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Politics · Armed Forces · Procurement · Technology

The greatest test for Ukraine

The capture of Avdiivka on 17 February 2024 marked a tactical and symbolic victory for Russia. Yet far more significant than the capture of the town itself was that the offensive heralded the deeply troubling trend of the return of Russian air power.

As this column warned back in ESD's January edition (see 'Breaking the stalemate', ESD 1-24), *"If left unchecked, Ukraine's SAM depletion could gradually lead to the dangerous scenario of Russia achieving air superiority. Even if this superiority only begins as localised to certain regions or small portions of the front, it could nonetheless still spell disaster for Ukraine, and radically change the state of the war."*

However, what was somewhat surprising was just how quickly the signs of localised Russian air superiority would begin to emerge. Already by mid-February, in the days immediately before Avdiivka fell, an unusually high number of air strikes were recorded by both Russian and Ukrainian sources, with some citing as many as 500 glide bombs being launched at Ukrainian positions around Avdiivka. Following the town's capture by Russia, the Institute for the Study of War (ISW) noted in their Russian offensive campaign assessment that, *"Russian forces appear to have temporarily established limited and localized air superiority and were able to provide ground troops with close air support during the final days of their offensive operation to capture Avdiivka, likely the first time that Russian forces have done so in Ukraine."*

Not long afterward, on 21 February 2024, President Vladimir Putin gave a speech at Chkalovsky Air Base in Moscow Oblast, in which he thanked the pilots and officers of the Russia Aerospace Forces (VKS), stating: "Thanks to their heroic actions and impeccable preparation, it was possible to achieve a turning point in the most difficult sectors of the front" and claimed the VKS had made "thousands of sorties". These claims appear to be at least partially backed by open-source conflict mapping projects, which showed an unusually high number of air strikes taking place at various points along the front line, with a particularly high concentration around Avdiivka.

More troubling than the raw numbers is that in the aftermath of Avdiivka's fall, some footage emerged on social media, which appeared to show Russian aerial assets flying at far higher altitudes than typical so close to the front lines. While air strikes throughout the war are not unheard of, not all air strikes are created equal. Due to the pervasive threat of air defence, both sides have tended to favour using two main types of air strike.

The first is the 'pop-up strike', commonly seen with ground attack aircraft such as Su-25, and various helicopters. In this style of strike, the aircraft follows the typical pattern of: 'fly low, pop up, launch unguided rockets (typically), pop flares, drop back down to low altitude'. Since flying at extremely low altitudes allows aircraft to stay below their opponent's radar horizon, this type of strike can be used close to the front lines. While it can be somewhat useful as a form of airborne indirect fire support, it is usually not particularly accurate.

The second type is the 'long-range strike', which essentially involves using aircraft as missile taxis for long-range standoff weapons. In this type of strike, such weapons are usually launched at medium or high altitudes far from the front lines. Yet due to the large size, weight, and cost of such weapons, along with their lower availability and more complex targeting cycles, these types of strikes are primarily reserved for high-value and static targets.

Ideally, neither would be the go-to choice for a typical sortie. When allowed to fly at medium altitudes, where they can locate and engage targets with relatively small air-launched weapons, aircraft can wreak absolute devastation. The aforementioned footage, along with reports of the Russians using KAB/FAB bombs of various weight classes modified with glide bomb structures, indicates that Russia's pilots have begun to grow bolder and fly higher.

This boldness has, to an extent, been punished by Ukraine, which claimed to have downed four Su-34 fighter-bombers and two Su-35 fighters in the period from 17-21 February. However, this interception rate is still lower than would be expected even if Russia's sortie rates were much lower than the "thousands" Putin claimed. Overall, it is difficult to escape the conclusion that a window of opportunity has indeed opened for the VKS.

Ukraine has made no secret of the fact that it is in dire need of more surface-to-air missiles, with calls for their delivery by Ukraine's leadership growing louder in recent weeks. Russian localised air superiority is a troubling development, but it should be noted that Russia's ground forces presently do not appear to be in a position to achieve a decisive breakthrough. Having said that, they may not have to. Russia's recent trend of conducting small-scale bite-and-hold attacks all along the front line keeps Ukraine's forces under constant pressure and makes it more difficult to establish a firm defensive line. The most likely immediate impact of Russia's air power returning will be that these attacks become more likely to succeed, empowering Russia's ground forces to bite bigger chunks out of Ukraine's territory than before.

Mark Cazalet

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Cover Photo: US Soldiers assigned to the Blackhawk Battery, 1st Battalion, 14th Field Artillery Regiment, 75th Field Artillery Brigade, fire an M142 HIMARS during a night live fire training as part of Exercise Spring Storm 23 held at Camp Tapa, Estonia, on 25 May 2023.
Credit: US ANG/Staff Sgt Agustín Montañez

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CENTCOM continues to target Houthis, whose arsenal now includes UUVs

(pf) The forces of US Central Command (CENTCOM) continue to strike at the offensive military assets of the Yemen-based Houthi militia in an attempt to curtail their ability to attack commercial shipping in the Red Sea region.

As well as targeting Houthi anti-ship missiles and bomb-laden unmanned aerial vehicles before they can be launched, on 17 February 2024 CENTCOM for the first time attacked what it described as an unmanned underwater vessel (UUV), which represents a new dimension to the threat to international shipping in the region.


Credit: CENTCOM

The Iran-backed Houthis remain undeterred, however, with CENTCOM reporting that from 1315 hrs on 16 February to 0100 on 17 February (Sanaa time) the Houthis launched four anti-ship ballistic missiles into the Red Sea.

"It is assessed that three of the missiles were launched towards commercial vessel MT *Pollux*: a Panamanian-flagged, Denmark-owned, Panamanian-registered vessel. There were no reported injuries or damage from MT Pollux or any other ship in the area," CENTCOM reported.

"Additionally, between the hours of 1:40 pm and 6:45 pm, CENTCOM successfully conducted two self-defense strikes against one mobile anti-ship cruise missile and one mobile unmanned surface vessel (USV) in Yemen. CENTCOM identified the mobile missile and USV in Houthi-controlled areas of Yemen and determined it presented an imminent threat to US Navy ships and merchant vessels in the region."

On 19 February, meanwhile, the UK Maritime Trade Operations (UKMTO) agency reported that the crew of the Belize-flagged, British-registered cargo vessel *Rubymar* had abandoned ship off Yemen after it was hit by missiles fired by the Houthis. The ship was in the Gulf of Aden and nearing the Bab al-Mandab Strait when it was struck, according to security firms operating in the area.

On 18 February the UKMTO had reported that the master of a ship assumed to be Rubymar had reported "an explosion in close proximity to the vessel resulting in damage".

According to BBC reporting, the security firm responsible for *Rubymar*, LSS Sapu, and data provider Lloyd's List Intelligence confirmed that the ship had sustained damage after being hit by two missiles.

The potential loss of Rubymar, which according to the UKMTO was left at anchor, only serves to demonstrate that the Houthis' capacity to do real damage to shipping continues despite the strikes against Houthis assets by US forces and occasionally UK Royal Air Force (RAF) Typhoon combat aircraft flying out of RAF Akrotiri on Cyprus. This is because the Houthis' offensive capabilities continue to be replenished by Iran.

On 15 February CENTCOM reported that a US Coast Guard cutter forward deployed to the CENTCOM area of responsibility had seized advanced conventional weapons and other lethal aid originating in Iran and bound to Houthi-controlled areas of Yemen from a vessel in the Arabian Sea on 28 January.

"The US Coast Guard Sentinel-class fast-response cutter USCGC *Clarence Sutphin Jr* (WPC 1147), assigned to US Naval Forces Central Command, located the vessel and boarded it in the Arabian Sea," CENTCOM reported. "The boarding team discovered over 200 packages that contained medium-range ballistic missile components, explosives, unmanned underwater/surface vehicle (UUV/USV) components, military-grade communication and network equipment, anti-tank guided missile launcher assemblies, and other military components."

"This is yet another example of Iran's malign activity in the region," General Michael Erik Kurilla, CENTCOM commander, was reported as saying. "Their continued supply of advanced conventional weapons to the Houthis is in direct violation of international law and continues to undermine the safety of international shipping and the free flow of commerce."

Ukrainians sink another major Black Sea Fleet surface ship

(pf) Ukrainian special forces using bomb-laden unmanned surface vessels (USVs) have sunk another Ropucha-class landing ship of the Russian Black Sea Fleet.

The Main Directorate of Intelligence (GUR) of the Ukrainian Ministry of Defence announced on its website on 14 February 2024, that earlier that day, special forces of the GUR's Group 13 had destroyed the landing ship *Caesar Kunikov*.


Credit: GUR

"The enemy ship was attacked by Magura V5 sea attack drones near the shores of the temporarily occupied Crimea near the city of Alupka, the GUR stated. "As a result, *Caesar Kunikov* received critical holes on the left side and began to sink.

Accompanying the news was a three-minute video comprised of footage taken from infra-red cameras on the USVs as they zigzagged their way toward *Caesar Kunikov*, including footage of sizeable blasts. Unlike previous footage of Ukrainian USV attacks there did not seem to be much defensive fire coming from the Russian ship as the USVs approached.

The GUR soundtracked the video with the classical/dance/electronic track Revenge of the Orchestra by Apashe featuring Magugu, which includes the constant refrain 'Revenge is a must'.

The GUR also noted on its website that "It is symbolic that the Russian officer after whom the ship was named was killed exactly 81 years ago."

Displacing 4,400 tonnes at full load with a crew of 96, *Caesar Kunikov* has thus been added to the list of major Black Sea Fleet casualties inflicted by the Ukrainians, who most recently sank the Russian Tarantul-class corvette Ivanovets on the night of 31 January/1 February using bomb-laden USVs.

US Army to end FARA programme amid overhaul of its future aviation initiatives

(pf) The US Army announced on 8 February 2024 that it will discontinue development of the Future Attack and Reconnaissance Aircraft (FARA) as part of a "transformational rebalancing" of its future aviation initiatives.

Beyond cancelling the FARA programme at the conclusion of FY24 prototyping activities, the army also announced that it will end production of the UH-60V ver-


Credit: Sikorsky

sion of the Black Hawk helicopter, which extends service life of existing airframes by 10 years, after FY24 due to significant cost growth; delay entering production with the Improved Turbine Engine (ITEP) to ensure adequate time to integrate it with the UH-60 and AH-64 helicopters; and phase out operations and sustainment of its legacy Shadow and Raven unmanned aerial vehicles (UAVs).

These measures are designed, the army stated, to "free up resources to make critical new investments in army aviation". These include: committing to a new multi-year contract to procure the UH-60M Black Hawk helicopter – a new airframe with a 20+ year service life – and invest in upgrades for the Black Hawk; ending uncertainty over the future of the CH-47F Block II Chinook heavylift helicopter by formally entering it into production, with a path to full-rate production in the future; continuing with the Future Long Range Assault Aircraft (FLRAA) programme as planned, ensuring the army remains on a path to field the first operational unit in FY30; and increasing investments in research and development to expand and accelerate the army's unmanned aerial reconnaissance capability, including future tactical unmanned aerial systems and launched effects.

In ending the FARA effort the army said that its leaders "assessed that the increased capabilities it offered could be more affordably and effectively achieved by relying on a mix of enduring, unmanned, and space-based assets".

The army added that, "without reprioritising funds in its constrained aviation portfolio, the army faced the unacceptable risk of decline and closure of production and sustainment lines for the Chinook and Black Hawk fleets". The army's new plan will renew and extend production of both these aircraft, while also sustaining the experienced workforce and vendor base that underpin the army's aviation capabilities.

The FARA programme, which was launched in 2018, ultimately saw the Bell 360 Invictus vying against Sikorsky's Raider X compound helicopter for the requirement; both aircraft were downselected from a larger field in March 2020. However, testing of these aircraft had been delayed by the late arrival of the army-stipulated ITEP powerplant, meaning they never actually flew in the required configuration.

Bell's tandem-cockpit 360 Invictus design features four high-speed articulating rotor blades derived from the larger Bell 525 Relentless medium helicopter along with wings to create lift when the aircraft is travelling at speed. Sikorsky's Raider X is a compound helicopter design with two coaxial rotors and a single pusher propeller.

Trump roundly condemned for indicating he would abandon NATO principles

(pf) Comments recently made by likely Republican nominee for the US presidency Donald Trump on NATO nations' defence spending have been roundly condemned from many quarters, including the alliance, current US President Joe Biden, the European Union and former US military commanders.

Addressing a rally in Conway, South Carolina, on 10 February 2024, Trump recalled that during his presidency the leader of a "big country" had presented a hypothetical situation in which he was not meeting his financial obligations to NATO, had come under Russian attack and had asked if the US would come to his country's aid in that scenario.

Credit: CNN_AFP_Getty

"I said: 'You didn't pay? You're delinquent?' Trump recalled, adding that he replied, "No, I would not protect you. In fact, I would encourage [Russia] to do whatever the hell they want. You gotta pay. You gotta pay your bills."

Trump's comments are in flagrant disregard for one of the key underlying principles of NATO: the alliance's Article 5 security guarantee, which states that an attack against one ally would be considered an attack against NATO as a whole.

NATO Secretary Jens Stoltenberg stated on 11 February, "Any suggestion that allies will not defend each other undermines all of our security, including that of the US, and puts American and European soldiers at increased risk."

President Biden issued a statement on 11 February that read, "Donald Trump's admission that he intends to give [Russian President Vladimir] Putin a greenlight for more war and violence, to continue his brutal assault against a free Ukraine, and to expand his aggression to the people of Poland and the Baltic states are appalling and dangerous."

European Council President Charles Michel called Trump's comments on NATO "reckless" on 11 February, adding that they "serve only Putin's interest".

Ben Hodges, who served as the commander of US Army Europe from November 2014 until January 2018, was reported by the UK's The Times newspaper on 12 February as saying that Trump's comments were "strategically illiterate" and risked "screwing" the United States' own security interests.

Hodges further suggested that Trump was "absolutely prepared" to turn his back on Europe if he returned to the White House.

US calibrates its military response to fatal attack on US outpost in Jordan

(pf) In a much-signalled operation, forces from US Central Command (CENTCOM) attacked dozens of targets in Iraq and Syria associated with Iran-affiliated militia groups on 2 February 2024.

The strikes were in response to a 28 January drone attack on a US military outpost in Jordan, known as Tower 22, that killed three US Army troops and injured more than 30 others. Although there have been numerous attacks on US forces in the region in recent months, this was the first to produce US fatalities in the Middle East since the 7 October 2023 Hamas raid on Israel, the consequent war in Gaza and the subsequent attacks on shipping in the Red Sea by the Iran-affiliated Houth militia in Yemen.

"US Central Command forces conducted airstrikes in Iraq and Syria against Iran's Islamic Revolutionary Guards Corps (IRGC) Quds Force and affiliated militia groups," CENTCOM stated on 2 February. "US military forces struck more than 85 targets with numerous aircraft [including] long-range bombers flown from United States. The airstrikes employed more than 125 precision munitions. The facilities that were struck included command-and-control operations centers, intelligence centers, rockets, missiles, unmanned aerial vehicle storage, and logistics and munition supply chain facilities of militia groups and their IRGC sponsors who facilitated attacks against US and Coalition forces."

The CENTCOM commander, General Michael Erik Kurilla, added in a 2 February statement, "Iran's Islamic Revolutionary Guards Corps (IRGC) Quds Force and Iranian-affiliated militia groups continue to


Credit: USAF

represent a direct threat to the stability of Iraq, the region, and the safety of Americans. We will continue to take action, do whatever is necessary to protect our people, and hold those responsible who threaten their safety."

Although Tehran denied any involvement in the Jordan attack on 29 January, the Islamic Resistance in Iraq, an umbrella group of a number of Iran-backed militias in the country, stated on 28 January that it had attacked a number of targets along the Jordan-Syria border, including a camp at Al-Rukban that is close to Tower 22.

French MoD orders 109 Nexter CAESAR 6×6 MkII SPHs

(pf) The French Ministry of Defence (MoD) has ordered 109 Nexter 155 mm CAESAR 6×6 MkII self-propelled howitzers (SPHs), the company announced on 2 February 2024.

Credit: Nexter

The CAESAR 6×6 MkII is a new version of the wheeled SPH that is currently under development. The order, the contract price of which was not disclosed, was planned under France's 2024-2030 defence programming law. The new systems will first replace the French Army's tracked AMX-30 AuF1 SPHs at the end of their operational service and gradually phase out the army's CAESAR 6×6 MkI SPHs.

"The French artillery will thus have an unprecedented capability since the introduction of the CAESAR 6×6 system in 2008," KNDS, Nexter's parent company, stated in a press release.

The order also includes support for the CAESAR MkII during the system's first two years of use.

The development of the CAESAR MkII was launched in December 2021.

The main improvements of the CAESAR MkII, which uses the same 155 mm 52-calibre gun as its predecessor, relate to the system's protection, mobility and communication capabilities. The new system features a cabin with enhanced protection against mines and ballistic projectiles to resist improvised explosive devices (IEDs) and small-calibre ammunition. This requirement was defined during France's recent operations in Afghanistan and Africa's Sahel region.

The mobility of the CAESAR MkII, meanwhile, is improved with a new engine (460 HP compared to the previous 215 HP), a new automatic gearbox, and a new chassis provided by Arquus.

The CAESAR MkII is additionally equipped with state-of-the-art fire control software, with its cabin prepared to integrate the future generation of French NCT-t radio systems.

Czech Republic signs LOA to officially join the F-35 club

(pf) The Czech Republic officially joined the Lockheed Martin-led F-35 fifth-generation fighter programme on 29 January 2024 when the Czech government signed a letter of offer and acceptance (LOA) for 24 F-35s under the US Foreign Military Sales mechanism. Procurement of the aircraft was authorised by the Czech government in September 2023.

The Czech Air Force will receive 24 conventional take-off and landing F-35As in the latest advanced Block 4 configuration, deliveries of which will begin in 2031.

"With the signing of the letter of offer and acceptance between the Czech Republic and US governments, the Czech Republic becomes the 18th nation to join the global F-35 programme," Bridget Lauderdale, Lockheed Martin's vice president and general manager for the F-35 programme, was quoted as saying in a company press release. "We are honoured to partner with the Czech Republic Air Force as its F-35s join other European nations in strengthening and growing interoperability, significantly increasing NATO's deterrent capability."

The Czech Republic has secured an industrial co-operation package as part of its F-35 procurement. The Czech Ministry of Defence (MoD) stated on its website on 29 January, "There are 11 projects prepared with Lockheed Martin and three projects with Pratt & Whitney in the aggregate value of CZK 15.3 billion (EUR 620 million). Those will see the participation of 13 Czech enterprises and universities involved in four areas: manufacture of components, research and development, pilot training and maintenance, [and] F-35 maintenance and servicing."

Credit: USAF

The Czech Air Force currently operates a fast jet fleet consisting of 14 leased Saab Gripen C/Ds (12 Cs and two Ds). Saab had sought to persuade the Czechs to acquire Gripen E/Fs before they ultimately opted for the F-35.

"The Swedish Gipen fighters in the Czech Air Force inventory will have performed their mission by 2035, when the F-35 system will reach its full operational capability," the Czech MoD stated. "There are intensive negotiations underway with the Kingdom of Sweden on the operation of the Gripens in the given timeframe."

British Army's first pre-production Challenger 3 MBT enters trials

(pf) The British Army's first pre-production Challenger 3 main battle tank (MBT) has been deployed to Germany for trials, manufacturer Rheinmetall BAE Systems Land (RBSL) announced on 19 February 2024.

"This prototype, along with further prototypes to follow close behind, will soon show their capabilities on trials. During the trials the prototypes will be tested under operational conditions to validate their performance and make refinements before another 140 are built and delivered to the British Army," RBSL had previously reported in January.

Credit: RBSL

The Challenger 3 features a new 120 mm L55A1 smoothbore gun built by Rheinmetall, enabling the use of the Rheinmetall's most advanced ammunition, as well as next-generation UK-sovereign modular armour designed by the UK Ministry of Defence's Defence Science and Technology Laboratory (Dstl). It will also have a fully digitised turret and the Trophy medium Variant active protection system (APS) provided by Israel's Rafael Advanced Defense Systems.

"Designed with the crew's safety, operational effectiveness and comfort at its heart, and with the users' advice at every stage, I am sure it will prove to be a very potent and popular addition to the British army's inventory," RBSL Challenger 3 Deputy Project Manager Nick Berchem was quoted as saying. "It is hugely exciting and very satisfying to be part of the team bringing this immensely capable tank to life."

Colonel Will Waugh, Senior Responsible Owner of the British Army's Armour (Main Battle Tank) Programme, added, "Delivery of the first pre-production Challenger 3 and the commencement of trials marks a critical milestone on the journey to the army's modernised main battle tank capability. Challenger 3 will be at the heart of the army's armoured brigade combat teams, alongside [the] Ajax and Boxer [AFVs], under [the army's] Future Soldier [strategy]. Events in Ukraine have underscored the need for credible warfighting capabilities. The army's armoured brigade combat teams, with Challenger 3 at their centre, are key to the UK's contribution to NATO's deterrence."

Greek purchase of up to 40 F-35As approved by US State Department

(pf) The US State Department has approved a potential Foreign Military Sale (FMS) to Greece of up to 40 F-35A conventional take-off and landing Joint Strike Fighters and related equipment, the US Defense Security Co-operation Agency (DSCA) announced on 26 January 2024.

The proposed sale, which is worth an estimated USD 8.6 billion (EUR 7.94 billion), has been passed to the US Congress for final approval. Assuming the FMS progresses, this would make Greece the 19th country that will operate F-35s.

Sensitive to the regional rivalry between NATO members Greece and Turkey, the Greek F-35 FMS approval was announced on the same the DSCA stated that the US State Department had approved an F-16 FMS package for Turkey, which was approved to acquire 40 new F-16 Block 70s and modernise 79 of its existing F-16s to the F-16V standard.

Credit: Lockheed Martin

Turkey previously joined the Lockheed Martin-led F-35 programme in July 2002, initially intending to order 116 F-35As to replace its F-16 fleet, but was ejected from the programme on 17 July 2019 after refusing to cancel a programme to buy Russian S-400 air defence systems that would have compromised the F-35's stealth characteristics. The backbone of the Hellenic Air Force's combat air capability is currently provided by a fleet of more than a hundred F-16C/Ds, 84 of which are being upgraded to the F-16V standard, as well as a Rafale fleet that will number 24 aircraft. However, the air force also operates older types, such as the Mirage 2000-5 and F-4 Phantom II, which the F-35As will replace.

NATO Secretary General praises 'unprecedented rise' in NATO defence spending

NATO Secretary General Jens Stoltenberg has welcomed an unprecedented rise in NATO defence spending across European allies and Canada.

Credit: NATO

Commenting on the latest NATO defence spending figures, released on 14 February 2024 in advance of a meeting in Brussels of NATO defence ministers, Stoltenberg announced that European Allies and Canada have added more than USD 600 billion (EUR 559 billion) in defence spending since the NATO Defence Investment Pledge was made in 2014, which targeted a 2%-of-GDP level of defence spending among NATO nations.

"Last year saw an unprecedented rise of 11% across European Allies and Canada," Stoltenberg said on 14 February. "This year I expect 18 allies to spend 2% of their GDP on defence. That is another record number, and a six-fold increase from 2014, when only three allies met the target.

"In 2024 NATO allies in Europe will invest a combined total of USD 380 billion in defence. For the first time, this amounts to 2% of their combined GDP," Stoltenberg added. "We are making real progress: European Allies are spending more. However, some Allies still have a ways to go because we agreed at the Vilnius Summit [in July 2023] that all allies should invest 2%, and that 2% is a minimum."

NATO Allies in Europe invested 1.47% of their collective GDP in defence in 2014. The pledge to go to 2% of GDP was triggered by Russia's illegal annexation of Crimea, while the latest defence spending increases were prompted by Russia's all-out invasion of Ukraine in February 2022.

Austrian MoD orders 225 more Pandur 6×6 Evo armoured vehicles

(pf) The Austrian Ministry of Defence (MoD) has ordered an additional 225 Pandur 6×6 Evolution (Evo) wheeled armoured vehicles, manufacturer General Dynamics European Land Systems - Steyr (GDELS-Steyr) announced on 19 February 2024.

A contract for the vehicles was signed that day in the presence of Austrian Chancellor Karl Nehammer and Austrian Defence Minister Klaudia Tanner.

As well as armoured personnel carrier variants and flexible conversion kits for medical, command-and-control and anti-tank missions, the order includes eight new vehicle variants to be introduced to the Austrian armed forces, including 120 mm mortar carriers, as well as mobile air defence and electronic warfare variants.

The procurement is part of Austria's Development Plan 2032, which is designed to effect a comprehensive modernisation of the Austrian armed forces. The additional vehicles will give the Austrian Army's medium infantry forces a significant increase in mobility, protection, and effectiveness, according to GDELS-Steyr.

Credit: GDELS

"The procurement of 225 additional Pandur Evolutions in different variants is the largest acquisition by the Austrian Army in 20 years," Tanner was quoted as saying in a GDELS-Steyr press release. "With an investment volume of EUR 1.8 billion, we are not only investing in the security of Austria, but moreover in Austria as a business location. With 70% value creation in Austria the domestic Pandur production secures and creates jobs at over 220 companies," she added.

A hundred Pandur Evo vehicles have already been ordered for Austrian Army: 34 ordered in 2016 and delivered by 2020, 30 ordered in October 2020 and delivered by 2023, and

a the third batch of 36 ordered in September 2022 that is currently in production and delivery.
In total more than 3,000 Pandur armoured vehicles of all types, in both in 6×6 and 8×8 configurations, are in service worldwide. Beyond Austria users include Belgium, the Czech Republic, Indonesia, Kuwait, Portugal, Slovenia, Ukraine and the United States.

■ 'Steadfast Defender 24', NATO's largest exercise since the Cold War, kicks off

(pf) NATO's Exercise 'Steadfast Defender 24' began on 24 January 2024. Planned to highlight and exercise NATO's ability to deploy forces rapidly from North America and other parts of the Alliance to reinforce the defence of Europe, it is the largest NATO exercise since the last 'Reforger' exercise near the end of the Cold War.


Credit: USN

Running until 31 May, 'Steadfast Defender 24' is NATO's principal multi-domain exercise for 2024 and will consist of a series of national and multinational large-scale, live exercises conducted across various geographical locations.
The exercise will involve around 90,000 personnel from the armed forces of 31 NATO allies plus Sweden and will take place primarily in Finland, Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Norway, Poland, Romania, Slovakia, Sweden and the United Kingdom. More than 1,100 combat vehicles will be deployed for the manoeuvres, including 166 tanks, 533 infantry fighting vehicles and 417 armoured personnel carriers, according to a NATO fact sheet
There will also be more than 50 naval assets, including aircraft carriers, destroyers, frigates and corvettes, and more than 80 air assets, including F-35s, F/A-18s, Harriers, F-15s, helicopters and myriad unmanned aerial vehicles.
The last equivalent large-scale NATO exercises were 'Reforger' in 1988, which involved 125,000 military personnel, and Exercise 'Trident Juncture 2018', which involved 50,000.
"'Steadfast Defender 2024' will be a clear demonstration of our unity, strength and determination to protect each other, our values and the rules-based international order," US Army General Christopher G Cavoli, NATO's Supreme Allied Commander Europe, was quoted as saying in a NATO press release.
The exercise is officially based on a fictitious Article 5 scenario "triggered by a fictitious attack against the alliance launched by a near-peer adversary", according to alliance officials.
However, given that Russia has launched the largest conflict in Europe since the Second World War in invading neighbouring Ukraine, 'Steadfast Defender' will inevitably incorporate defence plans based on Russia's actions.
"Russia's war of aggression against Ukraine will shape our understanding of conflict for years to come," a NATO official was quoted as saying in a US Department of Defense press release in the exercise. "NATO is observing the conflict in Ukraine closely in order to improve our readiness and refine our future training, capabilities and innovation."

■ Naval Group completes modernisation of La Fayette-class frigates

(pf) Naval Group has completed the modernisation of the third and last French Navy La Fayette-class frigate scheduled to receive such a refit, *Aconit*, after six months of work followed by a series of dockside and sea trials, the company announced on 13 February 2024.
With the delivery of this ship refurbishment, which was completed at the end of 2023, Naval Group has thus concluded a major modernisation programme involving three ships of the La Fayette class that now have new anti-submarine warfare capabilities and can continue to carry out their missions for five more years.
The other two vessels of the La Fayette class, *Surcouf* and *Guépratte*, are scheduled to undergo more modest structural and technical upgrades before being withdrawn from service in 2027 and 2031 respectively.
Notified to Naval Group in 2017 by the Direction générale de l'armement (DGA), France's defence procurement agency, the contract to modernise the La Fayette class covered the frigates *Courbet*, *La Fayette* and *Aconit*. In particular, the worksite made it possible to deal with a number of obsolescence issues, to modernise several systems and to add new capabilities.
Work on the first frigate, *Courbet*, began in October 2020 and the ship returned to sea in June 2021. The refit of *La Fayette* then began in October 2021 and was completed by November 2022. Work on *Aconit* began in February 2023.
Among the modernisations carried out was replacement of the ships' original combat management system (CMS) with the Senit system developed by Naval Group, improvements to the ships' optronic surveillance capabilities, structural strength and stability improvements, and replacement of the ships' Crotale anti-air defence system with two renovated Sadral systems armed with latest-generation Mistral very short-range surface-to-air missiles.
Moreover, with the addition of a Thales KingKlip Mk2 hull-mounted sonar, the three La Fayette-class frigates now have an anti-submarine warfare capability.

■ BAAINBw signs development contract with ARGE NNbS for short-/very-short-range air defence system

(pf) Germany's military procurement agency, the Federal Office for Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw), signed a development contract with the Short- and Very Short-Range Air Defence System consortium (ARGE NNbS) for the 'Air Defence System, Short- and Very Short-Range' (LVS NNbS) on 25 January 2024.
Set up in 2021, ARGE NNbS consists of three member companies: Rheinmetall Electronics of Bremen, Diehl Defence of Überlingen, and Taufkirchen-based Hensoldt Sensors.
The contract is worth around EUR 1.2 billion (including VAT), with Rheinmetall receiving EUR 607 million, Diehl EUR 339 million and Hensoldt EUR 284 million, reflecting their respective workshares.
"Making sure that Germany lives up to its role as NATO's lead nation in ground-based air defence and the European Sky Shield Initiative, the introduction of the LVS NNbS is a decisive step, closing one of the Bundeswehr's significant capability gaps," Rheinmetall stated in a press release.
The core objective of the LVS NNbS development project is to optimise medium-range air defence as well as developing high-mobility air defence capabilities to protect manoeuvre forces from aerial threats – even when on the move.
Key objectives of the project include achieving the necessary networking of individual components; integration of the medium-range IRIS T-SLM missile; assuring interoperability; and extending the intercept zone to include short-range threats. Networking will enable connection to the IRIS T-SLM fire units currently under procurement as well as to the Skyranger 30 ground-based mobile air defence system to be procured in future.

New commander of US Pacific Air Forces takes up post

(pf) General Kevin B Schneider officially became the new US Pacific Air Forces (PACAF) commander on 9 February 2024 at a ceremony at Joint Base Pearl Harbor-Hickam in Hawaii.

Gen Schneider succeeded General Ken Wilsbach, who commanded PACAF from July 2020 as the third-longest-tenured commander in PACAF's nearly 80-year history.

Presiding over the change in command, US Air Force Chief of Staff General David W Allvin stated, "We are committed to maintaining a free, open, and prosperous Indo-Pacific, but our pacing challenge consistently threatens regional interests, negatively impacting security, sovereignty, and prosperity. I know Gen Schneider assumes command with his eyes wide open to this contrasting strategic approach and I know he will continue to propel the PACAF team forward to meet the challenges of the future."

Gen Schneider returns to the Indo-Pacific having spent 12 years of his nearly 36-year career in the region, most recently serving in theatre as the US Forces Japan and Fifth Air Force commander from February 2019 to August 2021.

Credit: USAF

As the 37th COMPACAF, Gen Schneider oversees 46,000 USAF personnel across the Indo-Pacific – serving principally in Japan, South Korea, Hawaii, Alaska and Guam – spread across nine major US Air Force (USAF) installations and three Numbered Air Forces.

