 18 Leopard 2A6 MBTs from the Bun-

Credit: EU EAS/EUMAM Ukraine

A German instructor explains the turret of the armoured self-propelled howitzer (PzH 2000) to a Ukrainian gunner. Since October 2022, through the European Union Military Assistance Mission in support of Ukraine (EUMAM Ukraine) the Ukrainian Armed Forces personnel receives training over multiple locations on the territory of EU member states.

deswehr's stocks, and several other users announced they would provide Leopard 2 family MBTs from their own stocks.

Regarding ammunition, the Council of the EU reached an agreement in March 2023 to respond to this urgent requirement. A three-track approach was decided to speed up delivery and joint procurement to provide one million rounds of artillery ammunition for Ukraine over the next twelve months. The first part of the Council agreement was marked on 13 April 2023, when the Council announced an assistance measure worth EUR 1 Bn under the European Peace Facility (EPF) to reimburse member states for ammunition donated to Ukraine, whether from existing stocks or from redirecting existing orders.

In addition to these actions, the G7 Leaders' Statement of 12 December 2022 also emphasised coordination with regards to Ukraine's urgent requirements, "with an immediate focus on providing Ukraine with air defence systems and capabilities."

While ammunition and tanks are the most recent and publicised examples to illustrate the wide variety of equipment and sources, many others exist, with each having different degrees of complexity when it comes to logistics, especially maintenance and repair.

Beyond the Political Level, Coordination and Adaptation is Key at all Practical Levels

Regulations and Procurement Instruments

The approvals needed for the re-export of Leopard 2 tanks are also a reminder of the complexity of export regulations, as well as other administrative procedures and certification processes that govern the transfer and export of defence-related equipment. These various regulations are mostly national, and the experience with Ukraine has yielded some hints that export control processes and other regulations could be better-coordinated among allies.

As it may be expected, given the bulk of equipment delivered to Ukraine and the number of procurement authorities involved, the administrative effort on the Ukrainian side must be significant. Ukraine provided several 'urgent requests' that the Western countries tried to meet, in many cases after necessary national and multilateral political coordination. Once political agreement is achieved, the true logistics work begins. However, in the majority of the cases, procurement and delivery is done through countries' own national instruments and procurement procedures, sometimes by providing from national stocks and sometimes by procuring from industry. For example, the US Ukraine Security Assistance Initiative (USAI) allows the US to procure and deliver to Ukraine directly from industry instead of drawing down from DoD stocks. The EU three-track plan proposes a dual approach to providing equipment, which includes both drawing down from countries' stockpiles and purchases from industry in the short term, and over the longer term aims to ramp up overall production capacity.

The question is whether these multiple procurement instruments and procedures can be simplified given that equipment is supplied by different countries and multiple actors are involved.

Maintenance and Repair

To be able to use and maintain diverse equipment, coordination is needed with several parties – procurement authorities, industry, users – sometimes in parallel tracks since supply chains may be multiple and even severely challenged. Moreover, in some cases, manufacturing capacity may be insufficient to keep up with the pace of requirements.

The M777 155 mm howitzers and related ammunition were among the first critical pieces of artillery equipment delivered to Ukraine, and led to some of the first lessons to be learnt regarding the organisation of maintenance and repair in high-intensity combat scenarios. The M777, along with other NATO-standard howitzers, and a variety of other equipment can suffer from overuse, prompting a need to improve maintenance strategies in this type of conflict. In conditions where repair facilities in Ukraine can easily become a target, the challenge facing both Ukraine and its equipment suppliers is finding suitable alternatives and/or

Credit: Polish MoD

Polish Prime Minister Mateusz Morawiecki and Deputy Prime Minister and Minister of National Defence, Mariusz Błaszczak visited the Bumar-Łabędy Machine-Building Plant on 26 April 2023. He stated that the site would be used for production of Krab SPHs and as a service centre for Leopard 2 MBTs.

Credit: US Department of Defense

Ukraine Defense Contact Group meeting at Ramstein Air Base, Germany, on 8 September 2022. New support to Ukraine was announced, notably a new US pledge of up to USD 675 M for the provision of missiles for HIMARS, more 105 mm howitzers, artillery ammunition, up-armored Humvees, armored ambulances and other equipment.

innovative solutions to protect logistics facilities and stockpiles.

In a similar vein, according to the Polish Defence Minister Mariusz Błaszczak, the main problem in supporting Ukraine with Western tanks is spare parts. As reported by Polsat News, discussions between Minister Błaszczak and German Minister of Defence Boris Pistorius were planned on the margins of the EU defence ministers meeting in Stockholm to address this issue in relation to the Leopard 2 tanks. In March 2023, the Błaszczak also announced that Poland was ready to launch a service hub on its territory for the repair and service of Leopard 2 MBTs delivered to Ukraine. This was confirmed in April on the margins of the NATO Defence Ministers meeting in Ramstein, when Germany, Poland, and Ukraine signed a maintenance agreement. The hub is located at the Bumar-Labedy Machine-Building Plant in Gliwice, and is expected to officially commence servicing and repair operations in May 2023. Polish Prime Minister Mateusz Morawiecki also announced on 26 April 2023 that the production of Krab 155 mm self-propelled howitzers (SPHs) would take place at the same site. According to Reuters and other press sources, Rheinmetall is planning to set up a "service hub" in Romania to maintain the operational readiness of Western combat systems being used in Ukraine.