The region accounts for nearly 60% of global gross domestic product, two-thirds of global economic growth, five of the world's nuclear powers, and seven of the 10 largest militaries.

Speaking on his appointment, Gen Schneider stated, "The actions we take to ensure stability and deter aggression in the face of multiple growing challenges will have far-reaching and long-lasting impacts, but we do not do this work alone. The allied and partner air forces we team with in the Indo-Pacific grow stronger and more capable each day.

"This is a time of great consequence for the air force and the nation, and much is resting on the shoulders of PACAF Airmen," the general added.

Gen Wilsbach departed the Pacific after devoting more than 20 years of leadership and service in the region. At the end of February he will become the Air Combat Command commander at Joint Base Langley-Eustis, Virginia.

EDGE Group appoints new managing director and CEO

Credit: EDGE Group

(pf) The United Arab Emirates' EDGE Group announced on 29 January 2024 the appointment of Hamad Al Marar as its new managing director & CEO, effective from 1 February.

Al Marar transitions into his new role at the helm of EDGE following four years within the group's senior management team, where he was president of the Missiles & Weapons cluster, and succeeds Mansour AlMulla, who is returning to ADQ Group following a successful two-year managerial secondment to EDGE.

"In his new position Al Marar will utilise his proven leadership skills and experience within the UAE's defence industry to guide the group into the next phase of its evolution as one of the world's leading advanced technology and defence groups," EDGE stated in a press release. "He will be responsible for its commercial and strategic direction as it significantly diversifies its portfolio of technologically advanced solutions and services, and expands its capabilities across multiple domains in the defence and civilian spheres."

H E Faisal Al Bannai, chairman of EDGE Group, was quoted as saying, "Hamad is a much-respected son of the UAE's burgeoning defence and advanced technology sectors and brings with him tremendous experience and business know-how, having superbly led the Missiles & Weapons cluster as its president, and from his previous senior leadership roles within the industry.

"I am confident that he will lead EDGE into a new era of international growth as it further expands its capabilities and seeks new opportunities, which will enable the group to achieve its objectives and take its place as a world leader in the design and manufacture of next-generation products, solutions, and services across the air, land, sea, and space domains.

The group was established by Al Bannai in November 2019 more than 25 entities from the Emirates Defence Industries (EDIC), Emirates Advanced Investments Group (EAIG), Tawazun Holding and other independent organisations with the objective of providing the UAE with leading-edge defence capabilities.

BAE Systems acquires heavylift UAV specialist Malloy Aeronautics

(pf) BAE Systems announced on 2 February 2024 that it has acquired UK-based heavy-lift unmanned aerial vehicle (UAV) specialist Malloy Aeronautics.

Malloy's approximately 80 strong workforce will continue to operate from its site in Berkshire, supporting its existing customers. Meanwhile, BAE Systems and Malloy, who have been working together on advancing cutting-edge UAV solutions since 2021, will further develop Malloy's existing portfolio, which features a range of heavylift quadcopter UAVs that are capable of lifting payloads from 68 kg to 300 kg over short- to medium-range missions.

In September 2023 the two companies announced they had demonstrated the release of a Sting Ray torpedo from a Malloy T600 electric quadcopter UAV during NATO's Robotic Experimentation and Prototyping with Maritime Uncrewed Systems (REPMUS) exercise in Portugal.

Credit: BAE Systems

The companies have also been collaborating to develop the 300 kg T650 electric heavylift UAV as a potential new solution to deliver a cost-effective, sustainable rapid response capability to military, security and civilian customers.

"Our acquisition of Malloy Aeronautics is part of our ongoing strategy to develop and invest in breakthrough technologies that augment our existing capabilities and provide our customers with the innovation they need in response to evolving requirements," Simon Barnes, group managing director of BAE Systems' Air sector, was quoted as saying in a company press release. "We're confident that the synergy between our two companies will pave the way for even greater achievements in uncrewed aerial systems and technologies."

Beachheads and amphibious armour

Sam Cranny-Evans

Establishing a beachhead is the defining component of an amphibious assault. Fail, and the following forces may have to find an alternate landing site or fight their way onto shore. Succeed and it is possible to achieve surprise at scale, which has been identified as an important component of military success.

The impact a successful amphibious assault can achieve was demonstrated on D-Day, of course, but also at the Battle of Inchon in the Korean War. Amphibious armour can play a useful role in establishing and securing a beachhead; they can carry firepower to support an assault, as China's ZTD-05 does with its 105 mm gun, and provide armour to increase survivability of assaulting infantry like the Assault Amphibious Vehicle (AAV)-7. However, amphibious armour carries additional compromises on top of those inherent in conventional armoured fighting vehicle (AFV) design. This piece will examine the design of amphibious armoured vehicles, and how they are developing to meet the evolving battlespace.

Credit: US DoD

A Bradley exits the water in 1981 with its trim vane deployed. The trim vane was removed in the upgrade to the M2A2 standard, which added additional spaced armour.

Defining amphibious AFVs

For the purposes of this article, an amphibious AFV is regarded as a vehicle with a ship-to-shore capability. It may not always be used, but it essentially requires an AFV that is not just able to float, but float for many hours and navigate open ocean, surf and potentially challenging terrain upon reaching the shore. This typically means that it can be launched from a larger vessel such as the US Navy's *America* class or Turkey's Landing Helicopter Dock (LHD) TCG *Anadolu*. Generally speaking; amphibious operations are enabler-intensive; they require a lot of firepower, valuable vessels coming within very close proximity to land, and many specialised platforms with restricted utility in other scenarios. This may be the reason that they are a relatively rare commodity amongst the world's AFVs.

Author

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Historically, the AAV7 and its variants represent arguably the most successful design, with 12 users and more than 1,000 vehicles sold. However, more modern designs have emerged since, including the ACV from Iveco and BAE Systems, which is due to replace the AAV7 in USMC service, China's Norinco ZBD-05 family, which has been exported as the VN16 to Thailand and Venezuela, and the Zaha – a domestic design from Turkey's FNSS.

The above definition excludes vehicles that are technically amphibious such as the BMP-2. The BMP-2, as originally envisaged, could raise a trim vane at the front of its hull and navigate bodies of water using its tracks for propulsion at a speed of 7 km/h. However, it is primarily designed to use this capability to cross inland bodies of water and is less capable of conducting a ship-to-shore operation. Its low speed can lead to challenges in fast-flowing rivers, however, its ability to cross a river with relatively little preparation, theoretically enables a Russian motorised rifle formation to quickly seize a bridgehead on the opposite side of a river using its BMP-2s and prepare for its tanks to join after snorkelling across on the riverbed. Many other Cold War era vehicles had similar capabilities, the original M113 is one example and even the M2 Bradley was technically amphibious at the beginning, however, subsequent up-armouring has effectively removed this capability. In any case, these kinds of vehicles are not well suited for the kind of ship-to-shore operations considered here.

Building amphibious fighting vehicles

Amphibious vehicles tread an awkward line in AFV design. Where standard AFVs must balance mobility, firepower, and lethality, an amphibious AFV must balance all of this with the often-contradictory challenges of having to float and steer in water. The design characteristics that make a vehicle perform well on land; a vehicle length-to-track centre ratio of ~1.6, a sloped glacis, and others, are not correlated with good performance at sea. An amphibious vehicle must be watertight and be able to transition from a ship's well deck to the sea without sinking. This requires a buoyancy reserve of at least 25% of the vehicle's weight. Ideally, an amphibious vehicle will also be able to self-recover if it rolls 100°, a non-amphibious but water capable vehicle for comparison, should be able to pitch or roll between 5° and 15° without flooding its engine. An amphibious vehicle also needs to be able to turn quickly within its own length and navigate a 'plunging surf' with waves up to 3.6 m.

The vehicle should also have two propulsion systems: its tracks or wheels for operation on land, and a system for propulsion at sea. The design also needs to minimise drag in the water, but external appendages such as wheels and tracks add a lot of drag. Some vehicles are propelled by their wheels or tracks, which produces a relatively slow water speed that can be estimated by $0.5[\frac{hp}{ton}]^{0.75}$. Put more simply, it is rare for a vehicle using its wheels or tracks to exceed 10 km/h at sea. True amphibious vehicles typically employ water jets or propellers for propulsion and aim to exceed this by some margin. The former method takes up additional space inside the vehicle, the latter adds drag to the outside. However, water jets generally provide greater speed and manoeuvrability at sea.

The requirements for amphibious AFVs are therefore complicated to a further degree than conventional AFVs. Consider, for example, the impact of protection requirements on an amphibious vehicle. The greater the protection, the greater the vehicle weight. This naturally equates to the requirement for additional automotive performance as it would on land; however, it may also increase vehicle size as the total volume must increase to maintain buoyancy. This in turn will impact manoeuvrability at sea and on land.

Credit: USMC/Lance Cpl Andrew Cortez

The ACV has been developed to replace the AAV in USMC service. It has experienced some teething problems, which is to be expected of an AFV trying to achieve such a complex set of design requirements.

Modern amphibious contenders

Turkey revealed the Zaha amphibious assault vehicle at IDEF in 2019 after signing a contract with the Turkish Ministry of Defence in 2017. Turkey has procured 27 Zahas, 23 of them in the APC role, two as command vehicles and two as recovery vehicles. It has a top speed on land of 70 km/h and can reach 12 km/h at sea. The vehicle provides room for 18 dismounts and three crew, all provided with blast and ballistic protection. The base structure of the hull is built from 5000 series aluminium alloys selected for their corrosion resistance and ease of welding. Ceramic armour is fitted over the top of the aluminium to provide ballistic protection. The aluminium in the bottom of the hull is fitted with supports and thickened for blast resistance. It has a 30% buoyancy reserve and can travel at 12 km/h in Sea State 2. It is capable of travelling in Sea State 4 (1.25 to 2.5 metre waves) with the addition of a special kit.

FNSS also manufactures the Kunduz armoured amphibious bulldozer, which requires a crew of two and uses an aluminium hull to provide weight-efficient blast and ballistic protection as well as the necessary buoyancy reserve. The 19 tonne vehicle can travel at 8 km/h on water using two waterjets or 45 km/h on land, and it uses a fixed dozer blade (which relies on the vehicle's hydro-pneumatic suspension system for elevation and depression), to provide earthmoving capabilities. Both vehicles are used by the Turkish armed forces and reflect the importance placed upon amphibious capabilities by Turkey. The Zaha was developed to provide the Turkish armed forces with an amphibious capability to launch from the TCG *Anadolu* LHD. The Anadolu is expected to carry uncrewed aerial vehicles (UAVs) as well as more conventional fixed- and rotary-wing systems. Alongside 27 Zahas, it will also have room for 13 tanks. Overall, it will represent potent vessel in terms of capability, providing that it can be protected from the anti-ship cruise missiles that have spread throughout the Middle East.

Credit: FNSS

The Zaha is designed to be used in conjunction with Turkey's TCG Anadolu. It is likely that it will operate alongside uncrewed aerial platforms launched from the LHD.

The AAV7 is probably the best-known amphibious AFV. It has been through multiple upgrades and modifications and deployed operationally to Afghanistan. However, the USMC is seeking is replacement in the wheeled 8×8 ACV. The ACV is manufactured and developed by BAE Systems and is based on Iveco Defence Vehicles' SuperAV design. It reached its initial operating capability in 2020 and more than 200 had been delivered in an APC configuration by March 2023. The vehicle is being developed into several variants; the ACV-P is the standard APC, the ACV-30 will carry a Kongsberg RT20 turret armed with a 30 mm cannon. There is also the ACV-C command variant, a recovery variant and plans for a reconnaissance variant.

The ACV is a 32 tonne vehicle with space for three crew and 13 dismounts. It can travel 19 km on open ocean at speeds greater than 11 km/h, with a 400 km range once ashore. The vehicles are designed for ship-to-shore operations and are provided with

Credit: BAE Systems

Two ACVs are shown here along with the Rex II unmanned vehicle from IAI/Elta. MUM-T may provide greater situational awareness and reduce casualties during amphibious operations. However, they do add challenges in terms of logistics, maintenance, and support.

blast protection that is close to that of a mine-resistant, ambush protected (MRAP) type vehicle, as well as protection against ballistic threats. As the vehicles are still relatively young for an armoured vehicle family, they are still exhibiting teething problems. Some were found to roll in surf heights that exceeded 1.3 meters in 2022. The ACV-C has been found to lack sufficient beyond line-of-sight (BLOS) radio capacity to command battalion or regimental operations on the move. At the moment, crew must stop the vehicle and set up additional antennas to achieve this. Initial testing also found that the vehicles were struggling to meet their required mean time between operational failures, although this was primarily attributed to the remote weapon station.

Furthermore, the ACV has been used as the test bed for two futuristic trials. In February 2023, BAE tested the Stalker and Indago small uncrewed aerial vehicles (UAVs) on an ACV-Command, Control, Communication and Computers, Uncrewed Aerial Systems (ACV-C4UAS) variant. The UAVs were provided by Lockheed Martin's Skunkworks to conduct long-range reconnaissance. Later that year, the ACV-C4UAS variant was used in a manned-unmanned teaming (MUM-T) trial, where it worked alongside the Rex MK II Unmanned Infantry Combat Support System from Elta. The Rex MK II can perform several roles including ISR, logistics support and it can carry weapons. It is not clear what capacity it was used in during this demonstration. However, it is clear that MUM-T is an area of importance for amphibious vehicles, as shown by other amphibious vehicle programmes.

Japan, for example is developing a tracked amphibious vehicle under a project called Future Amphibious Technology Research (FAT-R) in cooperation with the US. Japan is home to more than 200 islands, many of them surrounded by extensive coral reefs. In the event of an opponent seizing those islands, Japan expects to use amphibious forces to rapidly retake them. The FAT-R is designed around completing this mission, and to that end is powered by a 3,000 hp engine with rubber tracks, and a transmission that can generate an "upward driving force". This "upward driving force", combined with the thrust of the waterjets enables the vehicle to climb a 50° slope on a coral reef, and onto its surface, even in shallow waters. Japan has also explored the option of remotely operating the vehicle so that MUM-T can be used to reduce casualties during those operations should they ever occur.

China has also taken a comprehensive approach to its amphibious capabilities and developed the ZBD-05 family of tracked AFVs. The base variant is the ZBD-05 armed with a 30 mm automatic cannon and an externally mounted Red Arrow-73 series ATGM. It provides room for 11 dismounts and requires a crew of three. Notably, the family also includes the ZTD-05, an amphibious variant armed with a 105 mm main gun, and another that can launch a fixed wing reconnaissance drone whilst at sea. All variants are also capable of firing whilst at sea, and this is routinely demonstrated by the PLA in well-oiled training videos. The vehicle is fitted with a bow blade at the front, and a flat blade at the rear, both of which that are extended for swimming and work to create a hydroplaning effect, according to the PLA. As it enters the water, the suspension raises the roadwheels and tracks to reduce drag, and the engine's hp is increased to 1,500, resulting in a reported top swim speed of 25 km/h. Firepower is a critical component for amphibious vehicles – they must be able to win a firefight upon reaching the shore, and this is where doctrine becomes important.

Fighting with amphibious vehicles

US doctrine states that there are many reasons to conduct amphibious operations, and that many of them are far different from the archetypal image of a D-day style landing with waves of infantry borne ashore in landing craft. Within this operational category, amphibious vehicles can play a variety of important roles, regardless of the operation type. They might deter an aggressor during an evacuation, for example, or provide a rapid manoeuvre option to outflank an opponent from an unexpected direction and turn the tide of a war.

In the US context, amphibious operations are conducted by an Amphibious Force, which consists of an Amphibious Task Force (ATF) and a Landing Force. An ATF may consist of various assets from the US Navy, Military Sea Lift Command, and Maritime Administration assets. The Landing Force is provided by the

Credit: Russian MoD

The ZTD-05 deployed by China is armed with a 105 mm main gun that it can fire whilst at sea. The PLA places a premium on the delivery of firepower from its amphibious vehicles during the ship-to-shore phase of an operation.

USMC or US Army. They operate together to conduct ship-to-shore operations, potentially from over the horizon. It observes that the sea offers a large manoeuvre space for amphibious operations, and that the ATF commander should seek to maximise the use and effects of electronic warfare, deception, firepower, and developments in command and control to achieve surprise or advantage. It also states that the preferrable tactic against heavily defended positions is to bypass them, which of course requires manoeuvre at sea and excellent situational awareness.

If an enemy position cannot be bypassed, the ATF will have to engage it from the sea using precision strike assets delivered from the sea and air. It is clear that the process of building and deploying an Amphibious Force as well as building combat power ashore leads to multiple complexities and points of vulnerability. This requires the effective coordination of all arms of the military if it is to be successful. Firepower plays an important role, especially in a world where anti-ship cruise missiles (ASCMs) have proliferated so widely, potentially holding amphibious task forces at risk, whilst anti-tank guided missiles (ATGMs) will likely present a threat to amphibious vehicles as soon as they come within range. Furthermore, the quantity of amphibious vehicles deployed by most nations is much smaller than those used in the past. So, it stands to reason that the risk of an amphibious force suffering catastrophic losses – given the greater accuracy of modern weapons, and the lower number of vehicles that can be deployed – is perhaps higher than ever before.

Once ashore, amphibious vehicles must maintain excellent mobility to widen a beachhead and drive the opposing forces away from the next wave of troops that will inevitably follow. This combination of mobility and lethality is important for all vehicles, but an amphibious platform can expect to find sand both wet and dry, shingle, clay, and many other substances that are challenging for armoured vehicles. With exceptions such as ZTD-05, most will rely on their dismounts to supplement their on-board firepower, as well as very close cooperation with supporting arms to defeat well-emplaced and protected opponents. It should therefore go without saying, that amphibious operations are also inherently combined arms operations, and they should not be expected to succeed without combined arms coordination.

In sum

Every vehicle covered in this article is capable of, or in future practice likely to perform with some form of MUM-T. While it is generally true that land platforms are moving in this direction, it is likely that amphibious platform users will develop unique MUM-T use cases in establishing and securing beachheads. Beyond this, the design constraints imposed on armoured vehicles by physics are apparent. None of the designs here are radically new in terms of their capabilities, and all must take account of and balance, wave height, terramechanics, and likely threats within their design. Finally, in any operation, amphibious vehicles will require extensive combined arms support. Regardless of the scale of MUM-T that occurs, they will require close air support, air defence, and naval gunfire throughout an opponent's depth to be successful in many situations. In this regard, the nature of securing a beachhead is not all that different from 1944. Overall, perhaps it is the case that while the platforms securing a beachhead may change, the nature of operations required to do so successfully will not. As such, a country's ability to deliver in this regard matters most.

Modern artillery fire control equipment is a requirement for all armed forces

Leonid Nersisyan

The ongoing Russia–Ukraine war has shown that artillery – traditionally known as the 'king of the battlefield' – remains a key element of any country's armed forces. This runs contrary to the previous assessment in many countries that modern guided munitions and aviation would mostly replace artillery. It has also become clear that modern digital artillery fire control systems can greatly improve artillery's effectiveness, precision, munition expenditure, and reduce the time needed to react and open fire. There is a need for more attention to developments in this area, in terms of both existing and future systems, and their application on the battlefield.

Artillery fire control systems in a towed or self-propelled howitzer (SPH), mortar or multiple launch rocket system (MLRS) normally consist of a package of sensors (meteorological, inertial and satellite navigation, and in some cases muzzle velocity radar), along with a ballistic computer, communications system and automated gun laying mechanism. Almost all modern artillery now being produced are being fitted with a modern fire control system (FCS).

The American 155 mm M777A2 howitzer, for example, is equipped with an FCS produced by General Dynamics Mission Systems simply called 'Digital Fire Control System' (DFCS). It includes onboard navigation, digital communication with the fire direction centre (FDC), and automatic gun laying capability. The system is fed data from an inertial navigation system (INS), Global Positioning System (GPS), and a vehicle motion sensor to determine the weapon's exact location and orientation for precise aiming and firing. Integrated radio communications enables data transmission between the FDC and the howitzer, and the system includes multifunctional displays to show mission data to the crew. The use of an INS allows the FCS to continue operating in the absence of a GPS signal. Aside from these capabilities, DFCS allows the M777A2 to fire the M982 Excalibur precision-guided munition.

Credit: US Army/Capt Joe Bush

M777A2 towed howitzer during the Division Artillery Readiness Test at Fort Bragg, on 16 September 2015.

Similar FCSs are also common on modern SPHs, such as the Hanwha K9 or BAE Systems Archer families, but unlike towed howitzers, SPHs can also supplement these with an automatic loading system, allowing for higher sustained rates of fire. Modern digital FCSs have become a critical asset for any modern artillery system, but many countries still operate legacy systems lacking these.

Upgrading legacy weapons

Legacy artillery systems, especially ones of Soviet origin, are outdated in terms of fire control – they are operated manually, with fire calculations based on range tables. Yet despite this, Soviet artillery systems such as the D-20 or D-30 remain valuable assets and are likely to stay in service for many years or even decades to come.

Several types of fire control systems are under development through industry and state efforts. They can be divided into three groups:

1) Integration with offboard intelligence, surveillance, and reconnaissance (ISR) sensors for targeting;
2) Comprehensive on-board performance upgrade packages;
3) The use of non-integrated, offboard software-based solutions for speeding up ballistic calculation as well as command and control (C2) functions.

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Offboard ISR systems, such as modern sights for forward observers (FOs), typically integrate sensors (day and thermal channels, and a laser rangefinder) along with communications systems and software to enable FOs to quickly calculate target coordinates and relevant fire control data to a friendly artillery battery. A good recent example of such a system is the Russian Malakhit automated fire control station, which consists of a tripod-mounted sight with day and thermal channels, a laser rangefinder and designator, radio, global navigation satellite system (GNSS) positioning equipment, and a firing data computer. Malakhit derives the coordinates of the target designated by the forward observer and calculates the relevant firing data for the battery to which it is attached. According to Rosoboronexport, after the target is detected, the firing data can be delivered to the battery in 15 seconds.

Comprehensive upgrade packages for legacy artillery systems usually aim for major platform-level capability upgrades. They typically include components similar to those used in modern artillery weapons such as the aforementioned DFCS. Examples of such upgrade packages are LINAPS, produced by Leonardo, and the ATMOS upgrade package from Elbit Systems (distinct from the ATMOS SPH also offered by Elbit).

LINAPS includes a muzzle velocity radar, the FIN 3120L INS/GNSS navigation unit, a ballistic computer, a battery power module, and detachment commander's data terminal (a tablet-based solution). This package can be integrated with any artillery or mortar platform. The ATMOS upgrade package goes even further, as it not only includes modern fire control system elements but also offers users the option to convert towed guns (105 mm, 122 mm, 130 mm, 152 mm, and 155 mm) into SPHs, by mounting them on 6×6 or 8×8 truck platforms. The fire control elements include INS/GNSS navigation systems, muzzle velocity radar, a ballistic computer, and can be integrated with armed forces' existing command, control, communications, computers intelligence, surveillance, and reconnaissance (C4ISR) systems.

The lightest and cheapest options available on the market are non-integrated offboard software solutions, which can be laptop, tablet, or even smartphone-based. This kind of software typically allows for integration of C2 processes, ballistic calculations, and in some cases feeding intelligence data from different sources such as unmanned aerial vehicles (UAVs). One of the best-known examples of this type of solution was the 'Ukrop' app developed by Ukraine for use during the War in Donbas, during 2014–2015.

Credit: Rosoboronexport

Russia's 'Malakhit' ISR system was developed for forward observers, and in addition to improving the accuracy of unguided rounds, it can also be used to guide semi active laser (SAL) guided munitions, such as Kitolov-2M.

The app's name stems from a derogatory name used by some Russians for Ukrainians. It features a ballistic calculator, which allows users to calculate firing data after choosing their target on a digital map, and adding in the details of the gun type and ammunition nature being used. The application was so effective that even Russian-backed Donbas separatists started downloading and using it, while this was still possible.

This project was further developed during the 2022 Russian invasion of Ukraine, and

Credit: Logika

Offboard software-based solutions such as Ukraine's 'Kropyva' app have a major advantage over other means of improving artillery insofar as they do not require modifications to the weapons they work with.

now the Ukrainian Armed Forces (UAF) are operating the much more capable 'Kropyva' app. This app allows the integration of intelligence data from satellites, UAVs, and land units into decision-making and targeting processes. Intelligence data is used to facilitate and automate C2, providing commanders with data, supporting decision-making, and enabling effects. The app has been shown to be effective, and Ukrainian troops used Kropyva and GIS Arta C2 software to coordinate artillery strikes from the start of Russia's February 2022 incursion.

Commanders use such systems to synchronise reconnaissance and artillery operations. Once targets are detected and identified by UAVs or satellites, the information is uploaded onto an interactive map, enabling commanders to allocate targets to nearby batteries and, at times, to individual guns. The entire operation is managed using tablets and laptops connected to the internet via Starlink or other sources. The time claimed from target detection to firing is approximately 60 seconds, significantly faster than conventional targeting procedures. Moreover, the claimed circular error probable (CEP) for firing unguided ammunition is notably reduced. This aligns with the observed outcomes of artillery use by the UAF, including numerous direct hits on moving armoured vehicles – an uncommon feat for artillery. The improvement to decision-making provided by such apps enabled the UAF to mount a robust defence against the Russian Armed Forces during the spring and summer of 2022. Despite having significantly fewer pieces of artillery and lower ammunition usage, the UAF made effective use of their resources. Official Ukrainian sources estimated the rate of fire from Russian artillery initially at 60,000 shells per day, which were then estimated to have decreased to 20,000 shells per day. Concurrently, US sources estimated the Ukrainian rate of fire to be in the region of 4,000–7,000 shells per day. Using offboard software to assist with targeting and C2 facilitates the more efficient use of individual artillery pieces compared to coordinating fire with artillery detachments in classical batteries. This in turn complicates counter-battery fires, particularly if camouflage is employed effectively to conceal the locations of artillery detachments.

It is noteworthy that this concept is being developed and applied by many small and mid-sized players in the armaments market, including Romania and Egypt. Even Armenia, with limited funds and faced with a challenging security situation, has been able to create a digital solution very close to Ukraine's Kropyva. This approach to fire control is much more cost-effective than bespoke hardware-based solutions, which can of course provide greater pace and accuracy, but take more effort, money, and time to introduce to the armed forces. The combination of ISR UAVs, which are now becoming a very affordable means of waging war, and such software packages can boost the artillery capacities of even the smallest and least well-equipped militaries, providing them with artillery capabilities not dramatically worse than major NATO armies.

Credit: Logika

Ukraine's 'Kropyva' app has proved itself to be a highly cost-effective means to improving artillery accuracy and C2.

Integration

The largest and most important pillar of artillery fire control is integration of all available weapons into the armed forces' C4ISR network. Many of the solutions mentioned above provide options to connect modern or upgraded guns to the general armed forces network. For example, the US FDC allows integration of full artillery brigade and coordination of firing missions using a computerised command centre. Batteries and even individual guns can acquire very detailed data on the number and type of munitions that should be fired at particular targets, making operations much more coordinated and effective.

In Europe, various actors have also has also placed great emphasis on such integration. For instance, the Thales 'Commander Fire' system integrates field artillery assets from the command post down to the individual gun. This allows users to manage field artillery intelligence, planning, manoeuvres, and fire missions as an integrated system, with tactical data shared across networked information nodes. This provides shared situational awareness and allows reconfiguration between organic or attached artillery units, improving both effectiveness and survivability. Commander Fire also facilitates automated mission management to support various artillery tasks, including planning, target acquisition, coordination of manoeuvres, airspace management, fire control, and logistics.

Once again, it is important to note that there are new players on the market even in this highly complex domain. Compared to the situation 20–30 years ago, digital solutions have become significantly more affordable, and many countries have IT capabilities that allow the creation of at least limited networks within their armed forces, in some cases even using dual-use or commercial hardware. This applies particularly to communications systems. Some solutions mentioned above such as Kropyva provide valuable C4ISR capabilities in addition to pure artillery fire control, even if their role is primarily to coordinate artillery rather than other armed forces domains.

The last important perk of using such tools is that they can alleviate many of the issued faced by armies using multiple different kinds of artillery pieces, made by different manufacturers to different standards, and even different calibres. Instead of having to train crews on existing firing tables for each individual system, software-based systems can easily provide the required firing data to any type, be it a Soviet D-20 towed howitzer or a French CAESAR SPH. This reduces the time needed to make artillery crews ready for battlefield deployment.

Credit: SSU

The massive rise in battlefield drones has provided new opportunities for improving artillery fire control and battle damage assessment. Yet these also pose a serious threat to artillery, since drones similar to the first-person view (FPV) example shown can be an effective counter-battery fire tool.

Conclusions

The most recent interstate wars, including the ongoing Russia–Ukraine war and the Second Nagorno-Karabakh War in 2020 show that traditional approaches to artillery fire control are not particularly effective on the modern battlefield compared to digital solutions. Even if armed forces possess a large number of artillery assets, without a certain level of digitalisation, artillery typically reacts too slowly and relies too much on weight of fire to achieve effects. Moreover, legacy systems used in large batteries become a much easier target for counter-battery fire, especially when they need to stay in one position for a long time, since aerial reconnaissance capabilities have dramatically increased, with UAVs becoming a very common sight on the modern battlefield.

Modern artillery FCSs cut reaction times and make it possible for units to operate effectively even when dispersed, through their use of networked communications. Moreover, the greater accuracy of fire they can provide not only boosts the effectiveness of fire missions, but also reduces munitions expenditure – even more if the system allows the use of GNSS or semi-active laser (SAL) guided rounds. The procurement of artillery with modern FCSs or the introduction of upgrade packages/software solutions for legacy weapons is a necessity. At the same time, the much higher availability of such systems on the market enables smaller countries' armed forces to rapidly improve their capabilities. This, along with other technologies becoming more affordable, can improve the odds for smaller countries seeking to defend themselves against larger adversaries. ■

The path ahead for tube and rocket artillery

David Saw

The ongoing conflict in Ukraine has very clearly demonstrated the continued importance of artillery – both tube and rocket – on the modern battlefield. It has also supplied real world data on what artillery can achieve today and what it needs to achieve to meet the conditions expected in the conflicts of tomorrow. Developers of artillery systems are already working on key technology areas that will be required to deliver capabilities that could be decisive in future conflicts. However, success in the future will not just be a matter of improving the physical performance of artillery systems, it will be a matter of integrating artillery with other systems and sensors to maximise that performance.

The US Army field manual "Fire Support and Field Artillery Operations (FM3-09)" looks at fire support (FS) and describes it as: "A rapid and continuous integration of surface-to-surface indirect fires, target acquisition, armed aircraft and other lethal/non-lethal attack/delivery systems that converge against targets across all domains in support of the maneuver commander's concept of operations." The manual also states that: "FS is inherently joint, conducted in all domains and simultaneously executed at all echelons of command. Lethal FS attack and delivery systems consist of indirect fire systems and armed aircraft to include field artillery (FA), mortars, naval surface fire support and air-delivered munitions from fixed-wing and rotary-wing aircraft."

While FS might be described as 'inherently joint', the realities of the situation could leave a ground forces commander more reliant on organic assets, such as FA, for FS capabilities. The availability of fixed-wing aircraft for ground support is dependent on winning air superiority and on being able to subdue or degrade hostile air defences over the battle area. The availability of rotary-wing support is also dependent on air superiority and reducing the threat of hostile air defences. Naval gunfire support (NGS) is always welcome, but its presence obviously depends on the location of the battle area. All of which means that the primary source of FS that a ground commander can rely upon is FA.

Credit: US Army

Pictured: M142 HIMARS rocket artillery systems deployed to Ali Al Salem Air Base, Kuwait. Peer war scenarios are likely to rely quite heavily on artillery for fire support.

Matters of doctrine

Returning to FM3-09, FA is described as follows: "equipment, supplies, ammunition and personnel involved in the use of cannon, rocket or surface-to-surface missile launchers". These are supported by non-lethal capabilities such as Cyberspace Electromagnetic Activities (CEMA), information-related activities, space and munitions, such as illumination and smoke. The end result is that: "The commander employs these capabilities to support the scheme of maneuver, to mass firepower and to destroy, neutralize and suppress enemy forces."