Standardisation and Interoperability

The full picture of the required maintenance and repair hubs for Ukraine's equipment is unknown for operationally sensitive reasons, but given the diversity of equipment, is it likely to be complex and distributed. From this point of view, the Ukrainian experience is the most practical reminder of what has been constantly repeated at the NATO and EU levels for more than 20 years – "avoid duplication" and "promote interoperability and standardisation".

The diversity of equipment provided to Ukraine is also a test of the extent and limitations of interoperability and standardisation. It is probably only after end of the conflict that the full picture of lessons learned here will emerge. Although much of the NATO countries' equipment is compatible, it does not mean that all equipment is standardised and interoperable. For example, compatibility issues with ammunition from other NATO countries were reported for 155 mm artillery ammunition, and ammunition supply issues arose following Switzerland's ban on exporting 35 mm ammunition for the Gepard self-propelled anti-aircraft gun (SPAAG).

Although useful, it should be noted that it does not makes sense to standardise everything. The September 2022 meeting of the National Armaments Directors from member states of the Ukraine Defense Contact Group, recognised the importance of standardising systems and munitions to create more interchangeable and interoperable systems. However, it was also suggested by Dr William LaPlante, the US Undersecretary of Defense for Acquisition and Sustainment, that standardisation needs to be primarily secured "where it makes sense", such as the 155 mm artillery rounds for the M777 howitzer.

Stockpiling

Like in other sectors, the 'just-in-time' production strategy has also proven its limitations in the defence sector. After the Cold War, stockpiling became rather unpopular because it was considered expensive to maintain and encouraged overproduction. Stocks of ammunition and spare parts were reduced, and strategies were implemented to ensure production and supply were conducted

in a more cost-effective manner. While achieving cost-effectiveness and avoiding overproduction should remain an objective, the strategies to do so should probably be revised, and should include cost-effective stockpiling.

Logistics Strategies

Logistics doctrines and concepts need to be adapted to the realities and tools of modern warfare – long-range precision fires, drones and other surveillance and target acquisition tools have rendered stocks and logistics hubs more vulnerable. Disguise and camouflage technologies have also evolved. All these factors need to be considered in the context of multi-domain operations. New concepts such as 'distributed sustainment operations' have emerged, and seem better suited to today's battlefield challenges.

Strengthening our Economies

Ensuring the aforementioned "bridge between deployed forces and the industrial base" means a logical continuity between production logistics, in-service and operational logistics, in the framework of short-, medium- and long- term capability planning, which reflects the doctrine, military and industrial requirements of a nation, or of a group of nations.

The particularity and challenge of the Ukrainian experience is that several elements of 'logical continuity' are discontinued and scattered. That is, in this author's view, because, at the beginning of the Russian invasion, the conflict was hoped to be a short one.

Unlike other conflicts where western countries were called upon to provide support using pre-established capability planning, the war in Ukraine has forced rapid adaptation of capability planning including at the production logistics level. It may even trigger a whole rethink of our industrial strategies with repercussions that go beyond the defence sector. The widely-debated ammunition shortage issue could also raise the question of whether post-Cold War capability planning was thorough enough in envisaging possible scenarios which could arise.

The Ukraine war also had several 'side-effects' which will likely impact how we think of logistics beyond the military. Firstly, the conflict has triggered an unprecedented level of unity at the European level, which has facilitated rapid decision-making on the reinforcement of European defence. Under different circumstances, it would have probably taken much longer. The EU Commission's plan to boost European defence production capacity via the European Defense Industry Reinforcement Through Common Procurement Act (EDIRPA) illustrates this.

The war was also a bitter realisation that we need to invest more in our industrial production capacity and better secure our supply chains. The war has heavily disrupted the latter, in nearly all economic areas, and added to existing challenges that became apparent during the COVID pandemic. As such, the countries of the trans-Atlantic space need to rethink their industrial strategies, as well as coordinate and to re-prioritise where necessary.

Conclusions

The Ukrainian experience so far has been a lesson in modern warfare, which has prompted the adaptation of logistics doctrines to its realities. It forced Ukraine and its Western allies to seek innovative solutions to assure continuity between operational, in-service and production logistics in new scenarios, and in new ways. It also demonstrated that shared values and objectives can help overcome many practical logistic problems, and served as a reminder of the importance of nearly forgotten concepts, such as stockpiling. It also reminded us that, besides equipment, the most important asset – including in logistics – is people, their training and their education, and that this is not only the responsibility of the military but of our education systems as a whole. This should incentivise thinking about and taking steps to strengthen our industries and boost our economies over the long term. Lastly, the conflict has demonstrated that coordination and cooperation can work, as well as the benefits of unity.

Credit: US Army/Staff Sgt. Gabriel Rivera-Villan

US Soldiers assigned to the 1st Battalion, 8th Infantry Regiment, 3rd Armored Brigade Combat Team, 4th Infantry Division, arrive on their assigned M2A3 Bradley fighting vehicles prior to live demolition training as part of Defender 22 at Oberlausitz Training Area, Germany, 10 May 2022.

UK Infantry Procurement in Troubled Times

Tim Guest

From major vehicle programmes and autonomous battlefield systems, to new individual equipment and devices, British infantry are in line for some much-needed upgrades and additions to their inventories.

Procurement is a long and winding process for any arm of service and only with the dark clouds of war gathering does any sense of urgency seem to enter the picture. Even then, timeframes bandied about appear to suggest we still have all the time in the world. For the infantry regiments and battalions of the British Armed Forces, there are procurement projects and programmes approved, as well as those yet to be approved, together with systems' field trials and evaluations underway, that will hopefully deliver critical and innovative solutions to the force before too long. Some might say 'too little too late', others 'better late than never'.

Credit: UK MoD/Cpl Kane

1st Battalion the Royal Welsh on Exercise Gothic Dragon, Germany. Procurement of new vehicle platforms and battlefield technologies has the chance to catapult British infantry into a new era of effectiveness, as long as the pace of procurement can keep pace with threats.

Procurement in General

In the MoD's 2022 Land Industrial Strategy (LIS), Jeremy Quin MP, Minister of State for Defence Procurement, has said that at a critical juncture for European security the army is undertaking its most significant modernisation in a generation, designed to enable it to operate on a continuous basis, fielding all relevant capabilities for "this era of constant competition", one that will see it persistently engaged around the globe. The war in Ukraine is cited as underscoring the "importance of delivering this modernisation at best speed", and that British Forces must be equipped with the technology and tools required to defend the nation's interests against adversaries. Quin underscored the intent to deliver a core nucleus of digitised capabilities – Challenger III, Boxer, Ajax and Apache – as well as new dismounted equipment, long-range fires, air defence, drones, electronic warfare, and cyber capabilities, many of which are directly impactful to the infantry, though with Boxer as the major infantry procurement programme cited.

Having touched on the need for urgency, it's a relief to see that the LIS is intended to help get equipment onto the frontline more quickly than has previously been managed, as well as aiming to deliver what it calls 'game-changing' combinations of latest tactics and technologies to the battlefield. These will incorporate opportunities offered by artificial intelligence (AI), automation and human-machine teaming, (see below field trial of autonomous system with Royal Yorkshire Regiment), as well as new technologies such as directed energy weapons, drone swarms, electric propulsion, and systemic protection systems. As many of these are dual-use technologies, the LIS encourages greater collaboration with the private sector in the pursuit of new concepts and ideas.

One of the major aims of the LIS is the modernisation and rationalisation of the army's inventory. The UK Armed Forces' current inventory actually comprises 35 unique land platform types, 400 variants and 26 different engine types, most of which are based on analogue technologies, closed or bespoke architectures, and have limited growth capacity, making them 'ill-suited for the information age'. As a result, the intention is to reduce these core military platforms down to 15 platform families that are modular, connected, and adaptable, with redundant equipment sold or disposed, all by 2035. Great intentions, but once again, a timeframe that is a long way off. As we have seen since 24 February 2022, a lot can happen over the course of 12 months, let alone 12 years.

One Major Infantry Platform Procurement Programme – Boxer

Nevertheless, one of those future platforms is Boxer, an 8×8 wheeled armoured vehicle being produced by the ARTEC consortium of Rheinmetall BAE Systems Land (RBSL) and WFEL. The vehicle will equip mechanised infantry battalions as part of the army's two armoured brigade combat teams. While the infantry's existing Warrior Infantry Fighting Vehicles (IFVs) were due to be sustained through the Warrior Capability Sustainment Programme, that programme was cancelled in March 2021 and these IFVs are now set to be replaced by Boxer in their entirety.

Credit: UK MoD/Cpl Eden

Warrior IFV on NATO Exercise Winter Camp in 2022. These will be replaced by Boxer in the coming years.

All these activities come under the auspices of Army Command, whose budget for the next decade was originally announced to be GBP 41.3 Bn in November 2021, following the unveiling of Future Soldier, with this figure repeated in the May 2022 Land Industrial Strategy, before being reduced down to GBP 40.6 Bn in the November 2022 Defence Equipment Plan (EP). According to the EP, the Mechanised Infantry Programme is intended to deliver a new ground manoeuvre capability based around the Boxer wheeled armoured vehicle, so that soldiers can deploy quickly and reliably over long operational distances, with minimal logistics and high tactical mobility. The vehicle will modernise the army and, specifically, the infantry, under the 'Future Soldier' concept, central to its new Brigade Combat Team structures transforming how it will operate in future.