Significantly, this US Army doctrine document does not assume that US and allied forces will have either superiority in numbers or in equipment capability in comparison to the FS capabilities of a peer competitor. US and allied forces have not operated without air superiority and FS superiority in the modern era, meaning that FS superiority will have to be fought for.

It is therefore likely, according to FM3-09, that future operational environments will see a situation where "US and allied forces' FS assets will be outnumbered and outranged by peer systems. To defeat peer forces in large-scale combat, US forces must first penetrate anti-access/area denial (A2/AD) systems, establish a position of relative advantage, retain the initiative and prevent enemy forces from achieving mass, momentum and continuous land combat A balanced application of both firepower and maneuver is essential for US forces to achieve these goals. This calls for synchronisation and convergence across the FS system to attack high-payoff targets (HPT) across the width and depth of the operational area (OA)."

The definition of an HPT is a target whose loss to the enemy would significantly contribute to the success of friendly forces. Whereas a high-value target (HVT) is a target that the enemy commander requires for successful mission completion. In US FS doctrine, not all HVTs become HPTs. The successful delivery of FS could take place in numerous different environments around the world featuring differing operational requirements. As such, the FS system must be flexible to operate in all of these different circumstances. Added to which, "Threat operations across all domains will

attempt to degrade all aspects of FS, from command and control (C2) to target acquisition (TA) to delivery."

Within all of this, the fundamental mission of artillery still remains the same, being the destruction, neutralisation and suppression of enemy forces, particularly their FS structure, C2 elements, TA capabilities, weapon systems and the supporting structure that sustains these capabilities. The mission remains the same, but achieving the desired effects requires new methodologies to deliver the FS required to prevail against peer or near-peer competitors. To do this will also require significant developments in the means of delivering FS; advances in tube and rocket artillery that will outpace the capabilities of threat systems in terms of range, accuracy and on-target effects. If this can be achieved, then friendly artillery can successfully conduct counter-battery missions, reducing the capability of hostile artillery to influence the fight and delivering a situation where FS superiority is achieved across the desired portion or totality of the OA.

The reality of all of this is that artillery, whether tube or rocket, still remains an arm of decision in ground combat. Napoleon said: "It is with artillery that one makes war." That was true then, it is still true now and will remain so into the future. The difference comes in the practical application of artillery, the integration of weapons, sensors and command systems to deliver the necessary results. Another important aspect is to think beyond the immediate battlefield, the scope of artillery is far broader than that. Artillery will range deep into enemy positions, its deep fires capabilities will seek to shape the OA, so that enemy forces at the frontline are separated from their supporting infrastructure, denied access to supplies and replacements and consistently degraded leading to loss of effectiveness. Delivering results of this nature once required airpower, now artillery can perform this mission as well and with much less risk.

Credit: Ukraine Joint Forces Command

The war in Ukraine has laid bare the importance of indirect fires and adequate munitions supplies in peer conflict.

Tube evolution

In an ideal world, tube artillery, whether towed or self-propelled, would be able to achieve extremely long ranges, while minimising dispersion, and achieving high levels of accuracy with standard projectiles. In addition, there would be the option of using guided-rounds to achieve even higher levels of accuracy, although this would come at a substantially increased procurement cost per round. Over the years, the growth in range exhibited by conventional 155 mm rounds has conclusively demonstrated that more performance can be extracted by weapons in this calibre.

The evolutionary possibilities in 155 mm guns and ammunition have not been exhausted, on the other hand there is still the challenge of defeating dispersion. One possible solution to meet the requirements for future long-range fires, while offering maximum accuracy and minimised dispersion, would be to look beyond the 155 mm calibre and consider something larger. At one stage, the US had the M107 self-propelled gun with 175 mm gun and the M110 203 mm howitzer. The M107 did not stand the test of time, with many being converted to the M110A2 configuration. The M110 could achieve – considered respectable for the time – a range of 25 km, but was replaced in the 1990s by the M270 Multiple Launch Rocket System (MLRS).

Assuming that there was a user prepared to look beyond the standard NATO 155 mm artillery system and who decided that 203 mm was the optimum calibre – and could pay for the privilege of having a new gun, accompanied by new ammunition, fuzing and a new charge system developed – then you could have the possibility of a rather special tube artillery system. Larger-calibre projectiles are thought to be less prone to dispersion at extended range and being larger, they can have a larger explosive filling or a more substantial submunition payload. There are potentially numerous possibilities with a larger calibre artillery system, but before embarking on such a programme, one would have to ask if this was a valid use of resources? The answer is probably not. The performance evolution of artillery rockets for MLRS and HIMARS really removes the need for a larger calibre tube artillery system, as rockets already fill that niche.

Credit: DE&S

Pictured: BAE Systems Archer SPH. The British army is acquiring 14 Archer SPHs, with Initial Operating Capability (IOC) due in April 2024.

Credit: KNDS

Pictured: RCH 155 SPH. Germany has so far ordered 18 such systems for delivery to Ukraine.

In fact, there is a body of opinion that believes that investing resources in major range extensions for 155 mm artillery systems has no merit. For example, while the British Army currently has 29 M270 MLRS launchers, its long-term objective is to have a force of 61 M270 launchers to provide it with its desired 'deep fires' capability. Various types of long-range rocket will be developed/deployed. The British Army also has the 155 mm self-propelled artillery system, the Mobile Fires Platform (MFP) and, at least initially, the outline MFP requirement was in 'deep fires' territory.

The original outline MFP requirement provides an insight into what was thought possible with future tube artillery systems. The British Army wanted the MFP artillery system to be air transportable in an A400M, and were looking at a range of out to 80 km with a rate of fire of 20 rounds per minute that could be sustained for 10 minutes. This new system was to be compliant with the NATO Joint Ballistic Memorandum of Understanding (JBMOU), which standardised 155 mm artillery, for example via a 23 litre chamber volume, and 155 mm artillery ammunition, with numerous STANAG requirements also forming part of the overall artillery design structure for NATO. The MFP started with a very ambitious set of requirements, many of which were difficult to achieve, and many were deemed unnecessary. As MFP was to be acquired under the Close Support Fires heading, there was therefore no need for a maximum range of 80 km, as that was a deep fires requirement that would be met by future MLRS developments. It was felt that there was no need to duplicate capability, hence the performance requirement for MFP started to be dialled down.

Germany also has a future 155 mm requirement which was described as a 'future medium-range indirect fire system'. The objective was to equip German ground forces with what eventually became a wheeled 155 mm artillery system. There were a number of factors that were considered to be important in the system selection process; these included reduced crew numbers meaning a high degree of automation was required, range and accuracy were key criteria, but achieving long-ranges with expensive guided rounds was not a metric for success. Long-range engagements were thought to be more suitable for rocket artillery systems and more cost-effective as well.

In 2022, the German government ordered 18 RCH 155 artillery systems from KMW (KNDS) for Ukraine, due to be delivered in 2024. German media reports from 2023 suggest that the RCH 155 has been selected for the German medium-range artillery requirement and that a first official order will be placed in 2024, and that eventually some 168 systems will be acquired, with first deliveries from 2026. This is a 155 mm L52 system mounted in an artillery gun module that also holds 30 projectiles and 144 modular charges, with full automatic loading. The artillery module is mounted on a Boxer armoured vehicle platform with a crew of two.

The RCH 155 was chosen over a proposal from Rheinmetall that was the product of cooperation between the German company and Elbit Systems in Israel. Elbit had been selected by the Israeli military to develop a fully automatic 155 mm artillery system installed in a turret that can be mounted on a 10×10 truck chassis, allegedly due to be named 'Ro'em'. Rheinmetall looked to build a European solution based on the foundations of the Elbit design, with the turret mounting the 155 mm L52 gun of the PzH 2000 (the same Rheinmetall gun is used in the RCH 155) based on an HX 10×10 truck chassis. While their gun system might not have prevailed, Rheinmetall will still be the primary source of ammunition and charges for German artillery.

Range extension

Rheinmetall already has a road map covering the development of 155 mm projectiles, fuzes, charges and guns over the long-term. Rheinmetall states that the 155 mm L52 gun of the PzH 2000, using

Credit: Hanwha

Pictured: South Korean K9A1 SPH. Hanwha has previously unveiled a long-term upgrade roadmap for their K9 family of SPHs.

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

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

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

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

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

Credit: DALO

Credit: KNDS

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

A key component of enabling rapid and precise fires whether on various types of howitzers or heavy mortars is 1; digitization of fire control, 2; utilizing meteorology data and finally 3; updating base line firing tables with accurate and current muzzle velocity data. These three parameters were already found in a US DARPA study on improving accuracy of mortars from 2005. And to be correct, the third factor was recommended to be solved through "lot firing tables", to be more specific than "type firing tables". However building a firing table needs the use of 800-1000 rounds, which may not be the best use of the ammunition during "ammunition famine". The question then is; how to obtain more effective fires without unnecessarily depleting scares ammunition resources?

For the last part (muzzle velocity data), Weibel's muzzle velocity radars of the 700-series provides new and legacy weapons with an easily integrated muzzle velocity radar system, from which data can be used by the fire control system to correct the platform's fires. From first round fired, the muzzle velocity data will make reducing unwanted dispersion possible, thus the desired effect is achieved faster and with less rounds.
On modern lightweight and mobile artillery systems, the MVR is e.g. integrated on the Hawkeye lightweight howitzer. Based on the Hummer CT-2 platform, it plays on its high mobility and fast deployment, and through that, it's a system designed specifically for "shoot-and-scoot" mission, making use of fire optimization tools extremely important.

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

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

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

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

the DM92 Modular Charge System, can reach 30 km with an HE-BT round, 40 km with an HE-BB round and 54 km with a Velocity Enhanced Long-Range Artillery Projectile (V-LAP) round. Rheinmetall has developed an Extended Range Charge (ERC) system using P6 propellant, that will increase the range of conventional, rocket-assisted projectiles (RAP) and guided rounds. They note that muzzle velocity is greater than JBMOU norms, but that the maximum pressure remains within STANAG 4110 artillery safety limits.

With ERC charges, 155 mm L52 gun can reach 36 km with an HE-BT round, 46 km with an HE-BB round and 63 km with a V-LAP round. In the medium term, with the introduction of the improved L52A1 gun, range will be 39 km with HE-BT, 52 km with HE-BB and 68 km with V-LAP. Rheinmetall believes that the long-term artillery solution will be new 155 mm L60 gun. The weapon remains JBMOU compliant, but can support higher pressure levels opening the way to longer range. The L60 gun reaches a range of 48 km with an HE-BT round, 64 km with a HE-BB round and 82 km with a V-LAP round.

The Republic of Korea (ROK) also has an artillery development programme, which involves generation-by-generation upgrades to the Hanwha K9 self-propelled artillery system that will see K9 variants in service through the 2040s and beyond. The first upgrade to the K9A1 configuration was fielded from 2018. By the end of this decade, the K9A2 configuration will be standardised, featuring a reduced crew of three instead of five, automatic loader, higher rate of fire (up to nine or 10 rounds from six), with the 155 mm L52 gun retained.

The next evolutionary stage, likely to have the K9A3 designation, is due to enter service later in the 2030s and will have significantly increased capabilities. The vehicle will be optionally manned or remotely operated, with an automatic loader to support a rate of fire of 10 rounds per minute. The difference comes is with the gun as the K9A3 will have a new 155 mm L58 gun capable of reaching ranges of between 70 and 100 km, depending on ammunition natures. The ROK is funding development programmes into indigenous precision-guided munitions for artillery, most likely to be fielded with the K9A3.

Credit: Nammo

Pictured: Nammo's Ramjet 155 projectile. This type of projectile using an air-breathing ramjet engine offers the potential to radically extend tube artillery engagement ranges.

As currently planned, the final K9 evolutionary stage will be the K9A4, which will have no embarked crew and autonomous mobility. It will also have a hybrid propulsion system, rather than the previous diesel. The K9A4 system is envisaged to arrive in the 2040s and by this point it is believed that ammunition will have developed beyond the capabilities of the K9A3, therefore maximum range will be in excess of 100 km. There will be an automatic loader and rate of fire should be in excess of 10 rounds per minute. Interestingly, there is no information on the gun selected for the K9A4, whether it is an evolution of the K9A3 gun or perhaps even a non-traditional high-technology solution.

As mentioned above, smoke rounds are an important part of FA non-lethal capabilities with smoke playing a role in both defensive and offensive fires and, more broadly, in shaping the battlefield. Smoke rounds do – at least on the surface – seem to just be another obscurant. However, in the US, the Defense Advanced Research Projects Agency (DARPA) has a programme known as Coded Visibility (CV) which is intended to develop the next generation of battlefield obscurants. CV is intended to develop tailorable, tunable, safe obscurants that will enhance friendly forces' visibility while suppressing hostile vision and detection systems.

The idea is to investigate two approaches in the shape of passive and active asymmetry. The passive option will have multiple obscurant materials deployed in specific ways that will allow one-way vision through a smoke plume. The active option will have a single obscurant material that can be tuned in real time to potentially enable dynamic control of its properties after being deployed and in cooperation with sensors. The CV programme is in the research phase, but if it can deliver either passive and/or active solutions, then this will represent a transformational capability for FA.

One theme in the discussion of tube artillery is the obvious desire to achieve extended ranges. Norwegian/Finnish company Nammo has been working on integrating Ramjet propulsion with artillery rounds to achieve extended ranges, out of standard 155 mm L39 and L52 guns. Boeing has teamed with Nammo to propose a Ramjet 155 mm round in connection with the US Army Long Range Precision Fires activity, specifically the XM1155 advanced projectile requirement for which two teams, Boeing-Nammo and BAE Systems, are competing. In 2023, tests with the Ramjet round were successfully conducted at Yuma Proving Ground with a 155 mm round fired from a 155 mm L58 Extended Range Cannon Artillery (ERCA) system. A precision guidance system, derived from the JDAM mission computer is being integrated with the Ramjet round.

The BAE Systems XM1155-SC round uses GPS guidance developed from BAE's Hypervelocity Projectile programme that has demonstrated a range of 110 km. BAE believes that they can achieve or exceed that range with their XM1155 round, while Nammo has openly discussed Ramjet rounds having a range of 150 km. The aim of this US Army programme is to successfully and accurately engage static and moving targets at extended ranges. Also likely to emerge are further extended-range versions of the M982 Excalibur guided round; in a test with the ERCA gun on max charge, this round reached a range of 70 km.

Rocketry evolves

MLRS systems were originally used as area weapons and were not particularly advanced. Today, they provide a sophisticated artillery option, whose capabilities for area and precision attack have been proven in combat in Ukraine, particularly by the M270 MLRS and M142 HIMARS systems. The ability to attack HPTs and HVTs has been a key feature of the success of these systems. More is to come, however; in the future, the MLRS category of systems will offer fires that accurately cover the totality of the battle area, but also a capability to deliver precision strikes against HPTs and HVTs deep into the enemy's strategic depth.

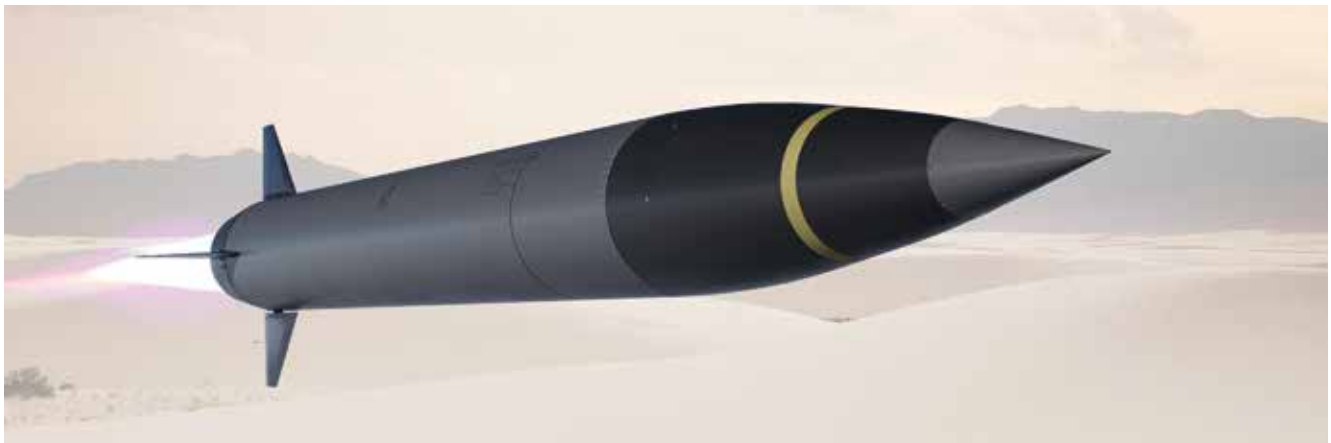
When the M270 MLRS first arrived in the 1980s, the system could fire an M26 rocket out to a range of 32 km; this was followed by Guided Multiple Launch Rocket System (GMLRS) with M230/M31 rockets offering ranges out to 84 km, while the GMLRS-ER extended-range variant can reach out to 150 km. The US had also developed the ATACMS rocket with a higher payload, for long-range engagements out to 300 km. However, the ATACMS role will be taken over by the Precision Strike Missile (PrSM). This system will meet US long-range precision strike requirements and started to become operational at the end of 2023, offering a range of 499 km. Work is already in progress on an improved guidance system for the PrSM, indicating a continuing evolutionary development investment. PrSM will certainly offer precision strikes against HPTs and HVTs deep into the strategic depth of the enemy.

Long-range precision engagement is becoming a major area of investment, for example DARPA is working on a programme known as Operational Fires (OpFires). This is a ground-launched hypersonic boost glide weapon that can penetrate A2/AD systems to rapidly and precisely engage critical time-sensitive targets at ranges out to 1,600 km. There is a potential problem with truly extended-range systems, as they move out of the category of battlefield weapons and into the area of strategic. Against a peer or near-peer level opponent, the use of what could be considered as strategic weapons could lead to rapid escalation with the potential for an excessive response. More practically air-launched stand-off weapons could fill or do fill this requirement, and with less investment.

For most though, the capability of PrSM is the limit of the long-range fires options that they would be seeking and for weapons with a 300-km range would be more likely to suit. The ROK Agency for Defense Development (ADD) and Hanwha have developed a 'tactical surface-to-surface missile' for launch from the K239 Chunmoo MLRS. The second variant of this 600 mm rocket, designated CTM290, has a range of close to 300 km. Apart from the ROK military, the CTM290 has also been acquired by Poland for its Homar-K MLRS system, which is essentially the K239 launcher mounted on a Polish 8×8 truck, doubtless leading to a third-generation development of the CTM290.

Apart from the ROK, significant MLRS system capabilities also exist in Israel; for example, Elbit's MLRS systems have been acquired by Denmark and are on order for Germany, The Netherlands and Spain. A wide range of rocket types are available, including an extended-range variant that can reach out to 300 km. Then there is Roketsan in Türkiye with a comprehensive MLRS offering. Very few barriers to entry exist with the development of a simple MLRS system, where the state-of-the-art is located with rocket systems offering long-range predictable performance and, most importantly, accuracy. That is a very difficult task to achieve.

It should not be forgotten that other nations possess MLRS capabilities and that they are continuing to develop them. First and foremost is Russia, the first military to use MLRS systems in the modern era; the country also has extensive development capabilities. The latest system to enter service is the 9K515 Tornado-S, a 300 mm calibre system designed to replace the old BM-30 Smerch. The system uses all standard 300 mm rockets as well as a newer extended-range precision guided rocket.



Credit: Lockheed Martin

CG render of Lockheed Martin's PrSM short-range ballistic missile. It is due to provide US forces with a major range improvement over the existing ATACMS missile.

Russian rocketry has also inspired developments in China and North Korea, with Iran building its rocketry capabilities on technology from all three. Iranian MLRS systems and artillery rockets have been widely supplied to Iranian surrogates, with Hezbollah in Lebanon having a vast supply of Iranian supplied rockets.

As to the future of both tube and rocket artillery, the trends are clear – it is a matter of more range and more accuracy. That this is already taking place is clear from the discussion in this article. That begs a question though – how much range is enough for an artillery system? Do ground forces truly need rockets with ranges of 300 or 500 km; surely engagements at these distances are what expensive air forces are for? Furthermore, will C2 and targeting systems be able to acquire targets at extended ranges, identify and then engage them accurately in a timely manner? Is there a danger of C2 and targeting systems being overwhelmed by the amount of potential targets from the forward area of the enemy back into their strategic depth? It would appear that the question for the future is not how much artillery capability is needed, but how much capability is enough? ■

Self-propelled mortar and ammunition overview

Sidney E. Dean

Self-propelled (SP) mortars remain crucial in providing support to fast-paced operations by mounted, mechanised and armoured forces. In addition to tracked and 8×8 wheeled armoured vehicles, mobile mortars are increasingly being mounted on 4×4 vehicles.

While mortars come in various calibres, vehicle-mounted mortars usually range from 81 mm (medium) to 120 mm (heavy), although a few larger calibres are in service. Given the high trajectory of mortar fire, it can be especially effective against defilade targets as well as against the comparatively weaker top surface of armoured vehicles. Various improvements and new technologies are now incorporated into mortar systems to enhance lethality and make them easier to use. These include onboard fire control systems (FCS) and integration into situational awareness networks to enhance target acquisition and increase engagement speed. Laser rangefinders, day/night optical sights and automatic gun laying systems make targeting more precise and permit faster target engagement.

Some now feature multiple round simultaneous impact (MRSI) capability through automated adjustment of firing trajectories, ensuring several mortar bombs can strike the target area at the same time. This can improve fire mission effectiveness, particularly against an unprepared opponent, but can only be performed within a certain range.

Credit: Italian Army

Italian Freccia mortar carrier firing the Thales R2M2 120 mm mortar.

Mortar ammunition developments

According to a forecast by Mordor Intelligence, the global mortar ammunition market is expected to grow from an estimated USD 87.46 billion in 2024 to USD 111.84 billion in 2029, reflecting a compounded annual growth rate (CAGR) of over 5%. This growth is partially due to efforts to increase stocks in times of crisis, and to some extent, due to efforts to develop and procure advanced munition types. Desired enhancements include lighter weight, increased lethality, extended range and precision-guidance capability. Several leading firms have been introducing significantly upgraded ordnance.

General Dynamics Ordnance and Tactical Systems (GD-OTS) introduced the 81 mm Roll Controlled Guided Mortar (RCGM) in 2012. Target coordinates are programmed into the munition via a portable global positioning system (GPS) setter. Once fired, the round's onboard global navigation satellite system (GNSS) guidance system constantly fine-tunes the aft-mounted steering canards to keep it on target. GD-OTS cites a circular error probable (CEP) of 5 m, enabling two RCGM bombs to precisely destroy a target which the manufacturer claims would typically require 10–18 unguided mortar bombs to achieve the same effect. In 2013, the firm also fielded the 81 mm mortar anti-personnel anti-materiel (MAPAM), claimed to possess twice the lethality of conventional mortar rounds of the same calibre. The primary lethality radius extends to 55 m, with a further danger zone extending to 130 m from impact. According to GD-OTS, the pre-fragmented payload can be tailored to the user's requirements to optimise lethality against various target sets, while providing precision control over the danger zone. Minimum and maximum range are 130 m and 5.5 km respectively, while muzzle velocity can be scaled from 80 m/s to 292 m/s.

Elbit Systems' Stylet 120 mm guided mortar bomb can strike targets at a range of 1–8.5 km and is outfitted with a multi-mode GNSS/INS guidance system which provides a CEP of less than 10 m. The automated fire control system requires no ranging to assure first-round hits on target, and can allow multiple targets to be engaged without having to change the mortar's angle of fire. According to Elbit, the high explosive fragmentation (HE-FRAG) warhead is effective against infantry and light armoured vehicles. Elbit also off the extended range Rapier 120 mm GNSS/INS guided bomb, which is capable of striking targets out to 16 km, and according to the manufacturer it remains accurate even in severe weather conditions.

Credit: GD-OTS

Side view of the 81 mm RCGM guided mortar bomb.

In 2021, Elbit Systems introduced the Iron Sting munition, with a range of 1–12 km. This 120 mm guided mortar bomb has both semi-active laser (SAL) guidance, as well as INS/GNSS guidance. The former guidance mode allows a CEP of about 1 m, while the latter permits a CEP of around 10 m. According to Elbit, the Iron Sting's HE-FRAG warhead is capable of penetrating 20 cm of double reinforced concrete, making it suitable against fortified positions. All three of the aforementioned Elbit mortar bombs have a multi-mode fuze which offers a choice of proximity detonation, point detonation or point detonation delay. Additionally, the manufacturer states for all three, that the mission loading time (from target data input to projectile launch) is 15 seconds, with no meteorological data input required.

It should be noted that while SAL guidance for mortars isn't new – for instance, the KBP 'Kitolov-2' 120 mm SAL-guided mortar bomb was accepted into Russian service on 31 December 2002 – widespread adoption and proliferation of this technology has been somewhat slow. SAL guidance has particular utility in urban combat, as it allows mortar bombs to be guided into narrow alleyways, through windows, or onto a specific vehicle. This also allows a user to significantly reduce collateral damage compared to an unguided mortar fire mission. The SAL seeker requires the target to be illuminated by an external ground-based or airborne laser source; the seeker detects the aim point of the laser and homes in on it.

Beyond seekers, fuze technology is generally progressing. Junghans Defence has introduced the Furya dual-mode fuze which can be set for either proximity or impact fuzing modes. Furya is suitable for various artillery munitions including 120 mm mortar bombs. Selection of the fuzing mode can be made inductively or manually, without a fuze setter. According to the manufacturer, the sensor is highly resistant to electromagnetic interference. Junghans has also introduced the electronic multi-option Flame fuze for high explosive (HE) mortar rounds. Operators can choose between four detonation modes: two proximity modes with different detonation heights, and two impact modes with or without detonation delay. The fuze is suitable for all NATO standard mortar calibres.

US Army mortar choices

The United States Army currently operates the M1064A3 self-propelled mortar mounted on the tracked M113 armoured personnel carrier, and the M1129/M1252 mortar carrier variant of the wheeled Stryker. The M1064A3 is equipped with the M121 120 mm carrier mounted mortar system produced by Elbit Systems, and carries 69 rounds along with their charges on board. Situated on a turntable in the rear of the M113, the mortar has a 90° range of traverse (45° left/right of centre). The integrated M95/M96 Mortar FCS – Mounted (MFCS-M) interfaces with the M577A3 mobile command post/fire direction centre vehicle; the networked, digital fire control system allows the mortar to receive fire missions on the move, stop, fire, and reposition within one minute. The Army has now begun the multi-year transition from the M113 to the armoured multi-purpose vehicle (AMPV); this will include the ultimate replacement of the M1064A3 by the M1287 AMPV mortar carrier variant.

The Stryker M1129/M1252 mortar carriers utilise the turntable-mounted Recoil Mortar System 6 – Light (RMS6L) 120 mm, based on the Cardom 10 mortar system developed by Israeli company Soltam Systems, a subsidiary of Elbit Systems. The Stryker's mortar system also integrates the M95/M96 FCS. The weapon system has a maximum rate of fire of 16 rounds per minute (rpm) and a sustained rate of 4 rpm, with a maximum range of around 8 km.

Both current US mortar carriers require the mortar hatch to remain open while firing, placing the crew at greater risk from counterfire. The US Army has been seeking to replace the muzzle loading weapons with breech-loading, turret mounted mortars which would allow the crew to remain under armour protection. To this end, in 2020, the Pentagon entered into a Cooperative Research and Development Agreement (CRADA) with Finland's Patria Land Oy to determine whether the Patria's NEw MOrtar (NEMO) system could be adapted to US platforms. The turreted, remote-controlled system is specifically designed for light tracked or 6×6/8×8 wheeled vehicles, and in the land role it has been installed on the Slovenian Army's Patria AMV 8×8 and the Saudi Arabian National Guard's LAV II 8×8. NEMO is compatible with all standard 120 mm smoothbore mortar bombs, including guided variants. The NEMO's semi-automatic loading system allows a maximum burst rate of fire of 10 rds/min, with sustained fire of 7 rds/min. The system is capable of delivering a 6-round MRSI, and also possesses a fire-on-the-move capability.

While the Pentagon has not announced any decisions regarding a mortar turret for the Stryker, the M1287 will be armed with a Patria NEMO supplied by Patria and Kongsberg Defence and Aerospace. As reported by Janes in December 2023, the AMPV mortar carrier will be publicly introduced at the Army-hosted annual Maneuver Warfighter Conference at Fort Benning, Georgia in September 2024. Janes also reported that BAE Systems' AMPV director Bill Sheehy stated that the event would include a live-fire demonstration of the prototype system.

Credit: Junghans Defence

The electronic multi-mode Flame fuze sits at the centre of a selection of Junghans mortar fuzes.

Credit: US Army/Patrick A. Albright

The NEMO mortar, mounted on a Patria AMV, during evaluation by the US Army in 2019.

European mortar systems

M120 Rak

Turreted systems are becoming increasingly popular due to the enhanced crew protection and often automated fire control. Poland's M120 Rak SP mortar system has been operational since 2017, with the latest tranche delivered in September 2023. The M120 turret, armed with a 120 mm breech-loaded mortar, is produced by Huta Stalova Wola (HSW), and mounted on a Rosomak 8×8.

The vehicle carries 20 ready-to-fire mortar bombs in a turret magazine, plus an additional 26 rounds stored in the hull. Using extended range munitions, the mortar can strike targets at 15 km. The mortar can also fire within 30 seconds of reaching a firing position, and relocate within 15 seconds of firing. The WB Group TOPAZ FCS used by Rak is capable of automatic gun laying onto the coordinated selected on the accompanying digital map display, and for direct fire mode, the turret is equipped with a BAZALT sight with day and thermal channels, as well as a laser rangefinder. The M120 turret has also been offered on the M120G Rak variant, which is based on the Opal light tracked platform – a Polish domestically-developed variant of the MT-LBu design.

Thales 2R2M MEPAC Rifled Mortar

However, open-hatch systems continue to be fielded including the Mortier Embarqué Pour l'Appui au Contact (MEPAC) system which will mount the Thales 120 mm rifled, recoiled mounted mortar (R2M2) system on the French Army's VBMR Griffon 6×6 armoured vehicle. Although the configuration used requires the roof hatch to remain open for firing, crew members need not expose themselves above the roofline, as the mortar is breech-loaded through a tray located at the base of the barrel. The weapon is mounted on a turntable which allows the weapon to traverse through 360°, enabling the system to fire in any direction. Unlike many mortars in this category, the R2M2 is rifled, enhancing accuracy and range. Using SAL guided munitions, the MEPAC will be able to strike targets at a range of 17 km.

MEPAC is due to begin fielding with the French Army in 2024. The Belgian Armed Forces have also opted to acquire this system. The 2R2M is currently in service on several other tracked and wheeled vehicles in Italy (mounted on the Freccia platform), Malaysia, Oman, and Saudi Arabia.

Patria/BAE AMOS/Mjölnir

Multiple-barrelled mortars remain quite rare. A notable exception is the Advanced MOrtar System (AMOS) jointly developed by Patria and Hägglunds AB (now BAE Systems Hägglunds). the 120 mm smoothbore turret-based mortar uses semi-automatic breech-loading mechanism to allow rapid reloading. The system entered service in 2013 with the Finnish Army on the Patria AMV 8×8 platform, and bearing the XA-361 service designation. Finland remains the sole operator of this system. The double-barrelled configuration enabled AMOS to attain a maximum rate of fire of 16 rds/min, and capable of a 10-round MRSI fire mission. The system is also capable of credibly engaging armoured targets, for instance, through the use of infrared (IR) homing, high-explosive anti-tank (HEAT) Strix rounds developed by Saab Bofors Dynamics.

Compared to AMOS, BAE Systems' Mjölner mortar system is a simpler implementation of the twin-barrel mortar design, relying on a manual muzzle loading system via two loading tubes running parallel to the two barrels. Unlike AMOS' 360° of traverse, Mjolner has a more limited traverse range of 60° (30° left or right of centre). However, owing to its lower-complexity loading system, Mjolner has an inherently lower chance of experiencing failures through breakages of electronic or mechanical subcomponents, and is estimated to be somewhat cheaper and simpler to maintain than AMOS. The manufacturer has stated that the weapon is capable of attaining a maximum rate of fire of 16 rds/min, with the first four rounds fired in under eight seconds.