The number of Boxer vehicles purchased was actually increased from its initial 523 order to 623 in April 2022, following priorities outlined in the MoD's Integrated Review and further Boxer fleet enhancements, uplifts, and potential new variants are being considered to bolster greater coherence within the army's new Armoured Brigade Combat Teams. Those additional 100 vehicles were announced by the British Army's Deputy Chief of the General Staff, Lt Gen Sir Christopher Tickell KBE at WFEL in Stockport, where manufacture of the wheeled Boxer vehicles under the first contract was already underway. The contract extension included additional vehicles in the infantry carrier, command and control, and ambulances variants, for use by the new Brigade Combat Teams. WFEL also said at that time that the additional vehicles were to be manufactured in both the UK and Germany for delivery from 2024 onwards, whilst the original order for 523 Boxer vehicles are being delivered from this 2023, and expected to serve into at least the 2050s. Defence Procurement Minister, Jeremy Quin, said at the time that the order for the additional 100 units would "accelerate the delivery of the Boxer fleet".

Credit: RBSL

Manufacturing has begun on the British Army's Boxers at RBSL in Telford and WFEL in Stockport.

Re-joining Boxer in 2018 has involved an extensive technology transfer programme from Germany for the UK participants and while the army emphasises that the programme is now being delivered at pace, the project has not been without its leave-and-re-join controversy. The UK's early withdrawal from the original programme in 2003, only to re-enter in 2018, was the major faux pas. However, since the MoD's 31 March 2018 announcement that it would re-join the programme, things now seem to be on track to deliver a platform that will meet infantry requirements. As to how things have progressed since, manufacturing at both RBSL and WFEL are now in full swing. For its part, RBSL announced key component manufacture of the Boxer had begun as of 27 March 2023, at its Telford facility, which had previously manufactured the UK's Warrior fleet. With production sub-contracted equally between RBSL and WFEL both companies are undertaking fabrication of the armoured vehicle structures together with assembly, integration and test of the complete vehicles at their respective facilities. RBSL has invested GBP 40 M in its 29-acre site, so that it can deliver military vehicles and essential in-service support. The site includes system integration labs, which will support Boxer and other platforms, with updates and upgrades throughout respective lifespans. WFEL's Boxer facilities were opened in May 2021 by UK Minister for Defence Procurement, Jeremy Quin.

In September 2022, the programme hit two operational milestones when the ability of a Boxer Mortar Mission Module to integrate and fire a mortar from the vehicle was demonstrated for the first time. The Mortar Weapon System (MWS), with its fully-automated aiming capability, was developed by Rheinmetall Norway and during the demonstration on Salisbury Plain training area in southern England, multiple 120 mm mortar rounds were fired. Additionally, smaller-calibre weapons in service with British infantry, such as the 81 mm mortars, can also be fired from the plat-

Credit: RBSL

RBSL has demonstrated the ability of a Boxer MWS Mission Module to successfully integrate and fire a mortar from the Boxer vehicle. The demonstration took place on Salisbury Plain and was the first time in which a mortar has been fired from a Boxer.

Credit: RBSL

Boxer Overwatch Brimstone Module demonstrator.

Credit: UK MoD

The ARILLS, which can be fitted onto the SA80 A3 rifle, allows soldiers to out-range the enemy and conduct more thorough reconnaissance and hit the target more often at night. (Pictured: ARILLS with 2 Yorks in Cyprus.

form, depending on operational needs. Such versatility in firepower is critical to mission success for mechanised infantry. A semi-automatic mortar system can be fitted to accommodate different mortar calibres and designs, so the army can use current in-service mortar systems, or a different, future product. This MWS Boxer variant delivers automated gunlaying for mortar crews, and possesses a 270° rear firing arc, and a high rate of fire of 16-18 rds/min, with rapid shoot-and-scoot capabilities. The mortar platform can be operated by the four-person crew during day or night and in all weather conditions. It can fire high explosive (HE), smoke, or illumination rounds, and has relatively extensive storage space for ammunition. The MWS module can also be dismounted from the vehicle and operated as a stationary mortar emplacement, should the need arise.

Also demonstrated at that time on Salisbury Plain was the 'Brimstone Overwatch on Boxer', also referred to as 'Boxer Overwatch', a Brimstone missile-equipped variant of Boxer developed by RBSL in collaboration with MBDA. The companies developed the variant in response to British Army needs for a Mounted Close Combat Overwatch capability, part of its future anti-armour requirement known as Battle Group Organic Anti-Armour (BGOAA). Boxer Overwatch carries eight Brimstone 3B missiles with a ground-launch range of approximately 12 km, providing a fairly long-range anti-armour capability. The vehicle would be capable of delivering overwatch protection to friendly forces, or providing a screening effect to disrupt hostile forces. The vehicle's salvo launch capability enables it to achieve co-ordinated effects on multiple targets during a single fire mission. The missiles are provided with a dual-mode seeker, providing them with an all-weather fire-and-forget capability. RBSL MD, Colin McClean, said that the MBDA collaboration on the overwatch variant demonstrated the MoD's LIS accelerated procurement efforts to get new platforms and equipment done, dusted and delivered to front-line troops, fast.