Sweden has ordered a total of 80 Mjolner systems mounted on the CV90 tracked

CV90 Mjölner double-barrelled mortar.

platform. The first units were delivered in 2019, with the complete order due to be fulfilled by 2025. The CV90 Mjolner system requires two personnel to load the weapon, plus a commander and driver. It is compatible with all NATO standard 120 mm mortar ammunition, including Strix. Up to 56 projectiles are carried in the turret bustle, with another 48 rounds stored in the hull.

Israeli and Turkish options

Elbit Spear Mk2

In 2012, Elbit subsidiary Soltam Systems introduced the Spear 120 mm mortar system, as a derivative of the Cardom mortar. It was optimised for use on light vehicle platforms through the use of a soft recoil system, which reduces the recoil load to 11-13 tonnes, down from around 30 tonnes for typical 120 mm systems firing at full charge.

The upgraded Spear Mk2 variant introduced in 2017 provides greater automation of fire control, including automatic gun laying. It can be operated by a two-person crew in manual or fully autonomous mode. Via a battle management system (BMS), the Spear Mk2's FCS can directly interface with offboard sensors, including UAVs for enhanced targeting. Elbit states that the mortar carrier can be into and out of action within 60 seconds, and can attain a maximum rate of fire of 16 rds/min, or a sustained rate of 4 rds/min.

Elbit Sling

Elbit's Sling 120 mm SP mortar system is toward the special operations market end of the market. The mortar is integrated with an electronically-operated rig and provided with a baseplate, requiring it to be lowered to the ground for firing. This arrangement allows it to be mounted onto fairly light 4×4 platforms, since the recoil forces are absorbed by the ground rather than the vehicle suspension. However, this also means that it is not necessary to use a low-recoil mortar design. The Sling completed development and testing in 2023.

For transport, the mortar and baseplate are folded forward onto the rear of the vehicle, which renders the vehicle sufficiently low to be air-transportable by a suitably-sized helicopter. The weapon is manually loaded, but gun laying is automatic, with manual backup, with a weapon traverse arc of 220° (110° left/right of centre). Similarly to Spear, the manufacturer states that Sling has an into and out of action time of 60 seconds, and can attain a maximum rate of fire of 16 rds/min, with a sustained rate of 3-4 rds/min. Sling is in use by the IDF, and has been tested by US Special Operations Command (SOCOM) received a unit for testing in May 2022.

Elbit Crossbow

Elbit's Crossbow turret-based 120 mm mortar intended for 6×6 and 8×8 platforms is under development and expected to be fielded with the IDF in 2025. It is capable of firing out to 10 km at maximum charge, is capable of firing on the move, and possesses a six-round MRSI capability. A relatively unique attribute is the autoloader design which aligns fresh rounds with the current position of the barrel, allowing the barrel to remain trained on target rather than needing to be returned to the loading position after firing each round.

Aselsan Alkar 120/81 mm

The majority of mortars described in this article have been 120 mm systems, which have greater range and effect than smaller mortars. However, 81 mm SP systems remain in demand due to their flexibility and portability. Aselsan's Alkar mortar range includes both 120 mm and 81 mm models. The 120 mm variant is in service with the Turkish Gendarmes, mounted on a BMC Vuran 4×4 protected patrol vehicle (PPV). The 81 mm variant has dimensions of only 1.85 × 0.85 × 1.02 m (LWH) and is suitable for fairly light armoured or soft-skinned vehicles such as pickup trucks. The modular system can accept any standard 81 mm barrel, whether rifled or smoothbore, depending on user requirement. The effective range is between 100 m and 6.4 km depending on barrel and munition. The weapon is equipped with an automatic gun laying system with manual backup, and the FCS can directly receive targeting data from forward observers and radar. The electromechanical turntable allows the barrel to traverse 180° (90° left/right of centre).

Credit: Aselsan

Alkar 81 mm mortar and turntable can be mounted on many vehicles.

Closing thoughts

The renewed emphasis on large-scale manoeuvre warfare and great power conflict has raised the value of self-propelled mortars as tactical support for mounted, mechanised and armoured forces. Given the sophistication of modern air defences and electronic warfare capabilities, ground forces in peer conflicts may have to rely less on air support and more on organic artillery. Within the tactical artillery category, mortars present some attributes which differentiate them from howitzers and rocket artillery. They have considerably shorter range, and are therefore generally operated closer to the line of engagement and controlled at a lower tactical echelon. This increases their flexibility and the ability to quickly redirect fire as the battle unfolds or as a unit's tactical UAVs detect targets of opportunity. This makes them especially valuable for forces relying on fast and decisive artillery support or quick strike capability against targets of opportunity. These attributes will keep mortars in high demand for a long time to come. ■

Credit: Elbit

Sling 120 mm mortar in firing position.

Gap crossing: the challenges of water obstacles in Europe

Tim Fish

The European continent is criss-crossed by a large number of waterways that make large-scale ground military manoeuvres difficult. This article examines the extent of the challenges that water obstacles present and why gap crossings are relevant in the case of the War in Ukraine. It discusses the risks inherent in performing a water-crossing operation and how the 'Saber Guardian' exercises are keeping NATO up to date with doctrine. Furthermore, it explores the UK's recent efforts to improve its river-surveying capabilities and provides details of the phases of gap-crossing operations, the equipment used and how some armoured vehicles are able to conduct river fording.

Credit: US Army/Cpt Avery Smith

A US Army M2A3 Bradley IFV crosses the Danube River on the Romanian-set ribbon bridge as part of the Saber Guardian 23 Exercise, on 6 June 2023.

From lakes and swamps, to small canals and streams up to larger and wider rivers – all known as 'wet gaps' – these obstacles present a significant challenge for military forces, especially when engaged in high-intensity warfare. Wide rivers, in particular those over 40 m wide, can significantly constrain ground forces' space for manoeuvre and can easily become campaign-critical obstacles.

Author

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Speaking at the RUSI Waterways Conference in 2022, retired Finnish Army Major-General Pekka Toveri told delegates that a 1965 Soviet Army report highlighted the extent of the problem that water obstacles can present across Europe. This report stated that for every 5 km travelled, there would be a water obstacle at least 5 m wide that would need to be crossed. The further the distance a force is required to move, the higher the chance of encountering larger obstacles. For every 10 km travelled, a force would have to cross a waterway at least 10 m wide. Whilst the report estimated that 60% of water obstacles were less than 20 m wide, it also means that 40% are wider than this.

As such, for every 35 km travelled, there would be an obstacle at least 100 m wide and for every 100–150 km, an obstacle between 100–300 m wide would need to be crossed. At distances above this, it would be likely that obstacles could exceed 300 m wide. Most of these obstacles will have bridges and tunnels crossing them, or roads leading around them. However, during wartime conditions, many are likely to be destroyed or rendered uncrossable by defending forces. As such, the advancing force will be called upon to employ alternate means of crossing the gap.

Gap-crossing solutions in Ukraine

With terrain that includes so many water obstacles across the continent, the ability to cross water quickly while maintaining combat power and momentum is critical. If obstacles such as these cannot be crossed, the fighting ability of land forces diminishes greatly.

This indicates that any Army intending to conduct offensive operations with heavy armoured formations that include main battle tanks (MBTs), infantry fighting vehicles (IFVs) and armoured personnel carriers (APCs) will need bridging equipment to cross these types of obstacles. Furthermore, the doctrine and tactics, techniques and procedures (TTPs) must be developed and tested to ensure that river crossing can proceed safely.

The Russian Army found out to their horror the importance of the latter during the opening stages of the War in Ukraine in February 2022. Whilst it had significant stocks of bridging and barge equipment, it nonetheless found it difficult to conduct gap-crossing operations at scale and under fire. A particularly notable instance was the Russian Armed Forces' attempted crossing of the Siverskyi Donets River in May 2022, which saw the force lose over 400 men and a number of vehicles, including tanks.

The current deadlock in Ukraine has both sides sitting behind long and deep defensive lines that will be difficult and costly to break down. The expected Ukrainian offensive of mid-2023 never made progress as it encountered well-protected and established defences. These defences often protect the land corridors between the major rivers in eastern Ukraine. Elsewhere, water obstacles – the Dnipro River in particular – form a natural barrier which is extremely difficult for either side to cross in force. It means that in Ukraine, a gap-crossing capability could be a game-changing capability.

US Army Captain Josh Wiley, Mobility Officer for US Army Europe and Africa's Office of the Deputy Chief of Staff, Engineer (ODCSENG) told ESD: "Executed properly, a gap crossing also leverages a high tempo, audacity in the boldness of the plan (go where the enemy would not have prepared for you to cross) and concentration of combat power at the points of crossing and with a robust depth of fires, air defence, electronic warfare and other capabilities that will deter and degrade the enemy."

A risky endeavour

Gap crossing is both difficult and risky to perform; it is therefore preferable to use other options, such as existing infrastructure or going around obstacles if possible. In the case of Ukraine, the strength of the defensive lines makes this very difficult, and so in many cases gap crossing is the only realistic option for an advancing force to bypass existing defences and have a chance of achieving success. However, Ukraine does not yet have the force levels or resources to mount a gap crossing in force.

Credit: US Army

The M1074 Joint Assault Bridge (JAB) is a US Army AVLB based on the M1 Abrams platform. It replaces the M104 Wolverine.

Wiley said that a wet gap crossing "is a Division-level operation involving all imaginable types of forces and is widely considered to be one of the most dangerous types of operations a manoeuvre force can execute". When conducting a crossing, large formations, including heavy armour, are at their most vulnerable, especially to long-range artillery fires or air attack. This is because vehicles will be travelling at slower speeds and become concentrated in larger numbers as they wait to cross.

Wet gap crossing exercises are part of NATO's annual exercise programme, highlighting its importance. Exercise Saber Guardian 23 ran from 29 May to 9 June 2023 with US and Romanian forces crossing the Danube River. Saber Guardian has been running for some time but is becoming more advanced. In 2017, the 59th Mobility Augmentation Company (now 59th Combat Engineer Company - Armoured, Fort Cavazos, TX) conducted the first assault-bridging crossing of a Romanian Piranha V IFV with a US M104 Wolverine. The Wolverine has since been replaced by the M1074 Joint Assault Bridge System (JABS) and Saber Guardian has evolved into a more complex exercise with Wiley stating that it includes realistic scenarios "that challenges bridging units to practice and perfect the art of river crossing at a grand scale".

This latest iteration involved a series of crossing operations that employed small boats and floating pontoon barges strung together that allowed vehicles from nine NATO countries including Bulgaria, France, Italy, The Netherlands, North Macedonia, Poland and Portugal to cross. It is also about developing the TTPs for the whole force; in this regard, Exercise Saber Guardian allowed engineers from NATO countries to learn and develop their methods in a multinational environment.

The value of reconnaissance

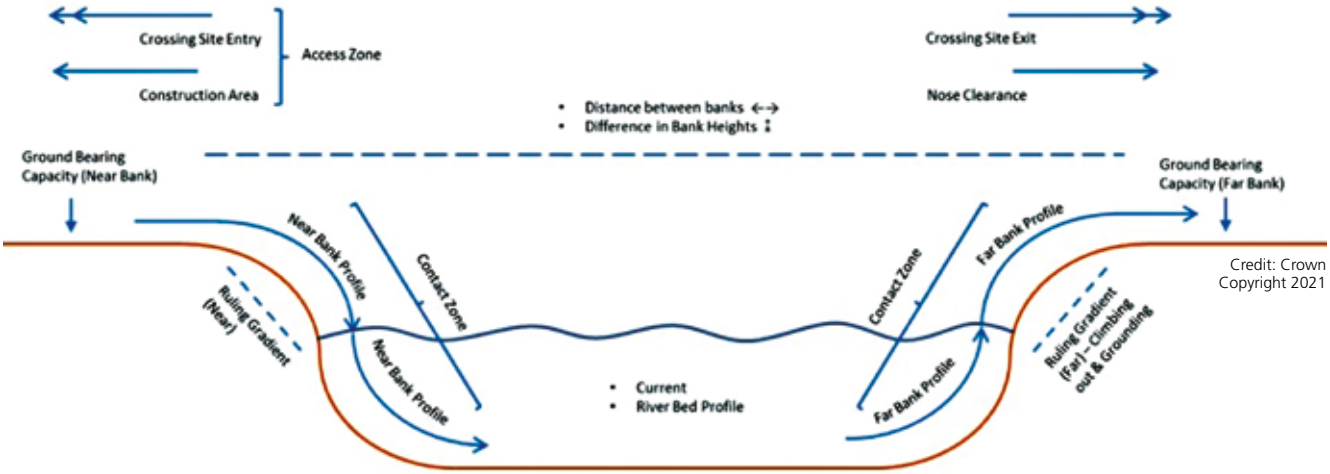
The first step in a gap crossing usually requires the identification, well in advance, of the most suitable area to cross a waterway. This work is performed as part of the overall reconnaissance effort. In the US Army, engineers contribute a staff running estimate that integrates engineer reconnaissance, which forms part of the support for a commander's decision-making process.

"Identifying information requirements to answer starts with the manoeuvre force understanding its responsibilities within an overall scheme of manoeuvre, analysing the terrain and the mobility corridors throughout the area of operations and then defining the number and size of the gaps (i.e., rivers, lakes, drop-offs, and other discontinuities to land manoeuvre) in the area of operations," Wiley said.

He explained that enemy force dispositions will be examined by Engineer Reconnaissance Teams (ERTs) along with existing obstacles to assess strengths and weaknesses and the potential for counterattack and close-air support. Other areas of focus will include soil conditions, hydrology, vegetation, seasonal weather conditions, entry and exit banks and gap length and profile. This analysis will be combined with that from other experts, including geospatial analysts, professional engineers, operations officers and data from allied countries.

The UK Ministry of Defence recently completed its 'Map the Gap' project, aimed at decreasing the time taken to survey a potential crossing point, so that more sites can be surveyed overall and give a variety of crossing options to commanders much sooner. This would allow them to increase manoeuvre options and sustain a higher tempo of operations. This is especially relevant for wide wet gaps more than 40 m wide, which can be critical obstacles.

The current method of reconnaissance for a water crossing is laborious. British Army Royal Engineer reconnaissance troops have to survey both banks of the river to generate a gap profile and obtain key characteristics using manually-operated equipment. Divers are also used to survey the underwater environment and riverbed profile. Operating forward also exposes them to danger and risks an enemy identifying the crossing point.



Survey information required for the assessment of a gap-crossing operation. Data on these characteristics will indicate the viability of the location.

The first phase of 'Map the Gap' was completed in March 2021, and saw five industry suppliers demonstrate a range of existing sensor solutions integrated on platforms, which were tested across a representative gap. The goal was to improve the ability of the British Army's Royal Engineer reconnaissance units to conduct wet gap surveying using more electronic sensors and autonomous platforms.

The second phase, worth GBP 2 million, was completed in March 2022. During this latter experiment, three industry suppliers – DCE, Ultrabeam and ISS Group – demonstrated semi-autonomous solutions. The solutions had to prove they could be deployed within a military environment in a low-bandwidth, GPS denied environment and achieve Technology Readiness Level 6 to allow potential development into an in-service capability.

The competitors' solutions were required to measure the riverbank ground bearing capacity, bank height, bank tolerances, water flow, and a river bed profile to a minimum depth of 3 m and 16 m wide. They had to support the identification of crossing sites with entry and exit routes for ground traffic, factoring in trees and foliage, as well as the size of construction areas. Overall, the Army needed to be able to cross a 200 m wide gap and reach an objective 100 km beyond.

A UK MoD spokesperson told *ESD* that 'Map the Gap' was "an extremely useful activity" to understand the applicability and TRLs of different sensors and effectors for military engineers. "The experiment has been closed and the lessons summarised," the spokesperson added, but it is not clear if this work has been taken forwards with equipment procured for British Army or NATO survey capability.

Phases of effort

"At its heart, the objective of friendly forces in a crossing is to project combat power to the exit (far) bank of a river or other type of water obstacle at a faster rate than the enemy can concentrate forces for a counterattack," Wiley said.

He also noted that a crossing consists of five active phases:

1) Advance to the river;
2) Assault across the river;
3) Advance to the far side;
4) Secure the bridgehead line;
5) Continue the attack.

Under US Army doctrine, each of these phases includes a series of complex and highly synchronised operations to isolate the crossing from enemy influence whilst also building capability, using engineering equipment and moving combat power from multiple sites – also using decoys – that will prevent the enemy from massing forces whilst boats are in the water and the crossing is contested. For example, securing the riverbanks requires combined arms operations and long-range fires to destroy any opposing forces.

It is critical that each phase is completed successfully before the next can begin. In the aforementioned May 2022 Russian attempt to cross the Siverskyi Donets River in May 2022, much of the failure can be put down to Russia's insufficient reconnaissance of the enemy capabilities in the area of the crossing, and their failure to sufficiently degrade or defeat the opposing force's artillery before crossing, as well as insufficient protection against enemy low-flying air support and enemy reconnaissance UAVs.

During Exercise Saber Guardian 23, helicopter and infantry units were used to provide covering fire and the Romanian Smardan River fleet of armoured patrol boats were used to provide suppressing fire on the opposing side of the wet gap. This prepared the crossing so that 11 US Army M2A3 Bradley fighting vehicles (each weighing 30–33 tonnes), Italian B1 Centauro fire support vehicles (FSVs), Polish KTO Rosomak IFVs,

Two Polish Rosomak 8×8 IFVs prepare to be ferried across the Danube on Dutch-operated rafts during Exercise Saber Guardian 23.

Credit: US Army/Cpt Avery Smith

Multiple Romanian Piranha V IFVs cross the 700 m Romanian-established floating ribbon bridge on the Danube River.

French PVP protected patrol vehicles (PPVs), as well as Romanian Piranha III APCs and Piranha V IFVs, were able to cross a 700 m long Romanian pontoon bridge, which was able to sustain 60 tonne loads. US rafts were also used to facilitate crossing by many of the aforementioned vehicles, whilst Bulgarian ferry vessels moved vehicles from North Macedonia. Over the course of several days, other wet gap crossings were performed to cross water obstacles up to 1 km wide and helped to prove the US ability to rapidly reinforce Europe and perform complex military tasks with allies.

Captain Wiley said that, "Saber Guardian 23 demonstrated the ability of allied forces to quickly secure a far side, emplace bridging and project combat power across it as a combined-arms and joint effort more rapidly and smoothly than before," adding that, "Much of the refinement in TTPs in an exercise from this comes from the lowest level, as non-commissioned officers and soldiers find ways to better compliment different systems and officers lead after-action reviews to refine best practices for a combined force."

Equipment solutions

Looking ahead, Wiley stated that some future technology "may enable our forces to cross rivers with zero or minimal risk to soldiers on the ground, to protect our greatest assets. Others involve upgrading the load bearing capacity of our bridging, which will allow even the heaviest armour in our inventories to cross at any time and place of our choosing".

Meanwhile, Wiley explained that NATO was not just considering crossing needs during an active conflict, but also before and after,

Credit: Bundeswehr/Detmar Modes

A German Army Leopard 2A4 fitted with snorkel completing a deep fording river crossing.

which required a greater partnership with industry-developed lines of communications for bridging.

Existing bridging assets in the US Army include the Multi-Role Bridging Company (MRBC), which uses the Improved Ribbon Bridge (IRB) floating bridge and Dry Support Bridge (DSB) for larger water obstacles. This can be interoperable with the M3 amphibious bridging vehicle used by the British and German armies, which both countries provide to NATO under the Wide Wet Gap Crossing (WWGC) capability, along with an increasing number of other European armies. The US Army also uses armoured vehicle-launched bridge (AVLB) vehicles, including the M1074 Joint Assault Bridge (JAB) and M104 Wolverine for crossing narrow gaps such as streams, which are much more numerous across Europe compared to wide rivers. The US Army also maintains a stock of panel bridging to help restore roads.

Organic vehicle capability

There are some armoured vehicles that have a swim capability enabling them to cross water obstacles. Some IFVs and APCs are amphibious without preparation, while others can be modified and prepared for gap crossing using propellers and buoyancy equipment. This can allow units to secure territory on the other side of the obstacle for a bridge or barges to land on. The presence of heavy armoured vehicles adds an extra level of security on the ground, as they are protected platforms with direct-fire weapons, adding further capability to that provided by aviation, infantry and long-range fires.

Tanks also have a fording capability that allows them to cross shallow rivers. KNDS, which manufactures the Leopard 2 MBT, has stated that it can conduct fording of rivers 1.2 m deep and a deep fording of up to 2.25 m deep. It also has a submerged mobility capability of rivers and lakes up to 4 m in depth using a snorkel which is set up on top of the turret prior to entering the water.

The standard fording in a Leopard 2 MBT requires the operator to activate the diving hydraulics for the tank to move through the water. This does not require any additional equipment or much time in preparation. For deep fording operations, as well as the diving hydraulics, a deep fording snorkel (essentially a large collapsible cylinder) is attached to the commander's hatch. This device is used to provide air for the crew, engine and cooling systems. It is wide enough for the commander to stand inside, allowing them pop out of the top to see where the tank is going. The device's height also serves to prevent water ingress by remaining sufficiently far above the surface of the water obstacle. Setting up the deep fording snorkel can take up to several minutes, including checks to ensure that the remaining hatches are properly sealed.

For submerged transit, the tank is completely underwater and only the snorkel is visible. Tank snorkels are transported by logistics units and are unpacked and attached to the commander's hatch. Ropes are also prepared to make it easier to recover the tank should it become stuck on the riverbed. Tank crews are also trained to use rebreather systems in case of accidental flooding of the internal compartments, and to escape through the commander's hatch and up the snorkel. During its transit under the river, the tank moves fairly silently, the engine noise muffled by the water.

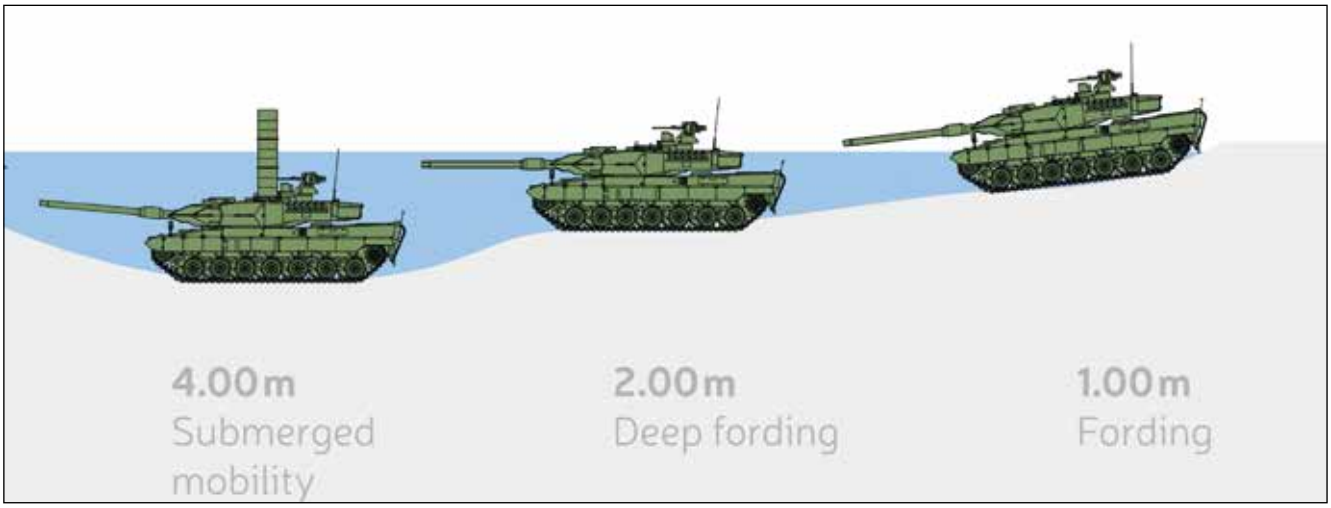
However, deep fording is only possible in small rivers and water obstacles up to 4 m deep. Whilst this is useful for crossing smaller rivers and streams quickly, and can allow a heavy armoured unit to continue its progress, larger obstacles will require bridging systems, barges and other wet gap crossing equipment.

Closing thoughts

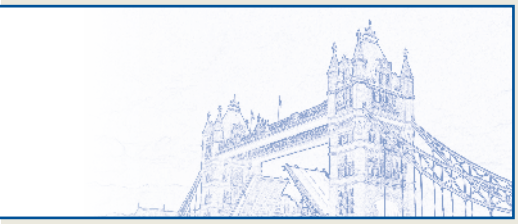
Gap crossing is a complex and time-consuming military operation that is inherently dangerous. However, when existing infrastructure is damaged or unusable, or land bridges between water features are defended – as seen in Ukraine – then gap crossing becomes the only way that manoeuvres can be sustained, or momentum created when a deadlock exists.

Exercises, training and developing modern equipment to support wet gap crossing operations are needed to ensure that this capability is maintained. However, whilst NATO supports some river crossing capabilities, it falls far short of what is needed for large-scale offensive operations. ■

Credit: KNDS



Artist's impression of a Leopard 2 MBT conducting a fording and submerged river crossing, highlighting the capabilities of the tank to perform its own gap crossing of small obstacles if required.



Viewpoint from London

Photo: author

Brace for autonomy

Sam Cranny-Evans

In 2023 the UK's House of Lords established a committee to investigate the use of artificial intelligence (AI) in weapon systems. It is valuable and important to have these inquiries, however, the resultant report has failed to properly take account of the current state of AI in weapon systems, and how it might change in the immediate future.

The committee published its findings in December 2023 and the British government was required to respond by 19 February 2024. The report's findings are predictable, it provides recommendations on lethal autonomous weapons (LAWs) definitions, the importance of the law of armed conflict, a suggestion about the spectrum of autonomy, and requests to prohibit AI from use in nuclear command and control (C2). It also recommends that the UK should become a leader in AI regulation and seek to ban certain use cases. However, it is unlikely that these recommendations will enable the British government and Ministry of Defence to consider and prepare for the future of LAWs because they do not address the current and emerging state of autonomy in defence.

The report's definitions of a spectrum of autonomy are not dissimilar from the US Department of Defense's own definitions, which apply to a variety of systems from Javelin through to the Phalanx air defence system. The primary difference in the House of Lords report is that they discuss the role of AI (by which they mean machine learning and other elements of AI), as opposed to hard-coded automation. Hard-coded autonomous weapons are not new, the Harpy loitering munition was developed during the late 1980s to hunt air defence radars, and was used in the 2020 Nagorno-Karabakh war. It autonomously detects, locates, and attacks air defence radars based on their emissions. It does this without human oversight in the targeting process, although a human decides where and when to launch it. The difference between Harpy, and the use cases discussed in the House of Lords report is that Harpy did not learn how to identify those radars from a set of data fed into an algorithm. It is eminently possible to achieve the same ends and more against a wider target set with AI – the question then is whether the means are important. Here, it is worth examining the war in Ukraine.

It is highly likely that weapons using AI and with a very high degree of autonomy have already been used in this war, and that fully autonomous weapons will be deployed by both sides before the war is over. One driver is the presence of electronic warfare (EW). Russia made EW a pillar of its way of war long before 2022 in a bid to degrade NATO's perceived superiority in C4ISR and the resultant precision strikes. Its EW forces have performed this role in Ukraine, but they have also found themselves in a near constant struggle against the thousands of drones used by the Ukrainian forces. Ukraine has likewise developed and deployed its own EW to degrade the resultant Russian acceptance of small drones. Each force is likely adapting its drones and EW at a tactical level to improve countermeasures and survivability. This process will drive them inexorably towards AI and autonomy, because an autonomous drone would be largely immune to EW.

At least some of Russia's Lancet loitering munitions are known to carry the Nvidia Jetson TX2, a single board computer designed for AI applications, including computer vision. Such Lancets are therefore likely capable of navigating without GPS by matching pre-loaded imagery to what they sees around them. It is also possible that they can conduct a portion of their engagements autonomously. New iterations of Lancet, such as 'Product 53' are claimed to be fully autonomous and capable of selecting and engaging targets within a geofenced area. Ukraine has in turn deployed the Saker Scout, an AI-enabled reconnaissance drone with the ability to engage targets and adjust its targeting with some degree of autonomy. AI-enabled autonomy will reduce Russia's EW advantage if it can be realised at scale. This is because a drone can become self-reliant and navigate to a target based on what it detects in the environment around it rather than the easily-jammed satellite navigation signals they currently rely upon. It may also ease the burden on 155 mm artillery ammunition, and restore Ukraine's combat power.

If Russia perceives its use of AI as a success, and Ukraine is able to embrace the benefits of AI to reduce the efficacy of Russian EW, it follows that the UK might have no choice but to develop its own. The kind of LAWs that are represented by Russia's Lancet are not destabilising nor disruptive to the international order. However, they can have a very valid and specific battlefield application in providing frontline forces with tactical reconnaissance strike capabilities. This amplifies their firepower and can make or break an operation. The House of Lords' recommendations are commendable in their intent, but it is time to move beyond trying to establish definitions for autonomous weapons, and into an active process of exploring their tactical combat utility.

Manoeuvre formations' air and missile defence

David Isby

In the decades following the end of the Cold War, most US investment in integrated air and missile defence (IAMD) had been on large, non-mobile systems. Manoeuvre formation IAMD was reduced and units removed from the order of battle. Other NATO members made similar decisions. Elsewhere, countries that continued to field new ground-based air defence (GBAD), including Russia and Israel, were concerned with defending the homeland against missile or rocket threats.

Today, for the US, NATO and countries throughout the world, manoeuvre formations' IAMD capabilities, have become near-term priorities, reflecting the wars in Ukraine, Gaza, Nagorno-Karabakh, Yemen, Syria and Iraq. New technologies and systems are being developed to enable future enhanced capabilities.

Manoeuvre formations' IAMD remains largely service-specific, rather than being fielded through joint or coalition efforts. Looking at examples of programmes by the US Army and Marine Corps and some by European/other NATO countries, near-term capabilities have already been added to their force structures while at the same time, creating infrastructure – including sensors and network connectivity – that can be used with emerging technologies. The war in Ukraine cannot be ignored, showing manoeuvre formation IAMD's capabilities and limitations.

Credit: US Army/Georgios Moumoulidis

M-SHORAD of the 5/4th ADA training at the Oberdachstetten Range Complex, Germany, 23 April 2023.

A changed environment

Mobile, network-connected, survivable and interoperable systems are objective capabilities for manoeuvre formation IAMD. Today, there are fewer brigades and divisions than during the Cold War, with fewer opportunities for mutual support, and these operate dispersed over wider areas. Operational tempos have increased, and decision times reduced.

Unmanned aerial vehicles (UAVs) have demonstrated an ability to transform current battlefields. The counter-UAV (C-UAV) mission overlaps with IAMD. For example, the US Army has made air defence units responsible for defeating Group 3 and larger UAVs, include loitering, attack drones and swarming UAVs. The need for indirect fire protection capacity (IFPC) underlines that IAMD requires a self-defence capability as well as defending other units.

Technologies such as low-cost interceptors, high energy laser (HEL) and high-power microwave (HPM) are currently operational for C-UAV and IFPC missions. The deployment of mobile HEL weapons in the 300 kW power class, currently being developed in prototype form, will provide a cruise missile defence capability. High-level automation, in operational use for decades with GBAD and IFPC systems, will likely see capability expansion and wider application through the introduction of artificial intelligence (AI).

Prioritising IAMD – the US Army

We're going to need organic air defence with our fires, our manoeuvre units", US Secretary of the Army Christine Wurmuth said at a talk in Washington on 19 September 2023. The US Army ranks IAMD as number four of its six top force modernisation priorities, with four major lines of effort: Manoeuvre-Short Range Air Defense (M-SHORAD), Indirect Fire Protection Capability (IFPC), Army Integrated Air and Missile Defense Networked IAMD (AIAMD) command and control (C2), and Lower Tier AMD Sensors (LTAMDS). Elements of all of these were delivered to operators before the end of 2023.

Author

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Credit: RTX

While not an organic asset of manoeuvre formations, the LTAMDS radar is capable of being networked with them through IBCS and has the potential to improve future effectiveness.

Linking IAMD systems together with the US military's Joint All Domain C2 (JADC2) architecture, AIAMD C2 capabilities include the Northrop Grumman Integrated IAMD Battle Command System (IBCS), which started initial operational test and evaluation (IOT&E) in 2022. In 2023, it was approved for full rate production (FRP) and, using low-rate initial production (LRIP) systems, achieved initial operational capability (IOC). While IBCS is currently operational in conjunction with the Army's larger Raytheon MIM-104 PATRIOT-equipped units, the integrated fire control networks (IFCNs) that it enables can, in the future, include manoeuvre formation IAMD. "IBCS transforms the battlespace by fusing data from any sensor to create a picture allowing commanders to see the battlespace," Rebecca Torzone, vice president and general manager, combat readiness for Northrop Grumman, said on 13 April 2023.

Intended as the primary IAMD sensor for Army manoeuvre formations, deliveries of the Lockheed Martin AN/MPQ-61A4 Sentinel active electronically scanned array (AESA) radars started in 2022, and is scheduled to achieve IOC in 2025. Providing 360° coverage, it will equip Army M-SHORAD and IFPC battalions. Raytheon AN/MPQ-64A3 Sentinel radars are being upgraded and will serve into the 2030s. These are capable of IFPC missions and are also used in conjunction with the Kongsberg Defence/Raytheon NASAMS, currently being used in combat by Ukraine.

Systems – such as PATRIOT – normally do not manoeuvre with troops. Through being networked, their sensors are able to contribute to overall situational awareness, not limited by being 'stovepiped' with a specific battery. The Raytheon LTAMDS 'GhostEye' family of AESA radars is undergoing developmental testing, which will run through 2024. LTAMDS is the same size as the older AN/MPQ-53 radar used by PATRIOT, but with over twice the power. The medium-range variant of the Ghost Eye family, known as Ghosteye MR, has been integrated with NASAMS.

M-SHORAD

The M-SHORAD program is central to upgrading US Army manoeuvre formation IAMD, using an incremental approach using existing systems while investing in new armament options.

Replacing part of the US Army's current force of Boeing AN/TWQ-1 Avenger self-propelled surface-to-air missiles (SAM) systems, the M-SHORAD Increment 1 design was developed as a rapid response programme that started in February 2018 and delivered prototypes for testing 19 months later. It uses the General Dynamics Land Systems Stryker A1 8×8 wheeled AFV platform, armed with Lockheed Martin AGM-114L Hellfire Longbow missiles and Raytheon FIM-92K Stinger SAMs. Its Northrop Grumman XM914 30mm cannon will fire the currently under development XM1223 Multi-Mode Proximity Airburst (MMPA) proximity round for C-UAV purposes. Its Leonardo DRS mission equipment package includes the RADA USA Multi-mission Hemispheric Radar (MHR) and networked connectivity.

The current US Army requirement is for 162 M-SHORAD Increment 1s, 144 of which will equip four division and corps-level air defence artillery (ADA) battalions. The first unit, 5th Battalion of the 4th (5/4th) Air Defense Artillery Regiment (ADA), stationed in Germany, received its initial platoon of M-SHORAD Increment 1 vehicles in 2021. A second battalion, the 4/60th ADA, was activated at Fort Sill, Oklahoma in April 2022, as the organic ADA battalion of the 1st Armored Division. The third and fourth M-SHORAD battalions will also be part of US-based divisions.

The M-SHORAD Increment 2 Multi Mission High Energy Laser (MMHEL) Guardian system has been developed by the Army's Rapid Capabilities and Critical Technologies Organization (RCCTO). It retains the Increment 1's vehicle and mission equipment but is armed with a Raytheon 50 kW laser, intended primarily for the C-UAV and IFPC

Credit: RTX

The Stryker Mobile Expeditionary High Energy Laser (MEHEL) provided risk reduction for M-SHORAD Increment 2.

missions. A prototype system participated in the Army's 2015 Manoeuvre and Fires Integrated Experiment (MFIX). The first Increment 2 vehicle was delivered in 2022, the first four-vehicle platoon of prototype vehicles was delivered to the 4/60th ADA in September 2023. In live-fire testing at Fort Sill and the Yuma Proving Ground Arizona in 2023, Increment 2 systems destroyed Group 1 and Group 3 UAVs. Increment 2 is scheduled to achieve IOC in fiscal year (FY) 2025.

M-SHORAD Increment 3 is due to replace Stinger with the proposed Next Generation Short Range Interceptor (NGSRI). In 2023, the US Army issued contracts to Raytheon and Lockheed Martin for a competitive prototype fly-off for NGSRI. A production decision will be made in FY 2027, followed by procurement of up to 10,000 missiles. Congress has indicated a willingness to reprogramme funds to accelerate this program.

Until Increment 3 is available, Stinger production, which had halted, was restarted in 2020-21 and is to increase to 60 per month in FY 2025, some 50% greater than current levels. Stingers remaining in the US stockpile may be upgraded, along with many of which those used by NATO forces, especially Germany.

IFPC Increment 2-Intercept Block 1

The US Army plans to deploy eight IFPC battalions as division and corps-level assets, replacing the current Avenger and Raytheon Land-based Phalanx Weapons System (LPWS). The IFPC Increment 2 – Intercept Block 1 system was developed in response to limitations in the IFPC Increment 1, which was the Rafael Iron Dome interceptor system, as operated by Israel. Two Iron Dome battery sets were delivered to the US Army. In 2021, during an exercise, an Iron Dome battery deployed as part of the air and missile defence of Guam. The Iron Dome equipment, including 200 Israeli-produced Tamir missiles, was then leased to Israel for 11 months (with an option for subsequent purchase), when the Israel-Hamas War started in October 2023. The Army decided, in September 2021, instead of procuring the Iron Dome system, to test the IFPC Increment 2—Intercept Block 1 system. This configuration will use the IBCS and include the Sentinel A4 radar, 16 Dynetics Enduring Shield Multi-Mission Launchers (MMLs) and 80 Raytheon AIM-9XB2 Sidewinder SAMs. Deliveries started in 2023 for developmental testing starting in early 2024, which may lead to production, following an operational assessment in FY 2024. The total requirement may include some 400 MMLs.

The Increment 2 system is intended have an IAMD capability, primarily against subsonic cruise missiles. The kinematics of the Sidewinder enables engaging a wide range of threats. In 2023, the Army asked industry for an interceptor capable of enabling the system to defeat supersonic cruise missiles. Increment 2's integration with LTAMDS was tested in exercises in December 2023.

US Marine Corps MRIC

The establishment of the Marines' 3rd Littoral Anti Air Battalion (LAAB) in 2022 provided the first of several new units that will provide overlapping IAMD, IFPC and C-UAS capabilities, planned to operate the Marines' Medium Range Intercept Capability (MRIC). "MRIC is a middle-tier acquisition rapid prototyping effort, serving as a short-to-medium range air defence system [Editor's note: despite being characterised here as short-to-medium range, Iron Dome's Tamir missile in fact operates at VSHORAD ranges] that fills a crucial capability gap in the Indo-Pacific," Lt. Col. Matthew Beck, the program manager, said at Quantico on 29 August 2023.

Credit: David Isby

Skyhunter SAM on display. Skyhunter is the US domestic variant of the Tamir interceptor. It is functionally identical in terms of performance, but uses subcomponents compliant with US standards.

The Marines procured an Israeli-produced Iron Dome IFPC battery set, which provided the basis for the MRIC, successfully integrating it with their sensors and command and control (C2). The MRIC started live-fire testing in May 2022. Its capability in the IAMD role was demonstrated in June 2023 testing against cruise missile targets at White Sands Missile Range New Mexico, leading up to a planned September 2024 quick-reaction assessment that could put the program on course to start procurement in FY 2025.

While MRIC testing has used Israeli-produced Rafael/Raytheon Tamir SAMs (as used by Iron Dome), operational versions will be equipped with the Raytheon Sky-Hunter, (a version of the Tamir that will be interoperable with it), a US-designed trailer-mounted 20-round launcher, the Marine's Common Aviation Command Control system and the Northrop Grumman AN/TPS-80 Ground/Air Task Oriented Radar (G/ATOR) AESA radar. MRIC deliveries are planned to start in June 2025. Three batteries – one for each Low Altitude Air Defence

Credit: Dynetics

CG render of an AIM-9X-2 Block II SAM, being launched from the Dynetics MMI launcher.

battalion – could be delivered by FY 2028, with a potential total procurement of up to 44 launchers and 1,840 missiles.
"A striking example of successful acquisition support to Force Design 2030 execution can be seen in our Ground-Based Air Defence system," Stephen Bowdren, the Marines' Program Executive Officer for Land Systems, said at Quantico on 29 August 2023. "In a very short period of time, we've established a comprehensive suite of capabilities designed to counter the full range of aerial threats to Marines."

NATO

The meeting of NATO defence ministers on 21 October 2021 took action on a range of IAMD-related capabilities. Modular GBAD aims to integrate medium and short range IAMD using C2 modules with a plug-and-play capability; Belgium, Denmark, Germany, Hungary, Italy, Latvia, The Netherlands, Slovenia, Spain, UK, Norway, Poland, Portugal and US are members. The GBAD C2 Layer (Denmark, Italy, Portugal, Spain, UK and US) provides interoperable IAMD fire distribution centers (FDCs) at the battalion and brigade level, directly enhancing manoeuvre formation capabilities. Rapidly Deployable C-RAM, developing interoperable IFPC, includes Norway, Poland, US, Germany, Greece, Hungary, and the UK.
The 2022 NATO ministerial meeting saw 15 nations (with a further two to follow) sign up to the German-led European Sky Shield Initiative (ESSI). Primarily focused on a framework for a multinational missile defence capability, it included provisions for integrating mobile SAM systems, notably the German-built Diehl IRIS-T family. Looking towards ESSI implementation, at the October 2023 NATO ministerial meeting, ten countries agreed to a framework for joint air defence system procurements (Belgium, Czech Republic, Denmark, Estonia, Hungary, Lithuania and the Netherlands). Latvia, Lithuania and Estonia's joint NASAMS and IRIS-T family procurements were announced in 2023.

CAMM

The MBDA UK Common Antiair Modular Missile (CAMM) family of SAMs, developed by the United Kingdom, shares features and components with the MBDA UK Advanced Short Range air-to-air missile (ASRAAM). The British Army had a long-standing requirement for a replacement for the Rapier SAM system, in service since the 1970s, and has procured the Sky Sabre system to provide the medium range air defence (MRAD) component of its Land GBAD program. It is the UK variant of the MBDA EMADS system; it is armed with the CAMM missile, uses the HX77 8×8 truck platform as the basis for mobile system components, and is provided with the Saab Giraffe Agile Multi-Beam (G-AMB) 3D multifunctional radar, and a Rafael Advanced Defense Systems Modular, Integrated C4I Air & Missile Defence System (MIC4AD) fire control centre, along with Link 16 and other tactical datalinks. Officially in service since December 2021, a Sky Sabre battery set is stationed in the Falkland Islands. Sky Sabre provides IAMD for 1 (UK) Division as part of 7th Air Defence Group, which has made rotational deployments to Poland.
Poland has also been a major customer for the Land Ceptor, which has been integrated, by a partnership of MDBA and Poland's PGZ-NAREW consortium, into the Mała Narew MRAD system. This includes Polish domestically-produced components, such as the Jelcz 8×8 truck platform as the basis for mobile system components, and the Zenit C2 system produced by PIT-RADWAR. Production in Poland is planned to include some

Credit: MBDA

A CAMM iLauncher based on the Jelcz 8×8 truck platform, for the Polish version of the MBDA EMADS system. EMADS is central to the Polish Army's manoeuvre formation air defence, replacing Soviet-era systems.

100 launchers and over 1,000 missiles. First deliveries took place in 2021. The first battery was equipped in September 2022, accelerated from the scheduled date of 2027 in response to the war in Ukraine. Batteries have been delivered to air defence units of the 16th and 19th Mechanised Divisions. A programme of ongoing Anglo-Polish cooperation on Sky Sabre was announced in March 2022.

Ukraine

The war in Ukraine has shown how both sides' GBAD defend front-line units. The Ukraine Defence Contact Group, meeting at NATO headquarters in Brussels on 11 October 2023, pledged that "Zelensky can protect his cities and also protect his troops", US defence secretary Lloyd Austin told journalists.

In 2022, Ukraine's manoeuvre formation IAMD relied on Soviet-era systems including the Osa (SA-8 Gecko), Buk (SA-11 Gadfly – which was apparently the most effective) and Tor (SA-15 Gauntlet) SAM-equipped units. Both Ukraine and Russia used MANPADS and gun systems for manoeuvre formation defence, with 19 Russian and 11 Ukraine jet aircraft reportedly lost to these weapons in 2022. Ukraine has continued to rely on MANPADS – with Soviet-era types reinforced by systems such as the Stinger, Piorun, Starstreak HVM, Mistral, and various cannon-based systems for manoeuvre formation IAMD, especially in the 2022 fighting in Mariupol and Donetsk sectors, outside of the cover of longer-ranged SAMs.

In December 2023, it was reported that Ukraine had moved Patriot fire units forward, allowing them to shoot down Russian fighters in the Kherson sector. Russian air attacks on Ukraine's front-line units relied increasingly on attack helicopters, which suffered substantial losses through 2023 despite using air-to-surface missiles such as the 9M127 Vikhr, which enables helicopters to engage targets from outside MANPADS range.

By 2023, international support provided Ukraine an unprecedented range of IAMD systems that, despite limitations in training, lack of standardisation and challenges to sustainment, have deterred Russia's numerically and qualitatively superior airpower. Ukraine's forces have demonstrated remarkable adaptability, as the numbers of aircraft and missiles destroyed indicate. By 2023, the C-UAV and IFPC missions – the latter including self-defence by IAMD systems – have been seen as forward area priorities.

Most of Ukraine's IAMD systems are used to defend cities and infrastructure throughout the country. Their effectiveness has led the Russians, starting as early as March 2022, to increase their reliance on missiles. Air Force spokesperson Yurii Ihnat was quoted in the Kyiv Independent on 21 December 2023 that Russia had launched some 7,400 missiles at various targets in Ukraine, reducing Ukraine's SAM stockpiles to a critical level.

Ukraine's forward area IAMD has been attacked by jammers, long-range artil-

Credit: National Guard of Ukraine

Ukrainian National Guard soldier with 9K310 Igla-1 MANPADS, November 2022, Kharkiv region.

Credit: Ukrainian Army

The Swedish RBS 70 MANPADS in service with Ukraine's 47th Brigade, July 2023

lery cued by UAVs, and loitering munitions – including first-person view (FPV) drones. Loitering munitions, along with larger strike UAVs had previously proven effective against Armenia's relatively old SAM systems during the 2020 Second Nagorno-Karabakh War. While Soviet-era suppression of enemy air defences (SEAD) weapons including air-launched Kh-31P (AS-17 'Krypton') and Kh-58 (AS-11'Kilter') anti-radiation missiles (ARMs) and the surface-to-surface Tochka (SS-21 'Scarab') ballistic missiles have been used in combat, their damage appears to have been concentrated on fixed targets such as static air defence radars; IAMD assets able to displace and operate from dispersed camouflaged locations were often able to survive.

The future

The importance of interoperability for joint and coalition operations has been emphasised through the ongoing multinational deployments to NATO's eastern members, in exercises such as NATO's Formidable Shield and experiments such as the US Army's Project Convergence. Manoeuvre formation IAMD is, of necessity, multinational; sensor and fire control networks must be able to reflect this.

Threats, such as attack drones, are cheap and plentiful while current SAMs are expensive, and SAM launchers are vulnerable to direct attack. The introduction of specialised C-UAV and IFPC systems will not remove IAMD's need to defeat these threats. Looking beyond the near-term future, technologies such as HELs are being 'scaled up' to enable them to supplement SAMs in carrying out the IAMD mission.

Ukraine has demonstrated that IAMD needs to be able to upgraded quickly, integrating new missiles, launchers, sensors. In this regard, Ukraine has adapted ASRAAM as a SAM, and integrated the IRIS-T missile with the NASAMS launcher. While the initial NASAMS deployment in Ukraine was for the defence of Kyiv, they have also been used to defend forward area troops. The Raytheon RIM-7 NATO Sea Sparrow Missile (NSSM) and AIM-9M Sidewinder were integrated with the Buk system already in Ukraine's inventory to create the 'FrankenSAM' launch vehicle which went into action in January 2024. The need to upgrade software will only increase; AI and cyber warfare will become increasingly important.

Outside NATO, other countries are investing in IAMD capabilities, including Austria, Taiwan and Australia, where the army identified air and missile defence as a priority mission in their 2023 Defence Strategic Review. Armenia, which in 2020 lost many of its SAM systems in combat, announced in October 2023 it would replace them by acquiring French-built Mistral VSHORAD missiles. ■

Credit: NATO

French Army MBDA Mistral SAM launcher on NATO exercises in 2022. The Mistral has been supplied to Ukraine.

Desert fighters: Gulf air forces consolidate their combat capability

Peter Felstead

Dominated by fighter types produced by Western manufacturers, the air forces of the Gulf region remain a viable market for future fighter sales.

While some Gulf states – effectively Saudi Arabia and the United Arab Emirates – have made significant moves in recent years to indigenise defence production, in the aerospace sector these efforts have largely focused on the development of home-grown unmanned aerial vehicles and air-launched weapons.

The region thus remains a potentially lucrative market for the world's fighter manufacturers, although in reality the United States, the Eurofighter nations and France account for virtually all Gulf fighter acquisitions.

Moreover, international military operations against the Islamic State since 2014 and the initiation of a Saudi-led military coalition against the Yemen-based Houthi militia in 2015 have seen most Gulf state air forces engaging in combat missions over the last decade. This and the current instability in the region – caused by the October 2023 Hamas terrorist attack on Israel, the Israel Defense Forces' (IDF) consequent campaign in Gaza and the Houthis' subsequent campaign against international shipping around the Red Sea and Gulf of Aden – have given added motivation for the Gulf states to maintain the strength of their air forces.

Credit: BAE Systems

An RSAF Typhoon sporting a special national livery. The RSAF's Future Fighter requirement is most likely to be fulfilled by a purchase of Typhoons.

Saudi Arabia

The Royal Saudi Air Force (RSAF) operates a fast jet combat fleet consisting of 80 Panavia Tornado IDS strike aircraft delivered from 1986 (and upgraded to UK GR4 standard), around 232 Boeing F-15C/D/S/SA multirole fighters delivered from 1982, and 71 Eurofighter Tranche 2 Typhoon multi-role fighters from 72 delivered from 2009. Deliveries of the RSAF's 84 new F-15SA aircraft were completed in 2020, according to Boeing.

The Kingdom of Saudi Arabia (KSA) formerly had a requirement for at least 48 – and possibly as many as 96 – new Typhoons to replace its Tornados and in March 2018 signed a memorandum of intent to purchase an additional 48 such aircraft. However, following the murder of Saudi journalist Jamal Khashoggi at the Saudi consulate in Istanbul on 2 October 2018, and due to human rights concerns, Germany placed a veto on further Eurofighter sales to the Kingdom. This led Saudi Arabia to court Dassault with regard to a potential procurement of Rafale fighters.

However, in light of the Hamas attack on Israel on 7 October 2023 Germany moved to lift its embargo on further Typhoon sales to the KSA. German Foreign Minister Annalena Baerbock stated during a visit to Israel on 7 January 2024, "The world, especially here in the Middle East, has become a completely different place since October 7," adding, "We do not see the German government opposing British considerations for more Eurofighters for Saudi Arabia."

The prospect of an additional Typhoon sales to the KSA is thus back on, but, that said, there are a number of potential hurdles to such a sale. The RSAF is known for wanting to operate Eurofighters that match the standards of the Typhoons in Royal Air Force (RAF) service. In addition to this, the RSAF is reportedly keen for any future Typhoons it acquires to be equipped with both the European Common Radar System (ECRS) Mk 2 active electronically scanned-array (AESA) radar and a large area display (LAD) in the cockpit. While the RAF has, indeed, committed to the ECRS Mk 2 for its Typhoon fleet, as yet there is no RAF commitment to a LAD.

The ECRS Mk 2 is a significant advancement compared to the previous Mk 0 and Mk 1 ECRS variants in that it features a wide-band array that will not only detect its own emissions and find other targets in that way, but will also passively detect emissions through a far broader range of the frequency spectrum and thus possess an electronic attack capability.

With any future Typhoon contract the RSAF will nevertheless want to be confident that no future veto from a Eurofighter partner nation will affect the support of any future aircraft it acquires.

Enabling successful flight operations with the Phoenix Aviation Management Software

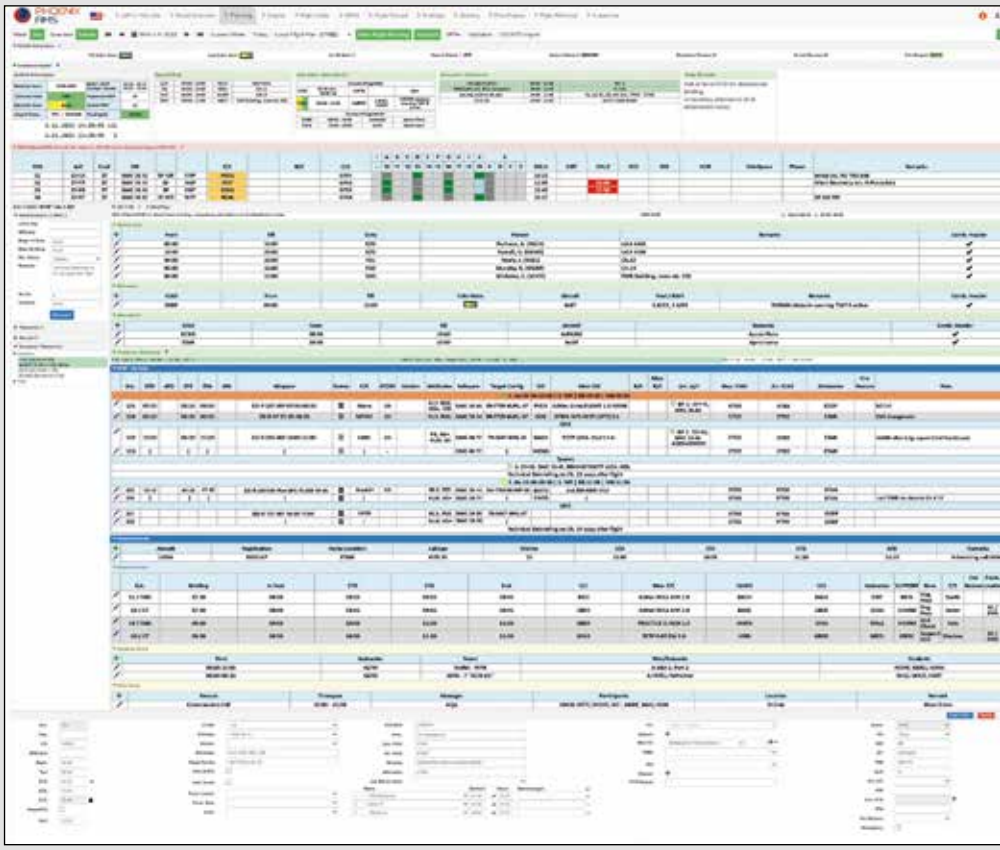
Planning and deploying high-value resources effectively and, above all, efficiently, in daily educational, training and operational flight operations - enabling aircrews for military operations - requires a strong sense of responsibility, maximum concentration and planning skills. These challenges are faced by military superiors and those in positions of responsibility, in particular operations officers, in their daily duties: Increasingly complex operational and training scenarios require an extremely broad skills profile from all those involved. Competence and performance are the basis to be able to successfully execute flying missions. To ensure this, structured planning - such as the creation of classes, syllabi, theoretical and practical training sections for lessons, simulators and flight - is essential during educational and training flight operations.

To support this increasingly complex planning effort, ESG Elektroniksystem- und Logistik-GmbH developed the server-based aviation management software Phoenix. It records, regulates, monitors, and analyses all resource information, e.g. the training status of aircrews, as well as the availability of all tangible and intangible resources.

Phoenix supports supervisors in fulfilling their responsibility to deploy their personnel for the various education, trainings and also missions, in accordance with all selection criteria - for example, based on certain pilot skills and currencies, taking into consideration aircraft availability with specified configurations or due to predetermined airspaces such as a certain range or a night low-flying system. Phoenix can coordinate and manage the complex capabilities of the personnel and resources in a structured manner, and integrate and deploy them efficiently in educational, training and operational flight operations.

Phoenix creates the necessary situational awareness by providing flight scheduling personnel with reliable information and determining the basis for assessing operational capability based on a complex database for different situations and scenarios in accordance with regulations. This information is based on the continuous review and validation of all resources, such as the validity of qualifications, clearances, licences, and many other factors, as well as the availability and configuration of tangible and intangible resources. It also considers the applicable military and civilian regulations.

Credit: ESG



Phoenix Mission Board

For flight operations, all crew requirements are displayed and monitored in the Phoenix Mission Board (see illustration). Scheduling staff can access calendar, class, syllabus progress and currency overviews as well as a range of other information relevant to flight operations. The management software is also used for flight orders and flight data recording, as well as to create mission cards, grade sheets and tactical combat training programmes. The continuous validation function issues warning messages if necessary: Flight plans with particular requirements for aircraft equipment, airspaces, tankers for air-to-air refuelling, range bookings, communication networks, JTAC, night low-flying systems and other factors are checked, validated and, if they are not fulfilled, are flagged with corresponding warning messages. In addition to statistical flight data, tactical events are also recorded digitally, and stored and evaluated for each person. Phoenix provides each participant with an overview of their personal status.

Whether for fighter aircraft, helicopters or mission and transport aircraft, Phoenix serves the specific requirements in all environments. ESG's agile and highly specialised software and development team supports the integration of new customer requirements into the tool, which is continually further developed.

Credit: BAE Systems

A pair of RSAF Typhoons. Saudi Arabia is likely to buy more Typhoons, although it remains unclear which ECRS AESA radar they are likely to be equipped with.

Meanwhile, news emerged out of the 2024 World Defense Show (WDS 2024), held in Riyadh from 4-8 February, that in a project it is calling the 'Future Fighter' programme, Saudi Arabia is looking for 54 new fighters. The increase in number from 48 is derived from the believe that, whatever new fighter is procured, it will be different enough from anything in the current RSAF inventory that additional conversion trainers will be required.

Suggestions also emerged out of WDS 2024 that the RSAF might be inclined to opt for Typhoons with ECRS Mk 0 radars since, although these do not have the functionality of the ECRS Mk 2, Typhoons equipped with them could be obtained much sooner (production of Qatari ECRS Mk 0-equipped Typhoons is due to be completed in August this year).

The latest BAE statement on the Saudi requirement reads, "We are supporting the UK government to respond to the Statement of Requirements issued by the Saudi Arabian government for a future requirement of Typhoon aircraft," suggesting that a Typhoon campaign for Saudi Arabia is, indeed, active.

Beyond current-generation fighters, Saudi Arabia is very keen to be involved in the UK/Italian/Japanese Global Combat Air Programme (GCAP) and its Tempest sixth-generation fighter – so much so that on 1 March 2023 the Saudi defence minister declared that his country had actually joined the programme, only for the UK Ministry of Defence (MoD) to walk back that statement. There does seem to be support from within the UK MoD for the Saudis to join GCAP 'in due course', although Japan appears less willing to accept another partner in the programme. It is possible that the UK might somehow allow the Saudis to participate in the wider, UK-led Future Combat Air System (FCAS) programme, which remains as a wider project that goes beyond the specific GCAP focus on the Tempest fighter.

United Arab Emirates

The UAE Air Force and Air Defence (UAE AF&AD) employs 4,500 personnel and currently operates more than 200 aircraft, with its combat air element consisting of 56 Block 60 F-16Es and 22 F-16Fs (three squadrons) and 59 Mirage 2000-9s (three squadrons). The F-16E/Fs feature the Northrop Grumman AN/APG-80 AESA radar, which gives them the capability to simultaneously track and destroy air and ground threats.

However, in December 2021 it was announced that the UAE had ordered 80 Dassault Rafales – the French manufacturer's largest ever export order for the type – in the aircraft's latest F4 configuration, which are to be delivered between 2026 and 2031. These will be the first Rafale F4s to be operated outside France.

The most significant feature of the F4-standard Rafale over its predecessors is the aircraft's adoption of the RBE2 AESA radar, which brings improved capabilities in the air-to-ground mode, but the F4 standard also brings several other enhancements, including: improved connectivity through new satellite and intra-flight links, communications servers, and software-defined radios; improvements to the navigation and weapon systems; a new infra-red search and track (IRST) sensor; introduction of the SPECTRA integrated electronic warfare suite and Talios targeting pod; and installation of a next-generation Scorpion helmet sight. New weapon integrations for the aircraft include the MICA NG air-to-air missile and the Armement Air-Sol Modulaire (AASM) air-to-ground modular weapon.

The UAE had previously been interested in acquiring 50 fifth-generation Lockheed Martin F-35A Lightning II fighters, having effectively been promised the opportunity to buy them by the previous US Trump administration in return for normalising relations with Israel. However, in January 2021

Credit: USAF

A UAE F-16 Desert Falcon photographed on 29 May 2019. The UAE AF&AD operates 56 Block 60 F-16Es and 22 F-16Fs.

Credit: USAF

QEAF Rafales fly in formation above Qatar in December 2020. The QEAF operates 36 Rafale DQ/EQs, but Qatar is reportedly considering the acquisition of a new batch of 24 Rafale F4s

the US Biden administration announced it was reviewing the sale of F-35s to the UAE. Although the Biden administration subsequently announced in April 2021 that such a sale could proceed, in December 2021 the Emiratis declared they were withdrawing from any F-35 purchase, having not agreed to additional US terms in relation to the sale, and instead signed the Rafale order with Dassault.

As previously mentioned, the indigenisation of UAE air-launched weapon capabilities means Emirati weapons made by EDGE Group subsidiaries are increasingly being integrated onto the UAE AF&AD's fast jet fleet. These include MK81, MK82, Mk83 and Mk84 aerial bombs made by Lahab; the Al Tariq family of precision-guided munition kits; the Halcon Desert Sting range of guided glide weapons; the Halcon NASEF-S120 low-cost cruise missile; and the Halcon Thunder range of short-range guided bomb kits.

Qatar

Operational since 1974, the Qatar Emiri Air Force (QEAF) continues to build a substantial combat aircraft fleet and the infrastructure to go with it. When its currently ongoing procurement is complete, the QEAF will be operating five different combat aircraft types.

Nine years ago the QEAF's existing fast jet fleet consisted of nine single-seat Dassault Mirage 2000-5EDA fighters and three two-seat Mirage 2000-5DDA operational trainers in the air superiority role, delivered from 1997, and six Dassault-Dornier Alpha Jets for ground attack, initially delivered in 1980. In May 2015, however, the QEAF ordered 24 Dassault Rafale DQ/EQ fighters from France (18 Rafale EQ single-seaters and six twin-seat Rafale DQ variants) followed by a second order for another 12 Rafales in December 2017. These aircraft were all delivered between 2019 and 2022. According to French media reports, however, Qatar is reportedly considering the acquisition of a new batch of 24 Rafale F4s plus an upgrade of its existing fleet to the F4 standard.

The QEAF Rafales are equipped with a range of French- and European-made weapons, including the MBDA AM39 Exocet Block II anti-ship missile, MBDA SCALP EG cruise missile, Safran AASM medium-range air-to-ground missiles, MBDA MICA IR air-to-air missile, and MBDA Meteor beyond-visual-range air-to-air missile. In June 2018 it was announced that Qatar had selected the Lockheed Martin AN/AAQ-33 Sniper advanced targeting pod (ATP) to equip its fleet of Rafales.

In another deal signed in December 2017 the QEAF purchased 36 Boeing F-15QA fighters from the United States (although the US Department of Defense (DoD) has repeatedly referred to a purchase of 48 aircraft and the US State Department has cleared Qatar to buy 72 aircraft), with the

Credit: Boeing

Qatar purchased 36 Boeing F-15QA fighters in December 2017, deliveries of which were completed in July 2023.

first five F-15QAs departing for the QEAF's Al Udeid Air Base on 27 October 2021. Deliveries of these aircraft were completed in July 2023, according to Boeing.