In August 2022, RBSL and WFEL signed Rolls Royce Solutions UK to supply MTU 8V 199 TS21 engines for Boxer. With a power output of 600 kW, the engines allow for enhanced operational mobility and agility, and a higher electrical load. The Boxers for the British Army will be the first versions of the vehicle equipped with this engine variant, delivering 70 kW more power than the MTU engines in previous versions of Boxer.

Credit: UK MoD

UGV experimentation and trials with 2 Yorks in Cyprus. UGVs reduce the logistical burden on infantry units by enabling the rapid, unmanned ferrying of extra ammunition and essential equipment to the front line, as well as providing a mechanism for the evacuation of wounded to rear areas.

Procurement Innovations and Experimentation Infantry

While Boxer may be one of the most high-profile ongoing procurement for British infantry, other innovations which will impact soldiers in the field, are in the procurement pipeline and being trialled.

In the UK MoD's 2022-2032 Defence EP's 'Land Environment Tactical Communications and Information Systems' category, for example, one of the projects mentioned is the Dismounted Situational Awareness (DSA) programme, which is currently under trial with infanteers of The Royal Yorkshire Regiment's 2nd Battalion, which currently has the DSA with them under extended field trial conditions, with the MoD expected to make a procurement decision in the 2024-2029 timeframe.

The Royal Yorkshire Regiment comprises 1 Yorks and 2 Yorks Battalions, both partnered by the 4th Battalion Army Reserve. Our focus here is on 2 Yorks, the British Army's Experimentation Battalion, which is at the heart of developing, testing and challenging infantry warfighting concepts, capabilities and technologies prior to wider procurement and adoption. The battalion is expert in close combat and urban operations and conducts its trial and evaluation activities under the guidance of the UK's Land Warfare Centre, Experimentation and Trials Group.

The battalion is currently in the final months of a 3-year programme experimenting with new kit that eventually may be destined for wider procurement across the British Army.

"The regiment was selected by the army to carry out a programme over three years of experimentation that has tried to bring light forces forward in terms of innovation and lethality, through a series of new kit for soldiers to use, but for that new kit to be incorporated into new ways of conducting combat, from new structures, as well as new tactics that will advance the way the infantry will operate in the future," said then CO of 2 Yorks, LtCol James Ashworth OBE (now Acting Colonel), at the time of a two-year deployment to Cyprus up until late 2022. He said his troops were literally the first to get their hands on some of the equipment and he emphasised that it was not simply the individual bits of new kit, but the 'power' of them operating together in combination that sees his men as architects of how the infantry, in general, will use such equipment in the future. Ashworth said that the regiment had been given a 'real mix' of kit including new communications and situational awareness devices, which allow the unit's command and control to move at a much quicker pace, as well as robotic patrol vehicles, which lighten the load for soldiers and offer new operational approaches to sustainment and dispersal in a very different way. He said, from new flying systems, to new sights, to new weapons, the mix was a real combination to make infantry companies and battalions more lethal.

During the Light Force Battalion Concentration in Cyprus, some of the new equipment tested by 2 Yorks included the DSA device, an advanced communication system, the Assault Rifle In-Line Low Light Sight (ARILLS), a nano-unmanned aerial vehicle (nano-UAV), and two different Robotic Platoon Vehicles (RPVs), a form of Unmanned Ground Vehicle (UGV). Starting with the DSA, this provides personnel with better ground appreciation and a greater understanding of both friendly forces and enemy dispositions across the mission area. The new communications system enables each personal radio the ability to act as a rebroadcast station, vastly increasing the range of tactical communications on the battlefield. The ARILLS, which can be fitted onto the L85A3 rifle, allows soldiers to out-range the enemy and conduct more thorough reconnaissance and hit the target more often at night. The nano-UAVs enable friendly forces to observe the enemy for long periods without detection. As for the RPVs, these reduce the logistical burden on infantry units by enabling the rapid, unmanned ferrying of extra ammunition and essential equipment to the front line, as well as providing a mechanism for the evacuation of wounded to rear areas.

Exactly when all these devices and systems will enter wider use is unconfirmed, suffice it to say that they are firmly in line for wider procurement in due course. One 2 Yorks officer said of the 3-year programme and the kit being trialled that being able to outthink the enemy is absolutely critical and having state-of-the-art kit allows friendly forces to keep the enemy on the back foot and locate them more quickly than they can locate British forces. Having trialled sights that are able to outrange the enemy and UAV that can identify them and target them ahead of time, he said that training and tactics are also adapted to ensure best use is made of the new equipment in the procurement pipeline and to counter new and emerging threats.

With such efforts by troops in the field, let's hope the procurement process doesn't let the side down and moves faster than ever to deliver. ■

Credit: UK MoD

Night vision devices are among the equipment in the potential procurement pipeline that have been trialled by the British Army's Experimentation Battalion, 2 Yorks.