Boeing has received a contract to integrate the AGM-84L Harpoon Block 2 anti-ship missile with the Qatari F-15s and Doha has also ordered the Raytheon AGM-154 Joint Standoff Weapon (JSOW): a long-range glide bomb that can be retargeted after launch and has a warhead that can penetrate hardened fortifications, offering a stand-off strike capability that will be combined with the DB-110 tactical reconnaissance pod.

Also in December 2017 Qatar signed an agreement with the UK for 24 Eurofighter Typhoons in conjunction with a weapon package including MBDA Meteor beyond-visual-range air-to-air missiles, Brimstone air-to-surface missiles, and Paveway IV laser-guided bombs. The first of these Typhoons reached Qatar in September 2022, while a BAE Systems spokesperson told ESD on 9 February, "Aircraft 17 and 18 were delivered to Dukhan Air Base at the end of last year." The last of the 24 aircraft ordered are due to be delivered by mid-2024.

Qatar and Kuwait are the first nations to operate Typhoons featuring the ECRS Mk 0 radar, which is a narrow-band AESA system primarily designed to detect airborne targets.

As part of the Qatari Typhoon deal the UK RAF and the QEAF set up a joint Typhoon unit, 12 Squadron, which was reformed as a joint RAF/QEAF unit on 24 July 2018. Although ostensibly based at RAF Coningsby, where joint operations began in 2020, 12 Squadron deployed to Qatar in September/October 2022 for air security operations during the World Cup and returned to the UK at the end of February 2023.

Once these acquisitions are complete (and assuming the Alpha Jets and Mirages remain in service for now) the QEAF will thus field a formidable fleet of 114 combat aircraft – and possibly even more if there is a follow-on purchase of F-15QAs or indeed any other type.

Although Qatar formally submitted a request to the United States to acquire the Lockheed Martin F-35 Joint Strike Fighter, both Israeli and Saudi pressure is likely to prevent any such procurement, so for now the QEAF's desire to operate a fifth-generation fighter is likely to remain unanswered.

Kuwait

The Kuwait Air Force (KAF) has some 2,500 officers and enlisted personnel and operates about 100 aircraft. In terms of its fast jet fleet the KAF still operates around 32 Boeing F/A-18C/D Hornets of 32 F/A-18Cs and eight F/A-18Ds a delivered in 1992-93.

However, in September 2015 it was announced that Kuwait had ordered 22 single-seat and six twin-seat Tranche 3 Typhoons in an order that is being fulfilled out of Eurofighter's facilities in Caselle, Italy. Delivery of these aircraft began in December 2021, with Eurofighter confirming on 9 February this year that 15 out of the 28 aircraft on order have so far been delivered. As previously mentioned, the KAF, along with the QEAF, is a first user of the ECRS Mk 0 AESA radar on its Typhoons.

In June 2018, meanwhile, Kuwait ordered 22 single-seat F/A-18E and six twin-seat F/A-18F Block III Super Hornets, deliveries of which were completed, initially to the US Navy, in September 2021, although the Covid-19 pandemic ultimately delayed their delivery on to Kuwait.

The Block III Super Hornets will include upgrades to the Raytheon AN/APG-79 AESA radar, an IRST sensor, 'shoulder'-mounted conformal fuel tanks and new enhanced F414-GE-400 powerplants.

The KAF's fleet of classic Hornets will thus ultimately be replaced by a two-type frontline fast-jet force consisting of Block III Super Hornets and Tranche 3 Typhoons.

Credit: USAF

US Air Force airmen prepare to disconnect a Kuwait Air Force Super Hornet from a Mobile Aircraft Arresting System at Ali Al Salem Air Base, Kuwait, on 10 July 2023. Kuwait ordered 26 F/A-18E/F Block III Super Hornets in June 2018.

Oman

The Royal Air Force of Oman (RAFO) is a capable and professional air force that has traditionally procured Western aircraft types.

Having initially been formed as the Sultan of Oman's Air Force (SOAF) with UK assistance in 1959 and initially staffed with British air and ground crew, the force was organised with a similar structure to the UK's RAF. In 1990 the SOAF was renamed the Royal Air Force of Oman.

Credit: Eurofighter

The first Typhoon to be delivered to Oman, pictured in June 2017. The RAFO operates 12 Tranche 3 Eurofighter Typhoons, alongside 23 F-16C/D Block 50/52+ fighters.

Today the force has a strength of around 4,100 personnel and operates around 130 aircraft of all types across 12 squadrons. The primary combat aircraft of the RAFO include nine single-seat and three two-seat Tranche 3 Eurofighter Typhoons, delivered between 2017 and 2018, and 23 Lockheed Martin F-16C/D Block 50/52+ fighters delivered from 2006 (17 of the 18 single-seat F-16Cs originally ordered and six two-seat F-16Ds).

To ensure that its F-16C/D fleet remains a viable force, Oman has requested a number of upgrades for the aircraft and in January 2018 the US Defense Security Cooperation Agency announced that the US State Department had approved a USD 62 million Foreign Military Sale of electronic warfare and communications equipment for the aircraft. This package includes Mode 5 identification friend or foe (IFF) and secure communications equipment, as well as an incremental operational flight profile (OFP) and joint mission planning software upgrade. The new IFF equipment will help Omani F-16 pilots achieve better interoperability with US and other allied platforms.

Bahrain

Although limited in terms of personnel and aircraft, the Royal Bahraini Air Force (RBAF) is deemed to be a well-trained, capable force that has shown itself to be prepared to engage in regional security operations. It also benefits from Bahrain having signed a defence co-operation agreement with the United States in 1991 as a 'non-NATO ally', meaning that, in return for US basing rights, the RBAF has access to training support under the US International Military Education and Training programme as well as funding via the US Foreign Military Financing programme.

Credit: USAF

The first RBAF F-16 Block 70 lands at Edwards Air Force Base, California, on 28 March 2023 for flight testing prior to delivery on to Bahrain, which has ordered 17 F-16 Block 70s.

The RBAF has a combat fleet consisting of 17 Lockheed Martin F-16Cs delivered from 1990 and eight F-5Es delivered from 1985. Four F-16D and four F-5F conversion trainers were delivered at the same time as the respective single-seaters. A contract for 17 F-16 Block 70s was signed in June 2018, with deliveries originally set to run until September 2023, but the Covid-19 pandemic ultimately knocked this schedule off course. The first Bahraini F-16 Block 70 was officially handed over at Lockheed Martin's site in Greenville, South Carolina, on 10 March 2023, while delivery of this F-16 Block 70 fleet to Bahrain will be completed this year. Once the F-16 Block 70s are received, the RBAF will retire its F-5s.

The F-16 Block 70 (as well as the F-16V upgrade) features the fifth-generation capabilities of the Northrop Grumman APG-83 AESA radar as well as a new high-resolution Centre Pedestal Display (CPD), which provides critical tactical imagery to pilots and allows them to take full advantage of the AESA radar and targeting pod data. The Block 70 F-16 also features Lockheed Martin's Automatic Ground Collision Avoidance System (Auto GCAS), among other enhancements.

A Lockheed Martin spokesperson told ESD on 7 February that two RBAF Block 70 F-16s are currently at Edwards Air Force Base, California, for testing with the US Air Force's 416th Flight Test Squadron prior to delivery on to Bahrain. The first of these arrived on 28 March 2023. The RBAF has also committed to upgrading its existing F-16C/Ds to the F-16V standard, having received approval from the US State Department to do so.

Credit: USAF

A formation of RSAF F-15s pictured in September 2020.

Future sales

The most likely prospect for more fighter sales into the Gulf region rests with the Saudi Future Fighter requirement, with Eurofighter now apparently in pole position given that the German veto on Typhoon sales to the Kingdom has been relaxed. Beyond replacing its Tornados, the RSAF may well also want to replace its F-15C/Ds, with Typhoons being a possible candidate for both of these requirements. An initial purchase of Typhoons equipped with the ECRS Mk 0 radar could possibly be followed up with a later purchase of Typhoons sporting the ECRS Mk 2 when that becomes available.

While Dassault will no doubt continue its regional campaign with the Rafale F4, Dassault sources have admitted that, with regard to Saudi Arabia, they had suspected that Saudi interest in the Rafale may well have been at least partially designed to put pressure on Eurofighter. Dassault might thus find more traction in Qatar with the Rafale F4.

Lockheed Martin, meanwhile, could still secure sales of F-16 Block 70s/F-16V upgrades, most obviously to Bahrain, since the Emirati F-16E/Fs already possess an AESA radar.

Sales of any fifth-generation fighters into the Gulf region, most obviously the F-35, appear unlikely in the near term, but one new aircraft type that does have potential prospects is the Boeing F-15EX Eagle II. While there is anecdotal evidence that the Saudi and Qatari air forces have not been overly impressed with the performance of their current-generation F-15s when fully loaded, Boeing is placing its faith in the F-15EX for future sales into the Gulf region and elsewhere.

A Boeing spokesperson told ESD on 9 February 2024, "The F-15EX is gaining interest from multiple international customers, both existing users and potentially new users, as militaries look to modernise and upgrade their fleets and enhance force structures. Potential customers around the world will benefit from the US Air Force's investments in the F-15EX and the next-generation capability it brings to the warfighter."

The F-15EX was developed to recapitalise the US Air Force's F-15C/D fleet due to inadequate numbers of fifth-generation F-22s in the US inventory, with the first aircraft expected to enter operational US service in July 2024.

As well as a pair of uprated F110-GE-129 engines, which each deliver 131 kN with afterburner (compared to 105.7 kN with afterburner for the F-15E), the F-15EX features a Raytheon AN/APG-82(V)1 AESA radar, a digital electronic warfare system in the form of the AN/ALQ-250 Eagle Passive Active Warning Survivability System (EPAWSS), the Legion IRST pod to better detect low-observable threats, and has a 13,300 kg payload capacity, which Boeing says gives it "the unique capability of holding 12 Advanced Medium-Range Air-to-Air Missiles or other large ordnance".

The aircraft also has a LAD and can employ the Joint Helmet Mounted Cueing System to cue weapons at high off-boresight angles and also features an open systems architecture to facilitate potential future avionics upgrades.

The Boeing spokesperson said of the company's opportunities for future sales to the RSAF, "The F-15EX would add critical capability for the RSAF as the country seeks to accelerate its armed forces modernisation."

Over the last few years there have been overtures into the Gulf from fighter manufacturers beyond the West: the Chinese/Pakistani JF-17 Thunder has been pushed in the region, Korea Aerospace Industries is marketing its KF-21 Boramae and Turkish Aerospace is developing its Kaan National Combat Aircraft, which performed its maiden flight on 21 February 2024.

It seems most likely, however, that the Gulf's air forces will stick with their traditional Western fighter suppliers, at least for the next several years. ■

Viewpoint from Lisbon

Photo: via author

Portugal's comprehensive equipment modernisation

Victor M.S. Barreira

The Portuguese Military Programming Law 2023–2034 – approved in July 2023 – seeks to provide a comprehensive boost to the modernisation of the country's depleted armed forces by acquiring new equipment worth EUR 5.57 billion. This amount, the largest ever, foresees the acquisition of land, naval, air, cyber security, space capabilities, as well as emerging disruptive technologies, according to the Ministry of National Defence.

The Portuguese authorities are spending significant amounts out to 2034 in order to maintain and modernise in-service equipment, and procure a wide range of equipment, including armoured vehicles, vessels, aircraft, missiles, torpedoes, ammunition and drones. At the same time, Portugal is seeking to bolster research, development, and innovation in cooperation with local industry partners and with public and private research organisations to contribute to developing the local defence technological and industrial base (DTIB).

The Portuguese defence economy has a myriad of defence-related small and medium enterprises, clusters, trading companies and research centres, with activity in a variety of areas. Over the past decade, Portugal has primarily resorted to the NATO Supply and Procurement Agency (NSPA), to meet its needs for more immediate capabilities. Despite budget limitations and procurement delays, the country aims to reach 2% of GDP in defence expenditure by 2030 from the current 1.38%.

However, there are challenges – notably the country's armed forces though are facing a staffing shortage, with 23,400 personnel currently employed, far below the authorised figure of 32,181. Several incentives and a relaxing of rules are being used to attract new personnel; however, they have yet to prove successful. Despite their small size, the Portuguese Armed Forces have been involved in several deployments as part of UN, EU, and NATO missions. Portugal currently deploys 579 troops aboard, the Cabinet of the Armed Forces Chief of Staff told ESD, including in the Central African Republic, Jordan, Mali, Mozambique, Romania, and Somalia.

Air Force's Director of the Engineering and Programs Directorate, Brigadier General João Rui Ramos Nogueira told ESD that under its transformation plan 'Air Force 5.3', the Portugeuse Air Force (FAP) is looking to acquire a long-range medium-altitude long-endurance (MALE) unmanned aerial vehicle (UAV) fleet for the intelligence, surveillance, and reconnaissance (ISR) role, a lightweight attack aircraft fleet for the close air support (CAS) and ISR roles, three new UH-60 Black Hawk helicopters, as well as a 5th-generation fighter jet fleet to replace its F-16AM/BM Fighting Falcon aircraft. The creation of a Space Command and Control (C2) Centre is also planned.

In recent years, the Air Force ordered six UH-60A Black Hawk and seven AW119 MkII Koala helicopters, twelve OGS 42N/VN UAVs, Sidewinder AIM-9X Block II missiles, as well as the modernisation of four C-130H Hercules airlifters and five P-3C CUP+ Orion maritime patrol aircraft. In October 2023, Portugal received the first of five KC-390 Millennium transport aircraft it ordered in 2019.

In the recent past, the Navy received two *Viana do Castelo* class offshore patrol vessels (OPVs), and on 29 December 2023, awarded West Sea a contract to build six further vessels of the class by 2030. On 24 November 2023, the Navy awarded Damen a contract to build and outfit the NRP D. João II multi-purpose vessel. The Navy has also recently modernised is Super Lynx Mk95A helicopters. Regarding further acquisitions, Portugal is also looking to acquire two replenishment ships, a multi-role logistics ship, and coastal patrol ships. Additionally, the Navy's Chief of Staff, Admiral Henrique Eduardo Passaláqua de Gouveia e Melo, will propose the purchase of two submarines to the new government.

In terms of frigates, Portugal operates two *Bartolomeu Dias* class, which were recently upgraded, and three Vasco da Gama class MEKO 200PN frigates, two of which will be modernised by 2027, and one will receive several platform control and communications updates, the Navy told ESD. All five frigates are intended to remain in service until 2035, and the current Military Programming Law also provides funds for their replacement, which is expected to enter service within this timeframe.

The Chief of the Army's Capability Development Office, Lt. Col Emanuel Alves de Sousa told *ESD* that the Army is acquiring all-terrain vehicles, lightweight armoured vehicles, 120 mm mortar carriers, a Role 2B field hospital, armoured recovery vehicles, bridging systems, 155 mm howitzers, a very short-range air defence (VSHORAD) system, air defence radars, equipment for the SIC-T tactical communications system, ground surveillance radars, anti-tank guided missiles (ATGMs), 47 4×4 and 61 6×6 unarmoured/armoured logistics trucks, unmanned ground vehicles (UGVs) and UAVs. Additionally, the force will modernise its Leopard 2A6 tanks and Pandur II armoured vehicles. Other equipment received by the Army in recent years includes: 4×4 VAMTAC ST5 armoured vehicles, 4×4 Q-150D airborne vehicles, grenade machine guns (GMG), the Minimi Mk3 light machine gun, HK416A5, Supernova TSS, SCAR-H/L and G17 Gen5 weapons, the SICCA3 integrated air defence C2 system, equipment for the ISTAR Battalion and the SIC-T system, Sportsman MV850, MTZR 2, MRZR D2 and MRZR D4 all-terrain vehicles, PRC-525, TWH-104R4 and Soveron HR5000 communication systems, NYXUS Bird LR imagers, Volvo FMX 380/420/540 and TGX 18.420 logistics trucks.

Farewell to Falconer?

Thomas Withington

The US Air Force (USAF) is continuing to modernise its Falconer command and control (C2) architecture, but does the system have a long-term future as the Pentagon embraces new warfighting doctrines?

In August 2022, the USAF awarded a USD 319 million contract to SAIC, for sustainment and modernisation of the AN/USQ-163 Falconer C2 system, which the USAF uses to manage air operations. SAIC is part of ongoing efforts to revamp the overall Falconer architecture. The USAF's own literature describes Falconer as "a system-of-systems that incorporates numerous third-party software applications and commercial off-the-shelf products." Falconer assists theatre air and missile defence, "pre-planned dynamic and time sensitive multi-domain target engagement operations,", plus intelligence, surveillance and reconnaissance (ISR) resources management.

The AN/USQ-163 provides a vital, operational C2 capability to support air, and wider joint, operations. Political direction flows from the US President, as commander-in-chief, and the administration, notably with the Secretary of Defense. US geographical combatant commands are responsible for the C2 of any conflict or contingency and are assigned this responsibility depending on where the situation is occurring. To this end, a geographical combatant command may take responsibility. Alternatively, Cyber Command, Space Command, Special Operations Command, Strategic Command and/or Transportation Command could take responsibility should the situation demand. The air dimension of any contingency will be the responsibility of the Joint Force Air Component Commander (JFACC), who will exercise command from the Combined Air Operations Centre (CAOC), which is where the AN/USQ-163 system resides.

A key role of the CAOC and Falconer is to draft the Air Tasking Order (ATO). In a nutshell, the ATO provides the 'sheet music' for all air operations and will cover the following 24 hour period. The author has seen ATOs in the past and can attest to them running to hundreds of printed pages. The ATO details a myriad of missions from combat air patrol and tanker orbits to close air support provision and battlefield interdiction. Put simply, if it flies, it is detailed in the ATO. The ATO translates the intent of the strategic political leadership and the operational commanders into a series of air actions to support this.

Credit: USAF

USAF personnel check an Air Tasking Order (ATO) during an exercise led by the US military in the Republic of Korea. The ATO is the 'sheet music' governing all USAF Air operations over a 24-hour period, including allied contributors if the air tasking order is covering a multinational operation.

Author

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Software upgrades

Efforts to modernise Falconer began just after the turn of the century. In 2003, the USAF launched its Air Operations Centre-Weapon System (AOC-WS) enhancement for the AN/USQ-163. At that time, the AOC-WS project was limited in scope, with limited funding available; improvements to the existing architecture tended to be small but were urgently needed. Perhaps unsurprisingly, given the strategic exigencies of the time, these improvements tended to be restricted to the Falconer system equipping US Central Command. As it does today, Central Command (CENTCOM), was responsible for combat operations in Afghanistan and Iraq.

Falconer is currently being enhanced with the AOC-WS Block-20 software package. The USAF had planned to upgrade the

ESG – Driver of digitalisation for multi-domain operations

Digitalisation is one of the defining topics of current discussions within the security community. It has been a recurring theme over the last twenty years under various names; however, the basic requirements remain the same.
Since the early 1980s, ESG has been supporting its customers as a hardware-independent solution provider for the digitalisation of armed forces.

Credit: ESG

ADLER– central interface for successful networking

Originally there were three binational programmes (DE-US, DE-GB, GB-US) for digital interoperability between the nations to enable mutual fire support. After initial successful tests in 1984, the realisation of the C4 and fire support system (C4FS) ADLER was commissioned in several stages. With the introduction of ADLER I in 1995, the German artillery had the first network of reconnaissance, command and control and effects - at the time it was aptly described by the German General of the Artillery, Brigadier Reichhelm, as "ADLER is the heart of the artillery network".
Today, the German artillery uses the third generation of ADLER. As a result, it not only has annually proven interoperability with 15 full members of the multinational ASCA programme (Artillery Systems Cooperation Activities), but also the system with the most interfaces to sensors and effectors as well as to other command and control systems.

Future-oriented command post systems

ADLER has many different capabilities, including standardised messages with alert functions for the user, calculations to ensure fire support coordination measures to avoid collateral damage, situation awareness based on APP6D (as well as APP6A / MilStd2525C), and a chat function. One functionality that is essential for the core mission of national and alliance defence should be highlighted: The change of the command post. ADLER makes it possible to operate two command posts (squadrons) in parallel at different locations. It constantly synchronises the data between the operational command post and the reserve command post. This also works during the relocation of the reserve command post. As soon as it is ready to take over the command role at the new location, all communication addresses - and therefore the roles of the two command posts - are exchanged directly. The realisation of this redundant command post concept ensures both highly mobile and flexible command and control as well as increased reliability.
Due to its unique range of functions and robustness, combined with flexible customisation, further nations - Lithuania, Switzerland and the Czech Republic – have decided to procure ADLER for different parts of their armed forces.

Expanding capabilities through digital innovations

With our proven technological expertise and in-depth domain knowledge, ESG also supports the German artillery with command posts, the COBRA weapon location radar (ESG is the design authority) and in many other Joint Fire Support (JFS) projects. Examples include the Joint Fire Support Team Training Simulator and the Joint Fire Support Team dismounted projects.
The JFSTT Simulator at the artillery school in Idar-Oberstein uses a dome, virtual reality headsets, a recce vehicle mock-up and relevant equipment replicas (radios, observation devices, etc.) to provide highly realistic training. It is also certified by NATO to replace real JTAC training.
ESG has also developed a system for Digitally aided Close Air Support (DaCAS). This software enables a direct connection to aircraft using the Variable Message Format. It has been tested by JTACs in various exercises, including BoldQuest. A complete set of carrying equipment for different target acquisition and marking sensors is being developed, with a focus on ergonomic design. The DaCAS and ADLER III software have been merged to give users the option to request both Indirect Fire assets as well as CAS.
These projects demonstrate ESG's holistic technological expertise as a reliable partner for military forces and its commitment to the capability-oriented further development of the armed forces.

Credit: USAF

Despite looking antiquated because of its old-style computer monitors, the AN/USQ-163 Falconer air operations command and control system is being overhauled via the Block-20 hardware and software modernisation.

AOC-WS via the Block-10.2 software modernisation, but this was cancelled. As a result, Block-20 is the first major AOC-WS software upgrade since the earlier Block-10.1 modernisation. Block-10.1 remains the current software standard for Falconer pending the full Block-20 rollout. The modernisation path for Falconer calls for Block-20 software and capabilities to be added incrementally to the current architecture. Falconer will thus have a 'hybrid' configuration combining some of the legacy Block-10.1 capabilities with selected Block-20 features before fully migrating to the latter status. Block-20 features will be added to the AOC-WS via what the Air Force calls Agile Release Events (AREs). Adornments added via Block-10.1 included mechanisms to swap legacy hardware out of Falconer, allowing their replacement with new systems relatively easily. Other enhancements included improving overall joint interoperability between Falconer and other operational/strategic level C2 systems.

Work on the Block-20 standard began in 2017, according to the Air Force. The service's official documents state that the effort is being led by the USAF's Kessel Run Experimentation Laboratory (KREL), opened in 2018, to "carry out the development of next-generation combat software" in the USAF's own words. *Star Wars* fans will know the Kessel Run as a smuggling route mentioned in the original 1977 *Star Wars: Episode IV – A New Hope* film. KREL is managed by the Air Force Life Cycle Management Centre's (AFLCMC) Battle Management Directorate. The directorate's home is Hanscom Air Force Base in Massachusetts, while KREL is in nearby Boston. The AFLCMC's Detachment-12, also located at Hanscom, has developed and is sustaining the AOC-WS Block-20 software. Detachment-12 has a satellite facility at Langley Air Force Base, Virginia, which coordinates the delivery of the Block-20 software and provides associated sustainment and helpdesk facilities.

Alongside SAIC, the Air Force says that Raytheon is involved in the Block-20 update provision. SAIC was approached regarding its responsibilities in the Block-20 effort but the company declined to comment. What has been disclosed in the public domain is that SAIC is working as the systems integrator for the Block-20 initiative. The Air Force took a similar stance, saying that it had nothing more to add to information already available in the public domain regarding Block-20.

The AOC-WS improvements for Falconer are being realised through the use of commercial off-the-shelf (COTS) software and hardware, according the Air Force. While COTS software and components are sup-

Credit: USAF

The USAF's 609th Air Operations Centre is located at Al Udeid Air Base, Qatar. This facility provides C2 for air operations under US Central Command auspices. The Falconer air operations command and control system is deployed at this installation.

porting the system's digital voice and data communications infrastructure, the US government is furnishing some proprietary software for air, space and cyberoperations planning, direction and monitoring. Government and COTS software and hardware are being fused with additional capabilities from unspecified third parties. These capabilities will fuse C2 data coming from other sources with Falconer's, with improvements also allowing these data to be shared across several communications links. Links used by Falconer include the US Department of Defense's (DoD's) Secure Internet Protocol Router Network (SIPRNET) and Joint Worldwide Intelligence Communication System (JWICS). SIPRNET is essentially a secure equivalent of the internet, carrying Classified and Secret data. JWICS, meanwhile, is a secure intranet system carrying Top Secret information – the highest level of DOD security clearance.

Block-20 software

The Block-20 enhancements discussed above are being rolled out across the USAF's regional Air Operations Centers (AOCs). The US Air Force maintains several regional AOCs, including the 601st AOC at Tyndall Air Force Base, Florida. The 601st AOC forms part of US Northern Command, as does the 611th AOC at Joint Base Elmendorf-Richardson in Alaska. US Southern Command is supported by the 612th AOC at Davis-Monthan Air Force Base, Arizona. Outside the US, the 603rd AOC at Ram stein Air Force Base in Germany supports the US African and European regional commands. US Indo-Pacific Command has two regionals AOCs: The 607th located at Osan Air Force Base in the Republic of Korea and the 613th AOC at Joint Base Pearl Harbour-Hickam in Hawaii. The 609th AOC at Al Udeid Air Base in Qatar supports CENTCOM.

Block-20 software releases began being fielded across these various Falconer systems from September 2022, according to the Air Force with initial upgrades made to the 609th AOC's system at Al Udeid Air Base. Similar releases are being installed on the AOCs discussed above, with initial installations are expected to be finished by the end of 2024. Software releases have been accompanied by an exhaustive test and evaluation regime which has identified and fixed problems experienced with these releases. The scope of the Falconer Block-20 modernisation is impressive, with US government documents stating that the system already contains over 40 C2 applications, even before the modernisation is fully rolled out.

The exact status of the Block-20 enhancement is unclear. As noted above, the USAF and SAIC declined to provide any information to this effect. Does this mean that the programme is experiencing difficulties? Without definitive information from either organisation, it is impossible to say for certain, although a reticence to discuss the programme does raise questions. For example, an analysis published by the USAF highlighted concerns regarding its test and evaluation strategy for Block-20. The analysis noted that the Block-10.1 enhancement was fielded in 2022; that same year, the analysis stated that a "required test strategy [for Block-20]" had not yet been approved. More worryingly, it claimed that the Block-20 software "released to date lacks sufficient capabilities to support major combat scenarios and the sustainment, maintenance, and training processes would not adequately support a meaningful operational evaluation." Although the Air Force had submitted a test strategy for Block-20, "critical com-

ments have not been resolved." Part of the problem might have been that the Air Force was moving Block-10.1 and Block-20 forward at the same time.

Unsurprisingly, for a software-based C2 system, cybersecurity is paramount, all the more so given that Falconer must be deeply networked to perform its tasks. According to the DoD's own analysis, the Air Force had "conducted a cooperative vulnerability and penetration assessment" at an undisclosed AOC site concerning the Block-10 software release. The service also overhauled its Test and Evaluation Master Plan (TEMP) for Block-10.1 which the DOD approved in 2011. The report continued that, as of 2022, no TEMP plan for Block-20 existed. Block-10.1 was further reinforced via regular capability and maintenance ARE software upgrades. These AREs were drafted on the basis of Falconer testing and evaluation performed at the Ryan Centre located at Joint Base Langley-Eustice in Virginia. Similar development work has also been carried out by the 612th AOC at Davis-Monthan Air Base.

Multi-domain operations

Where does Falconer go beyond the Block-20 upgrade? With the Air Force staying taciturn on the Block-20 initiative to date, it is hard to say for certain. There is every possibility that a further, similar, large-scale upgrade may occur over the next 20 years beyond this most recent initiative. Unlike a traditional platform, the AN/USQ-163 is a computerised system largely composed of hardware and software. Some of these components are bespoke and some are sourced as COTS elements. Within reason, it may be possible to continually improve Falconer by performing periodic software and hardware refreshes; such an approach could incorporate the 'best and brightest' software and hardware available into Falconer. On paper, this would appear to give the architecture a near-limitless lifespan. The continual improvement approach may also be significantly less expensive than acquiring a completely new system. Even if an AN/USQ-163 replacement is procured, this too would need to be continually refreshed throughout its life.

Over the longer term, Falconer will face distinct technological challenges that it must accommodate, hence no doubt necessitating further upgrades beyond Block-20. Perhaps the most vexing is the US Air Force embracing the multi-domain operations (MDO) approach heralded by the DoD. MDO is the Pentagon's overarching doctrine to defeat peer- and near-peer adversaries. The rationale behind MDO is to ensure that one's own forces take better quality and more timely decisions than one's adversary. The MDO concept stresses navigating the famed observe, orient, decide and act (OODA) loop faster than their opponents, by making better decisions. MDO manifests itself in the DoD's Joint All-Domain Command and Control (JADC2) system.

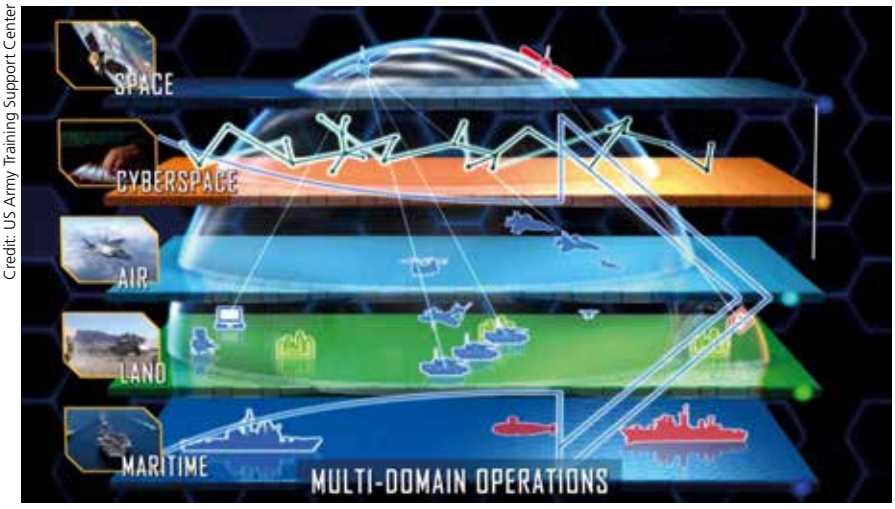
JADC2 is a collective term for a raft of DOD efforts across all the US armed services to realise the inter- and intra-force connectivity of all assets supporting any operation. Assets include all personnel, platforms, weapons, sensors, installations, bases and capabilities. JADC2 also places a premium on cloud computing. So-called 'Combat Clouds' will be the repository where tactically, operationally and strategically relevant data reside. These clouds will be rapidly accessed by those who need it. Each of the US armed services are configuring their C2 systems to ensure they are JADC2-compartible. The US Army is working towards this via Project Convergence. The US Navy's effort is known as Project Overmatch, while the Air Force is forging ahead with the Advanced Battle Management System (ABMS).

How does Falconer fit into the Air Force's ABMS architecture and the DOD's overall JADC2 vision? It may not, according to a 2022 publication entitled *Advanced Battle Management System: Needs, Progress, Challenges and Opportunities Facing the Department of the Air Force.* The report was edited by Ellen Y. Chou, board director of the US National Academies of Sciences, Engineering and Medicine. Input was received from the Air Force's ABMS committee and the USAF Studies Board, among others. The study paints a worrying picture. Referring to the Block-20 initiative, the report warns that "(w)hile progress is being made, notable challenges remain with the current AOC design and construct".