US–Turkey Relations: Biden Navigates Difficulties with Erdoğan

Eugene Kogan

This article highlights several complex issues affecting US–Turkey bilateral relations. The current state of US–Turkey relations can be characterised as tense and rather difficult. Furthermore, there seems to be no light at the end of the tunnel that might reduce tensions between these NATO allies.

Introduction: Human Rights or Humans without Rights in Turkey

Since the inauguration of President Biden in January 2021, the US administration has kept its relationship with Turkey to a bare minimum. For the Biden administration, the issue of human rights in Turkey remains very much on the agenda while for President Erdoğan, the issue seems to be a lower priority for his administration. Such behaviour infuriates not just Biden administration officials but also members of the House and the Senate. This has resulted in the Turkish president not being invited to Washington. Perhaps the two sides can each be blamed for their current relationship; however, Erdoğan is maintaining his course and appears unbothered by the consequences. For his part, Biden is keeping his cool despite a number of divergences in interests of the US and Turkey. In addition to the human rights issue and the nature of their transactional relationship, Turkey urgently needs to modernise its ageing F-16 fleet since the first model was acquired in 1987. Therefore, both the modernisation and the purchase of advanced F-16 Block 70 fighter aircraft has become a difficult issue in the bilateral relationship as the two sides see things quite differently. In short, from Ankara's perspective, Turkey's needs are not being met by the Biden administration. Whether or not Erdoğan will decide to purchase fighter aircraft from another country is discussed further below.

Author

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Photo: Office of the President of Turkey

Biden and Erdoğan met and spoke during the 2022 G20 summit in Indonesia. The two discussed bilateral and regional issues, particularly trade and security.

The F-16 Dilemma

When Turkey purchased the Russian-built S-400 air defence system in 2019, it was removed from the F-35 co-production programme. This distancing from the US has had repercussions – Turkey's defence industry is now unable to bring its F-16 fighter aircraft to the Lockheed Martin F-16 Block 70 standard since it lacks the necessary know-how. As a result, Ankara requested permission from Washington to purchase 40 advanced F-16 Block 70 fighter aircraft and kits for the modernisation of its current fleet of 79 F-16 aircraft at a cost of USD 20 Bn in October 2021. The request is pending approval by the US Congress.

The Biden administration unofficially informed Congress in January 2023 of its intention to sell F-16 fighter aircraft to Turkey but it knows that both the House and the Senate strongly oppose the deal. One of the strongest opponents of the F-16 deal is Senator Bob Menendez, Chairman of the Senate Foreign Relations Committee. He did not hide his opinion and he certainly did not mince his words when he stated:

"I strongly oppose the Biden administration's proposed sale of advanced F-16 aircraft to Turkey. President Erdoğan continues to undermine international law, disregard human rights and democratic norms and engage in alarming and destabilising behaviour in Turkey and against neighbouring NATO allies. Until Erdoğan ceases his threats, improves his human rights record at home – including by releasing journalists and [members of] the political opposition – and begins to act like a trusted ally should, I will not approve the sale."

Such stances put the Biden administration in an awkward position with regards to securing approval for the sale. As long as Senator Menendez and others continue to oppose the sale of these aircraft, Turkey will not receive them, since Erdoğan is unlikely to change his behaviour and agree to Menendez's conditions. Setting a possible timeframe for the sale is therefore probably unrealistic.

The potential sale of F-16 Block 70s to Turkey is further compounded by the Lockheed Martin backlog that affects countries that have already ordered the F-16 Block 70, such as Bahrain, Bulgaria and Slovakia, to name a few.

Photo: Office of the President of Turkey

Relations between the two leaders have been fairly frosty at best.

Whether or not President Erdoğan will decide to turn instead to President Putin, and order Su-35 fighter aircraft remains to be seen. This option was raised several years ago and may still be on the cards. This option, however, is likely to result in severe damage to the already frayed US–Turkey relationship and Erdoğan may think twice before making such a decision. The relationship between two presidents leads on to the next difficulty affecting relations between the US and Turkey.