One area of concern is that the system's underlying C2 architecture is not fit "to meet current operational and technological threats or support an accelerated pace of planning". These alleged shortcomings are present despite the Block-20 initiative, the report argues. An additional cause of concern was the extent to which Falconer can work with the MDO doctrine and its JADC2 manifestations: "It was clear that the AOC system of systems architecture ... would not support a transformation over time, because the inherently outdated technology and architecture utilised by the current system is unable to be restructured."

In short, it appears that the AN/USQ-163 in its current guise may simply not be fit for purpose over the long term. "It is moreover evident, even without a JADC2 ... that the Air Force requires an innovative and revamped AOC to interoperate with the new US Space Command and US Space Force operating systems and to meet broad operational challenges from adversaries seeking to counter US military advantages." With these shortcomings highlighted, the USAF clearly has important decisions to make on the future of Falconer. Can additional life be wrung out of the AN/USQ-163? Or will a new architecture be needed to provide the Air Force with the C2 tools it needs for future battles? Only time will tell. ■

Credit: US Army Training Support Center



The advent of multi-domain operations heralds a step change in expected levels of connectivity for all military assets and an exponential increase in the quantities of data moving around the battlespace. Questions are being asked as to whether the USAF's AN/USQ-163 architecture will cope with the MDO world.

Growing some backbone

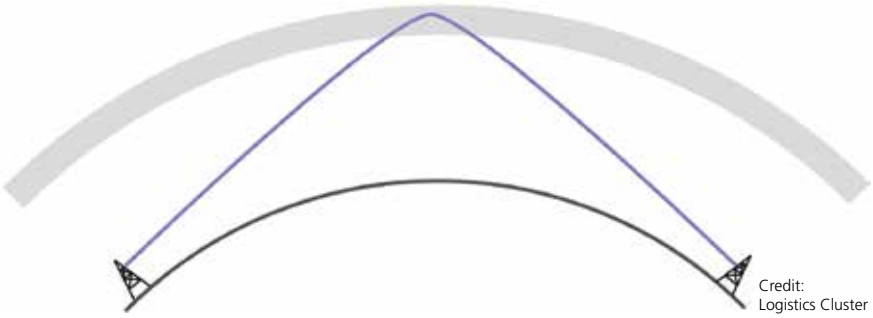
Thomas Withington

The United Kingdom's Ministry of Defence (MoD) is forging ahead with an important overhaul of its strategic high-frequency communications.

To some, it may seem an insignificant milestone, but on 9 July 2023, the UK's Defence High Frequency Communications Service (DHFCS) celebrated its 21st birthday. The DHFCS provides a nationwide and international high frequency (HF) strategic radio communications backbone. This backbone links military installations in the UK and abroad to one another using HF links. However, despite the birthday celebrations, the DHFCS is in its twilight years and will soon be replaced. In time, the DHFCS will be superseded by the Defence Strategic Radio Service (DSRS).

HF radio has been widely employed by the military since before the Second World War; they use a specific part of the electromagnetic spectrum – frequencies of 3–30 MHz. Transmissions across this waveband have properties not found in others, particularly some of the wavebands further up the radio section of the spectrum. HF signals aimed towards the ionosphere cannot penetrate this layer of the atmosphere. The ionosphere is between 48–965 km above sea level. When an HF transmission hits the ionosphere, it is reflected back to Earth. If you aim the transmission at an angle, it will bounce off the ionosphere at a corresponding angle. An oft-used analogy is a snooker ball aimed obliquely towards the snooker table's cushioned side. The ball hits the cushion and bounces off at an angle, allowing the player to hit the ball they are aiming for indirectly reducing the risk of a foul.

Radio communications are usually restricted by an antenna's line-of-sight. Suppose you are 2 m tall, standing in a flat field holding a 1 m antenna parallel to the ground. In this position, your radio signal will travel about 7 km in a straight line relative to the ground. However, beyond this, due to the curvature of the Earth, the distance between the signal and the Earth's surface will progressively increase. In theory, and depending on its power, the signal eventually reaches a point where it continues into space.



Credit: Logistics Cluster

Diagram showing how two HF radios can exploit the ionosphere to avoid the curvature of the Earth and therefore achieve global communications ranges. HF is increasingly attractive as a complement and alternative to SATCOM.

SATCOM versus HF

The ability of HF signals to 'bounce' off the ionosphere is a major advantage compared to other radio frequencies further up the electromagnetic spectrum. Using the ionosphere lets HF radio signals achieve intercontinental ranges rivalling those achievable with satellite communications (SATCOM). In fact, the ionosphere can be thought of as a global, naturally occurring satellite dish. After all, it works in a very similar way to its artificial equivalents. A key benefit of HF compared to SATCOM is that the bandwidth is free to use.

Militaries wanting to employ satellite communications must procure a satellite constellation and associated infrastructure to provide global beyond line-of-sight (BLOS) links which can cost billions of dollars. A less-expensive alternative is to lease SATCOM bandwidth from the private sector. Leasing still requires a financial outlay, and the secure channels which armed forces rely on may incur additional costs. Moreover, leased bandwidth can leave the user at the mercy of the private sector. The leaser could also decide to switch off the service if they do not agree with the conflict a military finds itself embroiled in. Threats such as these are not idle. Witness the furore in 2023 directed against Elon Musk, founder, chair and chief technology officer of SpaceX. Musk had threatened to end Ukraine's access to SpaceX's Starlink SATCOM network after thousands of Starlink terminals had been supplied to Ukraine following Russia's February 2022 invasion. Moreover, SATCOM companies can go bankrupt. On 27 March 2020, OneWeb Global, which was planning to build a constellation of low Earth orbit satellites providing global broadband internet services, indeed went bankrupt, though the company was rescued in July 2020 by a consortium comprising the British government and Bharti Group. Since the ionosphere is free to use, military HF users must simply purchase the radios and equipment needed to provide secure communications.

It should be stressed that HF does have some disadvantages, most notably regarding bandwidth. NATO and the US Department of Defense (DoD) standards govern military HF bandwidths and NATO's Standardisation Agreement 4539 (STANAG-4539) provides up to 200 KHz of HF bandwidth for use by Alliance members. Such bandwidths can theoretically provide data rates of up to 240 Kbps. The US DoD's Military Standard 188-110C provides bandwidths between 3–24 KHz, which are able to

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Credit: Google Maps

HF antennas at Kinloss Barracks support the UK's existing DHFCS and are expected to be re-roled to support the forthcoming DSRS as this is introduced in the coming years.

provide data rates 0.6–120 Kbps. To put things in perspective, fourth generation (4G) cell phones can achieve bandwidths of 173 Mbps – over 1,441 times more at the high end! A further disadvantage is that HF relies on the ionosphere to achieve over-the-horizon ranges.

The ionosphere is a capricious place and highly vulnerable to solar activity. Phenomena such as solar flares – localised emissions of the sun's electromagnetic radiation – can cause difficulties. Corona mass ejections, where there is an eruption of the sun's magnetic field and an accompanying mass of plasma (ionised gas), can be similarly problematic. Mathematics can be used to anticipate solar activity with reasonable accuracy to assist HF operators, and these calculations can be made rapidly using software. Nonetheless, the sun's behaviour cannot be influenced. Thus, HF radio is forced to live with these challenges. The considerable skill required to use HF radio, and the unique behaviours of the signal and ionosphere, can help make HF traffic difficult to jam. As with SATCOM, communications and transmission security protocols such as encryption can help safeguard HF traffic against eavesdropping.

Despite these challenges, the capabilities of HF compared to SATCOM continues to make it attractive as a complement to the latter. Arguably, it is for these reasons that the UK MoD has been an enthusiastic user of HF for trunk communications for many years. In 2003, several disparate HF networks operated by the UK armed forces were consolidated. This consolidation resulted in the creation of the Defence High Frequency Communications System (DHFCS), which was declared operational by the MoD in 2008. The network provides communications between British bases at home and abroad. HF was not the only communications mechanism military facilities possessed to remain in contact, as conventional trunk telecommunications also played a role. Having both HF and standard landlines available provided some redundancy. Landlines can also be used if HF is problematic, perhaps because of environmental factors, and vice versa.

The original DHFCS contract was awarded to VT Group, now part of Babcock, in 2003 and was worth USD 430.9 million in 2023 values. The network was ready for use by 2008 and carried several different types of traffic. Clear and secure voice and data moved across the DHFCS. The network also played a role in carrying traffic necessary for the UK's strategic nuclear deterrent. Open-source information states that this includes secure nuclear command and control (C2) data.

There are 12 facilities in the UK and abroad that support the DHFCS. The network is controlled from the DHFCS Forest Moor base, located in North Yorkshire. A backup control station is provided at Kinloss Barracks in Scotland. DHFCS transmitters are sited at RNAS Rattray Air Base at Crimmond

Credit: Babcock

Babcock was awarded the DSRS contract in September 2021. The company is the current supplier of the existing DHFCS. The new DSRS architecture should attain full operational capability by 2030.

in eastern Scotland, RNAS Inskip in northwest England and at St. Eval in the southwest of the country. Receivers are located at Forest Moor, Kinloss Barracks and Penhale Sands in Cornwall, southwest England. DHFCS transmitter and receiver sites can also be found on Ascension Island and on the Falkland Islands in the South Atlantic. The UK's Akrotiri Sovereign Base Area on Cyprus also hosts DHFCS facilities.

In addition to linking these facilities, the DHFCS links outwards to similar, allied HF networks. Publicly available information notes that the system connects to the US Air Force High Frequency Global Communications System (HFGCS) at RAF Croughton airbase, central England. The HFGCS is mainly used by the United States Air Force (USAF) and the US Navy (USN). A key HFGCS role is to transmit Emergency Action Messages to USAF and USN assets supporting the US nuclear deterrent. Alongside this US link, the DHFCS maintains a link to the Australian Defence Force's HF Communications System.

New networks

The DHFCS is now making way for a new system in the guise of the Defence Strategic Radio Service (DSRS). In September 2021, DHFCS supplier Babcock won a USD 165.8 million contract for the DSRS's implementation. The MOD's press release announcing the news said that the contract had a nine-year duration. Whether this is the lifetime of the system, or the duration of Babcock's involvement with the DSRS was not specified. Few details were given regarding the DSRS's architecture in the press release.

Nevertheless, the document did contain some important clues. For example, the press release stressed the utility of HF to provide connectivity to deployed units over BLOS ranges. This implies that the DSRS may also provide HF connectivity beyond British warships and military aircraft. The Royal Navy and the Royal Air Force have both been avid users of the DHFCS and its predecessors. This enthusiasm is understandable reasons given HF radio's global reach. However, will deployed British land forces using HF radios also connect with the Defence Satellite Communications System (DSCS)? Open-source information notes that the Bowman tactical radio system, used primarily by the British Army, comprises an HF radio. Bowman's L3Harris' UK/PRC-325 20-Watt/W backpack and

Credit: L3Harris

L3Harris's AN/PRC-150 HF radio shown here forms the basis for the UK's UK/PRC-235 and UK/VRC-328/9 HF transceivers. These two systems are likely to be replaced in the future as part of the UK's Project Morpheus land forces communications programme.

UK/VRC-328/9 100W fixed site/vehicular radios are anglicised versions of the company's AN/PRC-150 HF transceiver. It is unknown whether these radios can access the DHFCS or whether they will be able to use the DSCS network. As HF transceivers, it is more than likely that they can. Both the UK/PRC-235 and UK/VRC-328/9 are likely to be replaced over the coming decade as the British Army revamps its land forces communications systems via its troubled Project Morpheus initiative.

Another interesting clue regarding the DSRS's configuration was the press release's revelation that, "the radio system will also support civilian tasks when required, including mountain rescue and civilian aircraft emergency communications." What this provision means in practice was not specified. It is possible that the DSCS network will continually monitor certain HF wavebands for distress messages. In 2005, the International Amateur Radio Union (IARU) agreed that some amateur bands would be reserved for emergency traffic. Today, the Global Emergency Centre of Activity (GECOA) safeguards several frequencies to this end. The IARU is the custodian of the spectrum made available by the International Telecommunications Union (ITU) for amateur – or ham radio – enthusiasts (often colloquially referred to as 'radio hams'). The ITU is the global custodian of the radio spectrum. Frequencies of 3.750 MHz, 3.985 MHz, 7.060 MHz, 7.240 MHz, 14.300 MHz, 18.160 MHz and 21.360 MHz are reserved for emergency traffic, so people can make direct calls for help on these frequencies. Alternatively, ham radio enthusiasts can use these channels to transmit, receive and relay emergency traffic. The 14.300 MHz frequency is reserved for the global Maritime Mobile Service Network. It appears the DSRS's mandate has been expanded, vis-à-vis the DHFCS, to support humanitarian tasks beyond its core military functions.

Implementation

The MoD did provide some additional information regarding DSRS implementation, telling ESD that the new system was essentially an extension of the capability provided via the DHFCS programme. The ministry insisted that the DSRS would form part of a wider "layered communications plan that also includes (SATCOM)". The statement confirmed that the DSRS will be interoperable with other UK government organisations, including His Majesty's Coastguard, and alongside "international partners and allies". The MOD envisages that the DSRS architecture will continue to "keep pace with modern technology developments." In terms of implementation, the new system should be in full service by 2030, the statement added.

Given the challenges experienced by the UK's Project Morpheus tactical communications system, it is refreshing to see that the DSRS's introduction appears to be moving smoothly and at pace. Once in service, it will complement the additional SATCOM capabilities the UK is destined to receive via the Skynet-6 initiative. The Skynet-6A satellite is the first spacecraft in an anticipated new constellation and will complement the existing Skynet-5 constellation, which will eventually be replaced. The introduction of the DSRS capability gives the UK important redundancy in the strategic communications domain. This redundancy is being achieved at comparatively low cost, yet providing a robust and secure, communications architecture. The MoD's continued embrace of HF communications, and its unique attributes, is to be congratulated. ■

Coastal defence

Sidney E. Dean

Coastal zones face a broad array of airborne and seaborne threats. Since defence against airborne threats is not unique to coastal zones, this article will focus on the seaborne category.

The seaborne category includes a range of threats including: reconnaissance and direct attack missions by manned and unmanned vessels; stealth missions to conduct underwater sabotage, infiltrate special operations forces, lay mines, and prepare to ambush ships entering and leaving port; and full-scale amphibious landings. A viable coastal defence therefore requires multiple systems working in concert to address the various aspects of the threat scenario. These systems must form a layered structure to confront and neutralise enemy advances. Ideally, the enemy should be prevented from approaching the coast, or at least weakened while still in the outer reaches of the littoral zone. Since this is not always possible, coastal defence networks must also be prepared to repel the enemy up to the shoreline itself.

Key elements of a coastal defence need to include an effective offshore surveillance network to identify and track hostile forces early on. These will inform effectors including manned and unmanned aircraft, surface and subsurface vessels, as well as shore-based missiles to interdict enemy forces. Finally, mobile coastal defence units must be prepared to intercept hostile forces – including amphibious units – who penetrate the primary defensive ring.

Credit: Hensoldt

Tripod-mounted SPEXER 2000 Coastal radar

Surveillance and reconnaissance

Effective defence begins with situational awareness. The outermost detection ring will be formed by satellite, aircraft-based reconnaissance, and by offshore patrol vessels. These can be augmented by dedicated coastal surveillance radars, which can be supported by optical, acoustic, and signals intelligence sensors. Radars and other sensors can be deployed on the coast, preferably at elevated points, which include towers to provide over-the-horizon early warning. They can also be forward deployed on oil platforms, windfarms and other offshore infrastructure, as well as on nearby islands. Several dedicated coastal surveillance radar systems are on the market. These include the SCANTER family of radars produced by the Danish firm Terma A/S. According to the company, more than 3,000 SCANTER systems are in service, with 65% of all coastal surveillance radar systems relying on Terma's sensor technology. The SCANTER series comprises 2D X-band radars in a range of sizes and instrumented ranges. At the smaller end, the transceivers operating in the X-band. of the SCANTER series range from 26 kg (for the SCANTER 2000 series), to 77 kg (for the SCANTER 5000 series), and are therefore fairly easy to emplace. Depending on the configuration, the maximum instrumented range can vary from 89 km (48 NM) on the SCANTER 2200 series, out to 178 km (96 NM) for the SCANTER 4000/5000 series, the latter option providing over 98,000 km2 coverage according to the manufacturer. Again, depending on configuration, the system can identify manned and unmanned aircraft at various altitudes, as well as surface objects ranging from ships down to jet skis.

The SPEXER 2000 Coastal radar produced by Hensoldt offers a relatively portable option for coastal surveillance. Capable of detecting targets at sea, on land and in low-altitude flight, the X-band pulse-doppler AESA radar is equipped with an antenna measuring 1 × 0.7 × 06 m (width, height, depth), and can be deployed in a fixed mode atop a mast, or a relocatable tripod when portability is a priority. The instrumented range varies from 40 km (21.6 NM) in standard configuration, or optionally scaled up to 80 km (43.2 NM) at the higher end. The radar is capable of detecting surface ships and low-flying helicopters at or near the maximum range capacity, and the manufacturer has claimed that its high Doppler resolution enables it to locate small and slow-moving sea targets, including small boats at 20 km (10.8 NM), and swimmers at 1 km (0.5 NM). The SPEXER 2000 can be optionally combined with a camera system to provide additional target information.

Technical means of surveillance can be augmented by human coastal spotters. This is particularly important for nations with very long or complex coastal zones which cannot be comprehensively covered by fixed sensors. The Canadian Army maintains a 5,000-strong reserve force known as the Canadian Rangers, composed of residents of remote coastal communities; the Rangers conduct regular surveillance patrols and report unusual activities as well as sightings of ships or aircraft. The 22,000 strong Swedish Home Guard, while more versatile, also counts territorial surveillance as well as target identification and artillery spotting among their duties.

Land-based anti-ship missiles

Given the proliferation of long-range precision strike missiles, fixed coastal batteries have become too vulnerable to pre-emptive attack. By contrast, mobile systems remain a viable and vital weapon to counter hostile vessels positioned for land attack missions or amphibious assault. Beyond their ability to actually damage or sink ships, longer-range anti-ship missile (ASM) batteries incentivise enemy warships to remain at a greater distance offshore. This reduces the effectiveness of the enemy's own land attack missiles, and forces amphibious ships to launch their landing craft from over the horizon, all to the benefit of the defender.

The Exocet Mobile Coastal Defence System (EMCDS) produced by MBDA incorporates the latest version of the Exocet MM40 Block 3 anti-ship cruise missile (ASCM). The high-subsonic, very-low level sea-skimming missile has an effective range of over 200 km (108 NM), and provides a good penetration capability against defended enemy surface targets. A hybrid INS/GPS 3D navigation system coupled with a radar altimeter, allows coordinated flight of multiple missiles using different trajectories and terminal attacks from different azimuths, with simultaneous time on target. Terminal guidance against moving maritime targets is achieved through an X/Ka-band active radar seeker. The truck-mounted EMCDS consists of up to five vehicles, including a mobile control unit, a mobile sensor unit (with radar, mast-mounted electro-optical systems, and AIS for target discrimination), and up to three mobile firing units (each carrying four missiles).

The US armed forces are planning to attack maritime targets from existing rocket artillery systems such as the tracked M270 multiple launch rocket system (MLRS) and the wheeled M142 High Mobility Artillery Rocket System (HIMARS). Potential munitions to be equipped with multi-mode seekers capable of acquiring maritime targets include the new Precision Strike Missile (PrSM) with a 499 km (269.4 NM) range, and the Long-Range Anti-Ship Missile – Surface Launched (LRASM-SL), whose surface-launch range is undisclosed, but considered long-range. US Marine Corps and US Army experiments have also repeatedly fired the 227 mm Guided Multiple Launch Rocket System (GMLRS) against maritime targets. The supersonic (Mach 2.5) rockets have a range of 84 km (45 NM), while the developmental extended-range variant will strike targets as far away as 150 km (81 NM). HIMARS and MLRS can carry six and 12 GMLRS rockets respectively. These airmobile launcher systems and rockets are available in large numbers, and offer a significant capability to repel amphibious landings.

Credit: MBDA

Concept of the Exocet Mobile Coastal Defence battery on a European coastline.

Coastal defence surface vessels

Coastal defence vessels must be comparatively small and highly manoeuvrable in order move freely in shallow waters and take advantage of cover offered by islands or general maritime 'clutter'. The largest suitable ship type is the coastal defence corvette, which is large enough to carry a capable sensor suite and ASMs, but stealthy enough to reduce the detection risk by hostile vessels.

The shallow-draught Swedish *Visby* class corvettes built by SAAB Kockums AB entered service in 2009. Saab was awarded the Mid-Life Upgrade (MLU) contract in 2021, which will keep the *Visby* class relevant beyond 2040. The hull and superstructure are designed to significantly minimise the radar cross-section of the ships. Sensors and weapons are hidden internally when not in use. The thermal and acoustic signatures are also reduced, leading to the corvettes being considered low-observable, especially when operating under the cover of the Swedish coastal archipelago. Sensors include the SAAB Sea Giraffe AMB 3D Passive Electronically Scanned Array (PESA) air and surface surveillance radar, the CEROS 200 fire control radar, as well as hull-mounted and towed sonar systems by General Dynamics Canada. The post-MLU weapons load is optimised for coastal defence operations and includes a 57 mm Bofors gun, eight RBS-15 Mk3 ASCMs (upgraded from the original Mk2 variant);

Credit: Swedish MoD

Visby class corvette HSwMS Karlstad.

Credit: US Navy

Devil Ray T-38 (left) and Saildrone (right) USVs exercising in the Persian Gulf with a US Navy Littoral Combat Ship. The Saildrone can deploy at sea for up to a year, establishing long-term picket lines. The T-38 can reach speeds of over 36 m/s (70 kn), and can be optionally armed.

SAAB Torped 47 light torpedoes (replacing the Torped 45) designed for shallow-water operations against surface and submarine targets; 127 mm anti-submarine warfare (ASW) grenades; mines and depth charges; and CAMM surface-to-air missiles (SAMs). The flight deck accommodates an NH90 ASW helicopter.

Finland's new *Pohjanmaa* class multi-mission corvette will incorporate cutting edge technology to perform the full spectrum of tasks required for coastal defence, including stand-off range anti-surface warfare (ASuW), ASW, air- and missile-defence, minelaying, and electronic warfare/signals intelligence. Construction of the new ships, designed by Rauma Marine Constructions Ltd, began in 2023 and are due to enter service in 2029. Like the *Visby* class, the *Pohjanmaa* corvettes will employ the SAAB 9LV combat management system. Weapon systems will include a 57 mm deck gun, eight Gabriel V ASCM, with an effective range of over 200 km (>108 NM), ESSM SAMs, Torped 47 torpedoes, as well as a minelaying capability. The ships are equipped to operate throughout the Baltic under all weather conditions. They will also form the future backbone of the Finnish fleet, with primary missions including repelling seaborne attack as well as ensuring operational control of the nation's archipelago and the sea lines of communication. According to Finland's Sea 2032 plan, the Navy will conduct a networked defence based on a unified situational awareness to coordinate attrition of enemy forces in conjunction with other services.

Corvettes are augmented by missile- and gun-armed patrol vessels such as Finland's *Hamina* class. The MLU of the *Hamina* missile boats was completed in 2023, extending their utility into the 2030s. Heavily armed for their size, the 250 tonne displacement vessels now carry a Bofors 40 mm Mk4 dual-purpose gun, four Gabriel V ASCMs, Umkhonto-IR SAMs, and Torped 47 torpedoes, as well as a rail for depth charges or mines. The MLU included sensor upgrades which enhance the air-defence and ASW capabilities of the class.

Recently, unmanned surface vessels (USV) and unmanned underwater vessels (UUV) have emerged as a potentially potent tool to support coastal defence operations. This includes deploying large numbers of networked surveillance drones for wide-area situational awareness. From 2021 through 2023, US Navy Task Force 59 (TF59) successfully tested integration of UAVs, USVs and UUVs with manned vessels in the waters from the Red Sea to the Persian Gulf, with the goal of fielding a multinational flotilla of more than 100 networked drones in that region.

Various nations have also demonstrated small and agile USVs armed with torpedoes or missiles. They can be deployed from shore or from (armed or unarmed) manned vessels. These fast boats have a low radar and visual detection profile, improving their odds of surprise attacks on enemy vessels. As comparatively low-cost systems, they can be quickly acquired in larger numbers, permitting deployment of coastal defence attack swarms. During the October 2023 Digital Talon exercise, TF59 conducted the first US Navy test of an armed USV in the Middle East region. A MARTAC T-38 Devil Ray USV equipped with a Lethal Miniature Aerial Missile System (LMAMS) destroyed several boat targets, using targeting data supplied by sensor-equipped USVs.

Over the past two years, Ukraine's navy has been the first official armed force to systematically deploy armed USVs in war. According to Ukraine's government, domestically designed kamikaze sea drones have successfully attacked Russian naval vessels and the Kerch bridge, forcing Russia to restrict naval movements. The 5.5 m long remote controlled (optionally preprogrammable) Ukrainian USVs have an 800 km range and carry up to 300 kg of high explosive payload.

Coastal defence submarines

Submarines optimised for coastal defence operations are generally smaller than blue-water submarines, and have a comparatively shallow draught. The most recent design is the Fincantieri S800 which was publicly introduced at the February 2023 NAVDEX Exposition in Abu Dhabi. At the time, Fincantieri S.p.A. compared the status of the development programme to a post-critical design review milestone. The 800 tonne, 51 m long vessel is optimised for coastal and littoral environs. The submarine is designed to operate at sea for 30 days, whereby the air-independent propulsion (AIP) system permits up to seven days of continuous submerged operations. The control system employs four rudders in an X-configuration, in conjunction with forward hull-positioned hydroplanes to enhance manoeuvrability at low speeds and near the ocean floor. Acoustic and non-acoustic signatures have been reduced to minimise detection risk, while torpedo countermeasures can be activated in case of detection and attack. Sensors include multiple sonar systems, a search optronics mast, an attack periscope, and mast-mounted navigation radar, complemented by a mast-mounted radar electronic support measures system. The offensive payload consists of 10 Black Shark heavy torpedoes deployed via five torpedo tubes. Additionally, the submarine can deploy up to eight special operations forces (SOF) divers.

Fincantieri has not announced any customers or production schedule for the S800. Turkey's STM Defence, on the other hand, began construction of the first STM500 vessel in June 2022. The 42 m long, 500 tonne submarine is capable of blue-water operations but is designed for shallow-water missions. It carries an array of passive and active sensors. Four forward-mounted tubes can fire a variety of heavyweight or guided torpedoes; the payload per mission consists of eight torpedoes. The STM500

Credit: SAAB

Concept image of the A26 Blekinge class.

can also deploy and operate with UUVs, using them primarily in a reconnaissance and exploration role. Up to six SOF troops can augment the standard 18-person crew. Sweden is planning what is likely to be the most advanced coastal-capable submarine class in the world. Two SAAB-built A26 submarines (*Blekinge* class), vessels are on schedule for delivery in 2027 and 2028 respectively. The A26 is equipped with three diesel and three Stirling AIP engines, and is designed to carry large amounts of liquid oxygen on board. This will permit the diesel engines to run while submerged, avoiding the need to surface in order to recharge the batteries. Up to 18 days of submerged operations will be possible. In addition to torpedo tubes, the vessel is equipped with a 1.5 m diameter multi-mission portal at the bow, which can deploy mines, UUVs or SOF with their equipment. The combination of manoeuvrability and multiple payloads make the A26 suited for seabed warfare in coastal zones as well as in the greater Baltic Sea, including protection of underwater pipelines and communications cables.

At 65 m in length and with a 2,000 tonne displacement, the 'A26 Oceanic' design (used for the *Blekinge* class) is considerably larger than most coastal defence submarines. It is in fact equally suitable for blue-water operations, and will be marketed internationally as a dual-capable system. For nations solely concerned with shorter-endurance, littoral operations, SAAB has proposed a smaller option in the form of a 50 m, 1,000 tonne variant, dubbed the 'A26 Pelagic'. At the other end of the scale, SAAB has also proposed an extended version of the A26 Oceanic, dubbed the 'A26 Oceanic Extended Range', with a length of >80 m and displacement of over 3,000 tonnes, aimed more toward the blue water segment.

Layered defence

As a last line of defence, ground forces must be prepared to repel landing operations or hunt down hostile amphibious or airmobile units which make it to land. Most nations rely on regular army formations for this task, but a few – including Finland and Sweden – have dedicated coastal defence forces. The Swedish Amphibious Corps and Finnish naval infantry brigades both operate a combination of multi-mission marine rifle companies and coastal ranger commandos trained in reconnaissance and special operations in the offshore archipelagos as well as in the mainland coastal regions. Depending on the unit, these amphibious forces also operate truck-mounted ASMs to combat amphibious warships and their escorts, as well as fast attack craft capable of intercepting landing craft, laying mines, and deploying depth charges against submarines.

The existence of these units underscores that coastal defence requires a layered and networked approach, beginning at the outer reaches of the littoral waters and stretching all the way to the surf zone, beaches, and inland points. As aggressors' capacity for power projection grows, defensive arsenals and tactics must keep pace. This includes providing ship- and shore-based ASMs with greater standoff range, signature reduction, and electronic counter-countermeasures (ECCM) to confront hostile vessels as far from shore as possible. The capability to detect and neutralise the enemy's unmanned reconnaissance, targeting or strike assets – whether air, surface or subsurface -- will also be a priority for coastal defence in the near future. ■

Credit: Finnish MoD

Finnish Coastal Jaeger soldiers launch a Spike ER missile at an offshore maritime target.

Platforms for naval minehunting and mine disposal: Differing solutions to a common requirement

Conrad Waters

Technological developments in the field of naval mine countermeasures (MCM) are revolutionising a traditionally dangerous, difficult and time-consuming process. Advances in areas such as networking, autonomy and wider aspects of artificial intelligence are speeding the detection, identification, classification and disposal of mines. Significantly, they also offer the prospect of 'taking the ship out of the minefield'. One common question posed to fleets worldwide is how best to deploy this new technology. This article examines how leading navies are implementing different solutions to meet this requirement.

A mine countermeasures revolution

The development of effective countermeasures to the naval mine has proved to be a major problem since the weapon's first significant strategic use during the American Civil War. A prime example of an asymmetric weapon, the naval mine is able to deter access to vast areas of water and cause a potential hazard to warships and commercial vessels alike out of all proportion to its modest cost. By contrast, detection and disposal of naval mines has typically been dangerous and expensive. Much effort has been expended in attempting to address this disparity between threat and antidote, but success has been mixed.

Recent technological developments hold out the hope of going some way to reduce the naval mine's undoubted advantage. Of these, it is progress in the field of autonomy that have been most influential. Robotic systems are not new to mine countermeasures. For example, the French PAP (poisson auto-propulsé) remotely controlled minehunting vehicle was developed in the late 1960s. Similarly, the German 'Troika' minesweeping system has been in service for many decades. However, momentum in the area of artificial intelligence has, particularly, allowed the production of a wide range of truly autonomous uncrewed surface vessels (USVs) and uncrewed underwater vehicles (UUVs) for mine countermeasures duties. Moreover, these can be networked together to conduct minehunting and mine disposal missions much more swiftly and efficiently than was previously the case. When coupled with improvements in the performance of detection and classification systems, such as the increasingly common use of synthetic aperture sonar, the need for a minehunting vessel to enter a minefield to perform its mission is seemingly much reduced.

Credit: Crown Copyright 2017

The British Royal Navy minehunter HMS Penzance pictured returning to her home base of Faslane, Scotland after a Far East deployment. The Royal Navy is amongst many that are rapidly disposing of ships of this type in favour of the new generation of autonomous mine countermeasures systems.

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These technological advances – which can often be configured as a so-called 'toolbox' of readily-transportable, modular systems – have given rise to questions as to the most effective means of undertaking their deployment. In essence, it is now possible to separate mine countermeasures equipment from a specific platform in nearly all circumstances. This potentially dispenses with the need for specialised mine countermeasures vessels (MCMVs) altogether. For example, defensive, coastal mine countermeasures operations can be readily conducted from a land-based control centre using systems deployed from the shore or by 'craft of opportunity'. Equally, the mine clearance requirements of an amphibious assault could be met by the embarkation of equipment and operators on an expeditionary vessel. This is, for example, one of the key missions envisaged for the US Navy's Expeditionary Mine Countermeasures Companies. However, there is a general acceptance that the requirements of more demanding and/or enduring missions will still require a seagoing platform from which the toolbox can be deployed. This is particularly the case when the operation is at distance from friendly coasts.