Erdoğan's Relationship with Putin

An additional sore point between the two countries remains the cordial relations between the Turkish and Russian presidents, which is viewed by the Biden administration with considerable concern. Erdoğan embracing NATO's adversary is seen as undermining NATO unity. In addition, Russian financial support for Erdoğan's administration remains a problem for the US. Washington is of course aware that Russia has agreed to a cheap energy deal which Turkey pays for in Russian roubles. Russia has also prepaid USD 5 Bn for the construction of the Akkuyu nuclear power plant (NPP).
Finally, Russian tourists returned to Turkey last summer in the post-COVID era resulting in a welcome cash inflow to the Turkish Finance Ministry. Thus far, the US reaction remains tempered. For instance, Deputy Secretary of the Treasury, Wally Adeyemo, spoke with Deputy Finance Minister of Turkey, Yunus Elitas, on 19 August 2022 to discuss ongoing efforts to implement and enforce the broad multinational sanctions imposed on Russia after its invasion of Ukraine. Adeyemo raised concerns that Russian entities and individuals were attempting to use Turkey in order to evade sanctions put in place by the US and 30 other countries.
Additionally, while in Istanbul, Under Secretary of the Treasury for Terrorism and Financial Intelligence, Brian Nelson, met with the Banks Association of Turkey on 3 February 2023 to discuss the implementation of international sanctions on Russia for its war against Ukraine. Nelson raised concerns that Russian oligarchs and government officials have continued to buy property, dock their yachts, run businesses and receive services for their property in Turkey. Turkey's refusal to join EU and NATO sanctions on Russia also bedevils the state of bilateral relations. Any explanation originating from Turkey as to why Erdoğan's administration refused to join the sanctions lends supports to the argument that the relationship between the two countries is fundamentally transactional.
Furthermore, the US Senate in particular views Erdoğan's relationship with Putin as a betrayal of the NATO allied ethos, since NATO member states imposed sanctions on Russia for its unprovoked war against Ukraine and support Ukraine's militarily, while Erdoğan is seen as cosying up to Putin. Turkey's delivery of Bayraktar TB2 UAVs somewhat helped Ukraine in the early days of the war though. However, the number of UAVs remains small and incomparable to the military assistance provided by many EU NATO members since the war broke out, including the Baltic States, Czech Republic, France, Germany, Poland, Slovakia, as well as non-EU allies the UK and US. During an Al-Monitor PRO event in January 2023, US Senator Chris Van Hollen slammed Turkey as an "unfaithful ally."

Greece on the US–Turkey Agenda

If the Erdoğan–Putin relationship remains a problem for the Biden administration, then by the same token, the Mitsotakis–Biden relationship remains a problem for the Erdoğan administration.
For Erdoğan, Greece was and remains is a thorn in the side that has not yet been addressed decisively. Prime Minister Kyriakos Mitsotakis, who addressed a joint session of the US Congress on 17 May 2022, implicitly asked its members not to approve the sale of F-16 fighter aircraft to Turkey.
As a result, Erdoğan called off a strategic meeting between Turkey and Greece, stating: "Mitsotakis no longer exists for me. I will never agree to meet him." Obviously, Erdoğan's willingness to wage a war of words against Greece has not helped relations between the US and Turkey. At the same time, however, the US has been paying more attention to Greece, both in political and military terms. Erdoğan has arguably lost a political battle on the Eastern Mediterranean front and Turkey's indispensability as a US ally is increasingly coming into question. While Erdoğan no doubt understands this point, however, he is doing little to remedy deficiencies in bilateral relations.

Blocking Sweden's Accession to NATO

Another bone of contention continues to be the Turkish position regarding the admission of Sweden to NATO, having eventually relented with respect to Finland at the end of March 2023. The US considers the admission of both countries into NATO of crucial importance since it increases NATO interoperability, cohesion, and strength in the Baltic Sea and the Arctic Ocean areas in particular.
Erdoğan is, however, pursuing a policy of national interests which is seen as detrimental to the Alliance and, therefore, contributes to causing long-term damage to the Alliance's cohesion, strength and unity. This seems not to bother Erdoğan, since he has distanced his country from the US politically. Nevertheless, the Biden administration continues to believe that within the framework of the US and NATO, Erdoğan will not lean towards Russia any further. Time will tell whether such beliefs are well-founded.
As long as the aforementioned problems continue to bedevil the two countries' relationship, there will be no resolution to the current state of the relationship. Biden and Erdoğan have known each other for a long time, however, their worldviews are very different, and at present there is no light at the end of the tunnel. As things stand, the only winner from the current US-Turkey relationship is President Putin, who stands to reap the benefits of any discord among allies.

ESD Interviews – Rear Admiral (retd.) Jon Pentreath

Credit: Clarion Defence and Security

Rear Admiral (retd.) Jon Pentreath.

Ahead of DSEI in September, ESD is publishing an interview with Rear Admiral (retd.) Jon Pentreath, DSEI Senior Military Adviser – Navy and Army.

Q: What will be the highlights of the land domain at DSEI 2023?
A: DSEI's Land Zone is the largest and fastest growing zone featuring the latest in weapons, ammunitions and equipment. Supported by the British Army, the Land Zone is a key platform to see first-hand the latest developments and innovations in the land domain from international exhibitors.
DSEI 2023 as a whole is set to be the largest in its 24 year history. With planning well underway and the theme of "Achieving an Integrated Force" – DSEI will once more see a galvanising of UK Military, UK Defence and Security Exports (UKDSE) and the highest calibre of exhibitors from industry.
The Land domain forms a large part of this, with the British Army keen to display their latest capabilities to prove they remain a first-rate power and a reference army. The British Army are likely to focus on implementing the land industrial strategy at DSEI, which will be viewed through the lens of delivering the capabilities we need now and in the future, and on continuing to build the broad alliances in order to protect our vital national and international interests.

Q: Why should people visit DSEI 2023?
A: There is no other international event that encompasses such a broad span of cross-domain capabilities, and where senior representatives from governments and the defence industry can meet to discuss their priorities. DSEI connects governments, national armed forces, industry thought leaders and the entire defence and security supply chain on a global scale. There is a wide range of valuable opportunities for networking, platforms for business and extensive access to relevant content and live-action demonstrations. The DSEI community can strengthen relationships, share knowledge and allow visitors to view the latest capabilities across the exhibition's Aerospace, Land, Naval, Security and Joint Zones.

Q: What has changed since DSEI 2021 and how will this affect the show?
A: The major change since DSEI 2021 is unquestionably the war in Ukraine. The brutal and illegal invasion by Russia has focussed minds on how to deter, and if necessary defeat, a peer/near-peer adversary in order to maintain our hard-won freedoms. The conflict represents a significant shift in how allied forces think about warfare, particularly in the land environment. We will see continuing strong support for Ukraine, not only from the UK but also from a wide range of nations across the globe, notably the US, Poland and Germany but including a very broad group of partners.
Since Russia's invasion of Ukraine on 24 February 2022, bilateral military assistance has been stepped up, with many allies for the first time supplying lethal weapons to Ukraine. For some countries such as Germany, and historically neutral countries such as Sweden, this has represented a significant reversal of their previous defence policies which ruled out providing offensive weapons. Significantly, in the land domain the US has donated M1 Abrams tanks to Ukraine, the UK has given Challenger 2s and Germany, Poland and others have gifted Leopard 2 tanks as well as large numbers of armoured vehicles, engineering capabilities and air defence systems.
The Chief of the Defence Staff, Admiral Sir Tony Radakin, has highlighted that the Ukraine war had predominantly been fought on land, but has warned against "focusing on just one domain" when evaluating Russia's threat. He stressed: "If you see through the Ukraine war, Russia will still have its full cyber, space and nuclear capabilities and many of its long-range missile capabilities."
DSEI is a global event but as its based in the UK will have a significant UK MOD presence. The UK can be proud to be one of the largest donors to Ukraine having committed GBP 2.3 Bn in military assistance in 2022, and has pledged to match that assistance in 2023.
To be effective on the contemporary battlefield, clearly there needs to be further investment in the UK's forces. The war

in Ukraine has increased the urgency of modernising the UK's land forces, ensuring that combined arms warfare can be fought effectively. This is not all about mere platforms or numbers of soldiers, but includes strengthened stockpiles, true readiness and a resilience in the supply chain that will allow for a sustained use of force.

Q: How does the land domain at DSEI integrate with other domains for a joined-up approach?
A: Integration at a national level across the frontline commands is essential and I know that they are all in constant dialogue. Multi-domain operations was the underlying theme of DSEI 2021, and achieving an integrated force this year's focus. One clear lesson coming from the war in Ukraine is the need for combined arms manoeuvre, which of course includes not just land forces but also air and maritime, in order to avoid the attritional artillery barrages and trench warfare we are witnessing around Bahkmut.
It is, however, vital to look beyond the national picture. To establish an effective deterrence against the sorts of horror we're witnessing in Ukraine, the UK must focus on developing Armed Forces that are forward-deployed, equipped with the latest technologies, capable of operating across the globe and the spectrum of conflict, and integrated with allies to reinforce the rules-based system.

Q: How does the Integrated Review Refresh change the context for DSEI?
A: The Integrated Review (IR23) builds on the approach of Integrated Review (IR21), setting out the next steps in delivering on its aims, against the backdrop of a "more volatile and contested world."
IR23 states the security of the Euro-Atlantic is a "core priority" and the "primary theatre" to which the UK will commit the majority of its defence capabilities, whilst continuing to support its interests around the globe and particularly within the Indo-Pacific region.
Russia was identified in IR21 the "most acute direct threat to the UK" in the Euro-Atlantic region. Following its full-scale invasion of Ukraine in February 2022, the refresh concludes "we cannot discount the possibility of an attack against Allies' sovereignty and territorial integrity", but the IR refresh continues to identify China as the greatest long-term threat to UK interests.
The IR refresh didn't delve into specific capability areas, and at this stage we await the publication of the Defence Command Paper which we hope will provide the next level of detail, and which we anticipate will be announced this summer in June or July.
However, there are gaps in the capabilities the UK has committed to NATO within its defence planning process, arguably most notably in the land domain as it recovers from 2 decades of counter insurgency operations in Iraq and Afghanistan. The Secretary of State for Defence has said that "UK land capabilities were 15 years behind the UK's peers". He told the House of Lords International Relations and Defence Committee that the current armoured division was "lacking in all sorts of areas" including deep fires, medium-range air defence, electronic warfare and signals intelligence capability.
The Army's response to these challenges will be on full display at DSEI 2023, not only on the show floor but importantly also in the conceptual space in the keynote addresses and other conference sessions.

Credit: Clarion Défence and Security

DSEI's Land Zone features many varied armoured fighting vehicle platforms on display.

European Security & Defence

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