The traditionalist approach

Of necessity, a common interim solution to meet this requirement has been to refit existing MCMVs to carry the new generation of autonomous systems. This evolutionary approach has the advantage of facilitating the maintenance of residual 'legacy' capabilities as next generation technologies are implemented, not least the ability to deploy safely within mined waters. Many fleets are extending the lives of their MCMV flotillas in this way. Other navies are acquiring second-hand units to upgrade and operate in similar fashion. Some, arguably more-conservative navies also remain wedded to the concept of acquiring traditional MCMVs that can both deploy autonomous vehicles yet continue to enter the minefield if required. One example is the Indonesian Navy's acquisition of two MHV60-derived MCMVs from Germany's Abeking & Ramussen under a contract signed in January 2019. These Pulau Fani class vessels have hulls constructed out of non-magnetic steel but will – amongst other equipment – each carry two optionally-manned small waterplane area twin hull (SWATH) craft for deployment at distance. The two new MCMVs were commissioned at Surabaya in August 2023.

One significant problem with this approach is the relatively small size of many traditional MCMV designs. In effect, this means that there is only so much equipment from the toolbox that they are able to transport. This problem is arguably reflected in the Italian Navy's plan to reconstitute its aging MCMV force. This will incorporate composite fibreglass-hulled vessels in line with a hybrid 'unmanned when possible, manned when you have to' philosophy. The 12-ship programme initially envisages construction of 60 m coastal MCMVs of traditional size that will be evolved from existing designs. However, these ships will then be followed by orders for larger, 80 m 'd'altura' oceanic vessels of entirely new configuration that will be capable of carrying a much greater complement of autonomous systems and other equipment. An order for the detailed design and construction of the initial batch of coastal vessels is expected to be placed with Intermarine before the end of 2024. However, contracts for the oceanic vessels are likely some distance into the future.

In spite of its apparent attractions, the idea of acquiring larger MCMVs of non-magnetic construction is not without its drawbacks. Building such large vessels from specialised materials is an extremely costly proposition, as recently demonstrated by the derailment of the German Navy's MCMV replacement programme. Initiated in 2014, this envisaged the procurement of 11 vessels that would be capable of global deployment in contested waters. They would both act as a base for autonomous vehicles whilst also being able to operate safely within mined waters. It was initially envisaged that the total sum expected for this project would amount to EUR 2.8 Bn, a figure that was to prove a significant underestimate. According to a German Federal Audit Office report published in December 2023, expected programme costs had increased to as much as EUR 6 Bn by 2018, resulting in efforts to restructure the project. After rejecting a plan to operate a mixed flotilla

Credit: Bundeswehr

The German Navy continues to place a heavy emphasis on MCMVs being able to operate within the minefield but has struggled to combine this capability with the new generation of stand-off mine countermeasures systems. Existing ships such as FGS Sulzbach-Rosenberg, pictured here, will need expensive life extensions as a result.

of new-build and refurbished vessels, it has ultimately been decided to abandon new construction and modernise the existing flotilla. As noted in the Audit Office report, this will ultimately result in the operation of near 50 year-old vessels that are not entirely able to meet the anticipated mine countermeasures requirement.

The bespoke mothership

Possibly influenced by such cost constraints, an increasingly popular alternative approach is to procure bespoke 'motherships'. These vessels are optimised for the deployment of a wide range of autonomous vehicles but are not intended to enter mined waters. The intention is that such vessels' specialist design will enable them to operate the new generation of 'stand-off' systems to maximum effect whilst avoiding the high costs associated with more traditional MCMVs. Clearly, adoption of this approach is predicated on a belief that these new technologies will fully meet the performance expected of them.

At the time of writing, the most prominent example of the mothership philosophy is the Belgo-Dutch replacement mine countermeasures (rMCM) project. rMCM forms part of a broader programme of collaboration between the Belgian Naval Component and the Royal Netherlands Navy. It involves the procurement of twelve motherships – six for each navy – and an associated toolbox of autonomous systems and associated equipment. Delivery of the project has been entrusted to Belgium Naval & Robotics, a consortium comprising French companies Naval Group and Exail (formerly ECA Group), under a EUR 1.9 Bn contract awarded in May 2019. Construction of the motherships has been sub-contracted to Kership, the joint venture between Naval Group and Piriou, at shipyards in Brittany. The lead motherships for each navy had both been launched by the end of 2023 and Belgium's BNS Oostende is scheduled for delivery before the end of 2024. Meanwhile, production of the toolbox to be embarked aboard the motherships has largely been entrusted to Exail. The group opened a new, purpose-built factory at Ostend in Belgium in June 2022 to produce drones for rMCM and other customers.

Displacing over 2,800 tonnes and nearly 83 m in length, the rMCM motherships are equipped with a large mission bay amidships to house the principal autonomous systems. These are focused on two Exail 'Inspector 125' USVs. These craft, in turn, can deploy Exail A-18M UUVs, towed sonar and a minesweeping module, as well as identification and disposal robots. The USVs are deployed by means of two Naval Group-developed launch and recovery systems that have proved capable of recovering the 'Inspector 125'in conditions up to Sea State 5/6. Other important aspects of the mothership design include a flight deck and hangar to operate UMS Skeldar unmanned aerial vehicles (UAVs) and command and control facilities. There is sufficient accommodation both to house the core crew and the modular systems' operators.

In August 2023, France signed a memorandum of understanding with Belgium and the Netherlands that is expected to result in the use of the rMCM mothership design as the basis for its own bâtiment de guerre des mines (BDGM) project. It should be noted, however, that the French Navy has turned to Thales to develop its own toolbox of mine countermeasures systems as part of the Anglo-French maritime mine countermeasures (MMCM/SLAM-F) programme. One complication is that the Thales-developed drones have different dimensions from those being produced by Exail. This will therefore doubtless require modifications to the mission bay and associated handling equipment of their own motherships to ensure these systems' efficient deployment.

Credit: Naval Group

The rMCM programme mothership can deploy a range of systems from embarked Exail 'Inspector 125' USVs, which are deployed via twin Naval Group-developed launch and recovery systems. The vessels also have a flight deck and hangar for UMS Skeldar UAVs.

Multi-role vessels

A modification of the mothership proposition is represented by the original operating concept for the US Navy's littoral combat ships. In its original guise, this envisaged both the mono-hull Freedom (LCS-1) and catamaran *Independence* (LCS-2) littoral combat ship variants serving as 'Swiss Army Knives' that were capable of quickly switching between one or other of multiple roles. The concept was to be achieved by a modular design configuration under which a basic littoral combat ship 'seaframe' could be rapidly reconfigured by the embarkation of various mission modules and their supporting operators. Three modules – focused on anti-submarine warfare, surface warfare and mine countermeasures – were to be developed in support of this objective. Contemporary documents suggest that it was hoped that only as little as 24 hours would be required to swap different modules in and out.

In the event, it seems that the 'Swiss Army Knife' operating concept has proved to be something of a dead end in US Navy thinking. Whilst the littoral combat ship programme's well-reported difficulties do not need to be detailed here, in essence a combination of technical problems with ships and modules alike combined with a changed strategic environment put paid to the original plans. Instead, a reduced fleet of littoral combat ships will be permanently configured to perform either surface warfare or mine warfare missions. Up to 15 of the *Inde-*

Credit: US Navy

The US Navy's littoral combat ship programme was intended to produce rapidly reconfigurable vessels that would have mine countermeasures as one of their main roles. A rethink will now see many of the Independence (LCS-2) variant – USS Savannah (LCS-28) is seen here – permanently configured for the MCMV role.

pendence class ships will be allocated to deploying the US Navy Mine Countermeasures Mission Package that was developed to support the original operating concept. The package finally achieved initial operational capability (IOC) in May 2023 after previous delays.

In this revised guise, the mine countermeasures-configured littoral combat ships will operate in largely similar fashion to the motherships being acquired by other fleets. Key components of the new Mine Countermeasures Mission Package include an unmanned influence sweep system and Raytheon's AN/AQS-20C mine-hunting sonar. Both will be deployed from a pair of autonomous mine countermeasures mission USVs. However, a notable difference in the US Navy's concept of operations is reflected in the importance given to aerial systems. As such, other important elements of the package comprise the well-established AN/AES-1 Airborne Laser Mine Detection System (ALMDS) and the AN/ASQ-235 Airborne Mine Neutralization System (AMNS), which are both operated from an embarked MH-60 series helicopter. The airborne AN/DVS-1 Coastal Battlefield Reconnaissance and Analysis (COBRA) system, which can be carried by the MQ-8C Fire Scout UAV, and future Knifefish UUV form additional elements of the package. It is currently anticipated that mine countermeasures-equipped *Independence* class vessels will commence operational service in the Middle East during 2025.

The problematic experience of the littoral combat ship programme suggests that the concept of performing sustained mine countermeasures operations from a multi-role vessel is unlikely to gain widespread traction. In addition to technical considerations, it would seem that the difficulties of maintaining acceptable levels of operator skills for complex mine warfare missions in a frequently reconfigured warship form a material drawback inherent in this approach. At the same time, the use of dedicated mission bays and other modular systems on increasing numbers of surface escorts around the world is an important development. This will facilitate the general ambition of being able to deploy mine countermeasures systems from a much wider range of platforms as the need arises, albeit without the same level of capacity as a dedicated mine warfare platform.

Credit: US Navy

US Navy sailors unload an Airborne Mine Neutralization System (AMNS) aboard the Independence variant littoral combat ship USS Charleston (LCS-18). AMNS forms an important part of the broader Mine Countermeasures Mission Package system-of-systems that will be deployed aboard the Independence class.

The British Royal Fleet Auxiliary (RFA) has acquired the offshore support vessel RFA Stirling Castle to operate in the mine countermeasures mothership role.

Off-the-shelf solutions

Instead of constructing a purpose-built mothership, another alternative is to adapt existing commercial vessels to deploy the new mine countermeasures toolboxes. The availability of a large pool of offshore supply vessels built to service the subsea energy sector means that this is a practical and potentially cost-effective way forward. The British Royal Navy is a leading proponent of this approach, purchasing the former support vessel *Island Crown* for Royal Fleet Auxiliary (RFA) service in early 2023. Reportedly acquired at a price of GBP 40 M (EUR 47 M), the renamed RFA *Stirling Castle* is certainly a much cheaper vessel than the bespoke motherships being acquired by Belgium and the Netherlands.

Once fully in service, RFA *Stirling Castle* will be used to trial the most effective means of supporting the Royal Navy's next generation of autonomous mine warfare systems. In addition to the new equipment being developed by Thales under MMCM/SLAM-F, this matériel includes Atlas Elektronik's ARCIMS (Atlas Remote Combined Influence Minesweeping System) modular USV system. As its acronym suggests, this was initially acquired to carry out autonomous minesweeping missions but it is capable of performing other roles. The host vessel has a long working deck on which USVs and containers can be stowed, with system deployment performed by means of a 10 tonne capacity crane. An extensive series of initial handling trials were carried out off Portland on England's south coast in the summer of 2023. Open source reports suggest that as many as four additional offshore supply vessels may be acquired to support mine countermeasures missions if the full programme of trials is successful. The RFA have also acquired another support ship, re-named RFA Proteus, to act as a platform for ocean surveillance operations using UUVs.

The conversion of commercial shipping for the mothership role inevitably has both benefits and drawbacks. Negatively, vessels such as RFA *Stirling Castle* lack many of the more sophisticated features incorporated in bespoke vessels. Not least of these are their specialised handling systems and dedicated command and control spaces. Indeed, many argue that the Royal Navy's decisions have been largely driven by cost considerations, being based on difficulties affording more expensive purpose-built designs. The counter argument points to the flexibility inherent in the typically larger hulls of ships such as RFA Stirling Castle. This allows more ready adaptation to the embarkation and deployment of new autonomous systems and other equipment in a technological field that is still experiencing rapid evolution. Certainly, there have to be questions with respect to the Belgo-Dutch decision to embrace a turnkey contract awarding the supply of both ships and equipment to a single supplier given the increasingly wide range of solutions available to support mine countermeasures operations.

The way ahead

The continued rapid evolution of mine warfare technology referenced above makes it quite difficult to establish the most likely way forward for the future of mine countermeasures platforms. At the moment, there is still considerable scepticism in parts of the mine warfare community as to the true effectiveness of new generation systems, including autonomous vehicles. Given this backdrop, the desire to retain the ability to deploy within the minefield exhibited by some navies is understandable. More cynically, it is also conceivable that a desire to maximise the benefits of national leadership in industrial fields such as the construction of non-magnetic steel or composite hulls is also playing a part in supporting a conservative stance. Whatever the reason, the experience of the German Navy and others in seeking to retain an ability to operate within minefields suggests that this conservatism can come at a high financial price.

Much, therefore, will depend on the actual performance of the new toolboxes of mine countermeasures equipment as they transition from the developmental to the operational stage. These new systems have certainly demonstrated considerable promise in trial conditions but their deployment in 'real world' conditions has been relatively limited to date. As such, it seems that more time and experience will be required before the bespoke mothership's replacement of the traditionally-hulled MCMV is assured. ■

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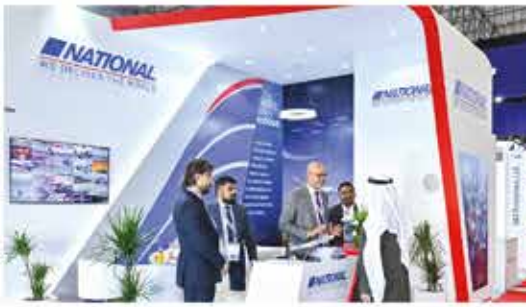

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Trouble in the spectrum

Thomas Withington

An innovative, new system employing artificial intelligence (AI) could help enhance the resilience of US Army tactical networks on the battlefield against aggressive electronic warfare.

"Shoot, move, communicate" was the mantra of the US Army's tactical doctrine in the 1980s. Seen as the three basic tasks a solider must achieve to not only survive, but prevail in battle, it has stood the test of time. The advice is as relevant today as it was 40 years ago. That said, the latter stipulation is as likely to be as harshly challenged by the enemy today as the first two.

During the Cold War, US land forces and their NATO counterparts were cognisant of the power of Warsaw Pact electronic warfare (EW). If NATO and Warsaw Pact forces had come to blows across the Inner German Border (IGB), the ether would have been thick with radiation. Electromagnetic waves in the form of ionising radiation would have endangered life and limb as the result of nuclear explosions. Meanwhile, Warsaw Pact EW cadres would have listened to the airwaves to detect and locate NATO land forces' radio communications. Once discovered, radios used by soldiers, vehicles, bases, weapons and aircraft would have been blasted with Warsaw Pact jamming. Attacking NATO radio communications was imperative as Warsaw Pact spectrum warriors would work to degrade, damage and destroy the links land forces relied on for command and control (C2). Some tactical/operational links would no doubt have been left unjammed to be exploited for intelligence. Pinpointing NATO units based on their radio emissions would provide aimpoints for fires and close air support. All-in-all, the electromagnetic spectrum in and around the IGB, and European theatre of operations, would be an arena of complete chaos.

The US Army's mantra today holds an added sense of *déjà vu*. "Gentlemen, after a nice little vacation, looks like we're back at it again," said Captain Franklin 'Frank' Ramsey in the 1995 thriller *Crimson Tide*. Capt. Ramsey, played by Gene Hackman, was commenting on renewed US–Russia nuclear tensions. In the film, Russia had descended into civil war and her nuclear C2 had been compromised. Art can imitate life and NATO finds itself once again locked in tension with Russia in a new era of geopolitical rivalry not unlike the Cold War.

Credit: Russian MoD

Systems like the Russian Army's 1RL257 Krasukha-4 have shown their ability to detect and attack radio communications networks on and above the battlefield in the Ukrainian theatre of operations.

During 2008, in an attempt to arrest years of post-Cold War decline, and in the wake of a short war with Georgia, the Russian government launched what were termed the 'New Look' defence reforms. For Russia's land forces, this overhauled the army's order-of-battle. Russian land forces also include naval infantry and airborne forces, each of which are separate services. Changes in orders-of-battle were matched with materiel modernisation. It did not go unobserved that Russian land forces' EW capabilities have received significant investment, with the service entry of a host of new capabilities. In 2014, during the first Russian invasion of Ukraine, several of these new EW systems deployed to the theatre of operations where they demonstrated their efficacy against Ukrainian radio communications.

Despite a lacklustre showing at the start of their second invasion of Ukraine in February 2022, Russian EW practitioners have learned from their mistakes. An article published in January 2024 in the *Financial Times* entitled 'Russia has the upper hand in electronic warfare with Ukraine' pulled no punches. Russian electronic jamming remains potent and is particularly effective against Ukrainian uninhabited aerial vehicles (UAVs). Anecdotal evidence shared with the author highlights some of the problems: Unencrypted radio links connecting the aircraft to their pilot for C2 and telemetry have been vulnerable to electronic attack. Likewise, global navigation satellite system (GNSS) position, navigation and timing (PNT) radio signals – that UAVs rely on for navigation – have also been at risk. GNSS PNT signals used by precision-guided weapons such as US-supplied Boeing joint direct attack munitions (JDAMs) have been adversely affected by Russian jamming. PNT vulnerabilities were highlighted in a trove

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of classified US Department of Defense (DoD) documents, leaked in 2023.
Moreover, Russian EW has proven effective against Ukrainian tactical communications lacking in robust communications/transmission security (COMSEC/TRANSEC) protocols. Techniques including encryption can help protect traffic from eavesdropping. Frequency hopping can also frustrate an opponent's ability to detect the radio transmissions in the first place and then jam them. This is because the signal's frequency is continually changing in a pseudorandom fashion, sometimes several thousand times per second. However, one seemingly insurmountable problem is that whenever forces emit on the battlefield, they announce their presence. Land forces may have sophisticated radios with a myriad of COMSEC/TRANSEC techniques, and low probability of detection/interception techniques may try to keep signals as discreet as possible; nevertheless, every radio transmission must move through the ether.


Credit: US Army

The US Army developed the Advanced Dynamic Spectrum Reconnaissance (ADSR) System to combat jamming directed at blue force tactical communications networks. The system can also be used to assist friendly network emissions control.

Pathfinder

News came to light in November 2023 that the US Army had deployed a new capability called the Advanced Dynamic Spectrum Reconnaissance (ADSR) system during a multinational exercise in Germany. Reports said that ADSR uses artificial intelligence (AI) techniques to let deployed radio networks detect, and then avoid, electronic attack.
ADSR was developed under the US Army Research Laboratory's (ARL's) Pathfinder initiative. Pathfinder was launched in June 2021 to harness academic know-how and expertise to rapidly solve problems the US Army is facing. The programme is managed by the Armaments Centre of the Army's Combat Capabilities Development Command (DEVCOM) in conjunction with the ARL. Both organisations are in turn working with the US Army's 18th Airborne Corps' 82nd and 101st Airborne Divisions. Academic assistance has been provided by universities in North Carolina, Tennessee and West Virginia. The universities have been supported by the US Defence Advanced Research Projects Agency in their ADSR endeavours.
How does ADSR work? Reports covering the recent deployment of the system to support an exercise in Germany involving the 101st Airborne Division provides some clues. The exercise took place in late 2023 at the US Joint Multinational Readiness Centre in Bavaria, southwest Germany. Essentially, ADSR exploits the Army's own deployed tactical networks to achieve two tasks: First, ADSR works to reduce tactical radio frequency (RF) emissions writ large across the battlefield. Second, the system also employs these networks to sense and avoid hostile jamming. The logic here is two-fold; prevent networks, radios and hence assets (personnel, vehicles, bases, weapons, sensors and capabilities) being detected via their RF emissions. What has not been detected cannot be jammed. Likewise, by ascertaining where hostile jamming is occurring, areas where jamming may be prevalent can be avoided.

Credit: TrellisWare

TrellisWare's TSM waveform is largely replacing the Soldier Radio Waveform to provide secure intra-platoon and company communications, amid concerns over the latter's reliability and performance.

Networks

US Army units deploy a bewildering array of tactical networks on the battlefield. The force uses TrellisWare's TSM very/ultra-high frequency (V/UHF: 30 MHz–3 GHz) waveform. TSM replaces the US Army's erstwhile Soldier Radio Waveform (SRW), a UHF waveform for intra-platoon and company communications. Moving up in echelon, company headquarters use the Wideband Networking Waveform (WNW) and Army Networking Waveform-2 (ANW2). The WNW uses V/UHF frequencies, while the ANW-2 is restricted to UHF (300 MHz–3 GHz). Both waveforms carry tactical voice and data traffic between vehicles, deployed headquarters and dismounted troops. Company-level command posts can also

access TSM networks. WNW networks, meanwhile, connect company headquarters to their battalion-level counterparts. A plethora of satellite communications (SATCOM) constellations provide beyond line-of-sight (BLOS) links to a US Army deployed manoeuvre force.

Since the commencement of the US-led counter-insurgency operation in Afghanistan and Iraq just after the turn of the century, the US Army has primarily organised its manoeuvre force around the Brigade Combat Team (BCT). This is now changing with the force adopting a divisional structure. According to the US DoD, the reorganisation around larger formations is to enable overmatch against near-peer rivals. While not named explicitly, these rivals are understood to be the People's Republic of China and Russia. The advent of the divisional structure should not have too big an impact on current manoeuvre force communications. Nonetheless, the reorganisation could see a higher reliance on BLOS links such as SATCOM. Two main BLOS networks are used by the manoeuvre force: The Warfighter Information Network-Tactical (WIN-T) is joined by the Mobile User Objective System (MUOS). Both MUOS and WIN-T use V/UHF links and are primarily used at battalion and company levels. Units and headquarters at company level and below use SATCOM networks provided via the Integrated Waveform (IW) and the JBCP (Joint Battle Command Post). The IW is a UHF waveform with the JBCP, which is the Army's blue force tracking system, also using UHF.

As one can see, the manoeuvre force relies on a plethora of networks to maintain communications; a profusion which is not accidental, and which provides advantages from a redundancy perspective. Successful electronic attack against one or two of these networks will not deprive the manoeuvre force of communications. However, as the war in Ukraine has illustrated, Russian land forces take electronic attack very seriously. The Russian Army deploys three systems at the tactical level to detect, locate and jam V/UHF radios and networks. These EW platforms include the R-330B Borisoglebsk-2, R-330Zh Zhitel and RP-377U/UV. Ukrainian sources have shared with the author that encrypted waveforms have remained robust in the face of severe Russian jamming. US-supplied Single Channel Ground and Airborne Radio System (SINCGARS) transceivers have held their own when bombarded by Russian electromagnetic waves; this resilience is made more remarkable by the fact that this radio system relies on a design over 40 years old. Nevertheless, it would be negligent to rely on waveform COMSEC/TRANSEC to act as the first and last line of defence against jamming.

Listening to the ether

The stakeholders involved in ADSR declined to publicly share further information on the system. As a result, one must resort to speculation to understand how ADSR might work. As articulated above, ADSR uses deployed army networks to sense and avoid jamming. This means that ADSR must have some means by which to ascertain what is happening in the ether.

Situational awareness to this end could be delivered via deployed US Army EW systems. The force is in the process of receiving new manoeuvre force EW platforms. These platforms are built around the Army's Terrestrial Layer System (TLS) which constitutes two distinct capabilities. Tactical land manoeuvre force EW will be supported by the TLS Brigade Combat Team (TLS-BCT) ensemble. Electronic warfare at the operational level will be performed by the TLS Echelon Above Brigade (TLS-EAB) system. Lockheed Martin is currently developing TLS-EAB and TLS-BCT prototypes. According to the US Army, the force is expected to complete the introduction of both the TLS-BCT and TLS-EAB between 2030 and 2035. The two TLS configurations will be joined by a backpack electronic attack system intended for dismounted troops. Mastodon Design, part of CACI

Credit: Lockheed Martin

Lockheed Martin's TLS-BCT electronic warfare system, a rendering of which is shown here, could be one means by which ADSR can sense what is happening in the spectrum, chiefly the extent to which jamming is affecting deployed US Army tactical networks.

Credit: US Army

The US Army's manoeuvre forces rely on a comprehensive array of communications networks on the battlefield. ADSR aims to use these networks as a means by which jamming could be detected and friendly RF emissions controlled.

International, won a USD 1.5 million contract to provide a prototype in late 2023. The backpack forms part of the TLS-BCT architecture.

Manoeuvre force EW elements are knitted into Raytheon's Electronic Warfare Planning and Management Tool (EWPMT). The Army says the EWPMT provides electronic warfare C2 and training, in support of electromagnetic manoeuvre. In short, the EWPMT acts as the clearing house for incoming Signals Intelligence (SIGINT) and subsequent outgoing electronic and cyberattack taskings. One concept of operations for ADSR could be for it to act upon information collated by the EWPMT. Let us suppose that a BCT's infantry battalion is experiencing jamming in its area. The jamming has been detected by the BCT's organic TLS-BCT systems. The TLS-BCT has determined the areas being most adversely affected by the jamming. Red force electronic attacks are degrading parts of the tactical networks used by the battalion in the affected areas. ADSR could receive notifications from the EWPMT regarding these affected areas. Working with network management software, ADSR could present options for configuring these networks to avoid jamming. One option presented by ADSR could be to alter the network's topology. This might mean that traffic from the affected infantry battalion's units follows paths via nodes further back from the tactical edge to avoid the worst of the jamming.

Similarly, ADSR may be connected with the network's management software and continually monitor the network's performance. By using machine learning approaches, ADSR's software could be trained to recognise when jamming is taking place. For instance, if traffic suddenly becomes intermittent or stops altogether on one part of the network, this may indicate that jamming is occurring. Available bandwidths suddenly experiencing significant constrictions may provide an additional, similar clue. In a sense, tactical communications mobile ad-hoc networking (MANET) approaches have some of this functionality built-in. If part of the network is compromised for whatever reason, the network reconfigures to continue functioning. Fusing MANET approaches with those of ADSR could increase and deepen network integrity. Using tactical networks to sense and react to jamming enhances the force's overall spectrum manoeuvre capabilities. It is possible that ADSR can supplement the TLS-BCT or even assume some of its SIGINT burden.

ADSR is also tasked with reducing tactical communications emissions across the battlefield. How this might work in practice is less clear. For example, ADSR may continually monitor RF emissions via the network's management software. Once again, machine learning may have much to offer. ADSR software could be trained to understand an infantry battalion's usual radio emission behaviour at various stages of battle. The software could correlate this behaviour with effective jamming incidents. If the battalion's emissions were at a particular level, did the enemy start jamming? Was this because the strength of the battalion's radio signals were at a level that could be detected with relative ease by red force SIGINT? Once detected, how severe was red force jamming? How long did the jamming last? Where was the jamming concentrated and how effective was it against friendly emitters? There are a myriad of factors that ADSR software could account for to determine when blue force emissions prompt a red force response. All these factors could help ADSR's algorithms advise how the network should be configured to remain survivable. Recommendations could be shared with the network's management software which can make the necessary alterations to reduce emissions.

Challenges ahead

It is important to remember that AI is not a silver bullet. Like all aspects of computing, it depends on the reliability and quantity of data that it can be trained with. 'Garbage in, garbage out' (GIGO) is an oft-used refrain, but it may be a paucity of data that capabilities such as ADSR will have to address. Mercifully, the US and its allies have not found themselves embroiled in conflicts involving a peer- or near-peer adversaries in recent years. Those wars that have involved these actors over the past 30 years have tended to feature low-tech opponents. Enemies such as these were unlikely to deploy sophisticated jamming against allied land forces' communications networks. A lack of 'real world' data will force ADSR's AI techniques to be trained with simulated data. Additional useful information may be culled from signals intelligence data shared by the Ukrainian military with its allies. A significant ongoing SIGINT 'soak' of the Ukrainian theatre of operations by the US and others may be helpful in this regard. At the very least, ADSR will have a reservoir of data that can be used to train its algorithms.

The reticence of the US Army and associated stakeholders to discuss ADSR make it difficult to articulate the system's capabilities with any certainty. Nonetheless, by examining information in the public domain and combining this with educated conjecture, one can contemplate the system's capabilities. ADSR's realisation comes at an opportune moment. The US Army will have to fight hard to win and retain control of the spectrum as a manoeuvre space in future conflicts. ADSR will have an important contribution to make in fulfilling this mission. ■

Russia's defence in depth and Soviet doctrine

Sam Cranny-Evans

The task of building and breaching battlefield obstacles has come sharply back into the spotlight following Ukraine's difficulties breaking through Russian lines during their summer 2023 counter-offensive. It therefore bears examining Russia's approach to defensive fighting, as well as the particular difficulties faced by Ukraine in overcoming the many obstacles in their path.

Russia's defences in Ukraine have caused, and will continue to cause, considerable casualties to Ukrainian forces. Now, there are emerging reports indicating that Western instructors did not properly understand the requirements of fighting in Ukraine and failed to appreciate how Russians would defend. One could argue that this reflects in part a loss of expertise within the Western community. Analysts in the 1980s took a great deal of time to understand Soviet defensive doctrine and how it would be employed. One example is FM 100-2-1 titled, 'The Soviet Army: Operations and Tactics' which was published by the US Army in 1984. The document provides a useful insight into how Soviet forces envisioned a defensive operation, and contains many parallels to current Russian operations in Ukraine.

Notably, the Soviets defined defensive operations as combat operations designed specifically to repulse attacks by superior forces, inflict heavy casualties and create favourable conditions for a decisive offensive. They are also used to consolidate taken ground and provide breathing room for an offensive that has failed. This is of course a fairly obvious assumption - but it provides context to wider commentaries focused on the progress of the Ukrainian offensive. 'The Russian Way of War', published by Lester Grau and Charles Bartles in 2017, is more current than FM-100-2-1, and is also used to inform the following analysis.

Author

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At the tactical level, FM 100-2-1 is insightful. It states that Soviet defensive operations conceptually consisted of a security zone forward of the main defensive area. The defensive area did not consist of continuous belts of fortified positions, but rather clusters of strongpoints defended by motorised rifle infantry with mobile reserves consisting of tank heavy formations. Grau and Bartles add that the defence should be stable, in the context of Ukraine this meant dispersed and concealed formations to minimise the damage caused by precision munitions. The defence should also be active, which encompasses several types of action in the context of a war with NATO, but most relevant for Ukraine is the requirement to "place the enemy under constant fire."

There are four aspects to a defensive operation identified in FM 100-2-1, each of which is worth examining with respect to the War in Ukraine.

1. The Security Echelon

The Security Echelon is deployed ahead of the main defensive area with the main role of engaging enemy forces, in an attempt to make them deploy prematurely and outside of direct fire range of their main defence. The security echelon uses obstacles such as mines and is expected to resist the enemy's advance stubbornly. Compare this with reports from Ukraine, which indicated that despite weeks of offensive operations, the Ukrainians only reached the first 'main line' of the Russian defences in August 2023. It is therefore possible that the first elements of the offensive were resisted by a Russian security echelon that likely decided to defend its positions forward, rather than concentrate most of its combat power in the first and second lines of defences.

2. The Main Defensive Area

The main defensive area sits behind the security echelon and consists of platoon or company level strong points. The Soviets were planning around nuclear weapons, so dispersion was key for survival, but not at the expense of overlapping fields of fire and the creation of Fire Sacks (see no. 3 below). Anything that could be dug in would be, and provided with protective overhead cover, communication trenches were dug to link positions and wired communications established. The defence would appear as bands or belts, as opposed to a continuous line, and represents a defence in depth.

The various open source attempts to monitor and observe Russia's defensives indicate that they have not strayed far from this principle. As with Soviet concepts, the defence was intended to funnel and channel Ukrainian forces into Fire Sacks where

Credit: Ukrainian MoD

A Ukrainian soldier takes a moment to eat during the Battle of Bakhmut in 2022. Trenches such as his have been prominent in the war in Ukraine since 2014.

indirect fires could be massed and applied along with combined arms assaults to counter efforts to advance, and to inflict losses.

3. The Fire Sack

The fire sack is basically the same as the US concept of a kill zone. It is a pre-registered area where an enemy force would be expected to bunch up and present a suitable target for massed indirect fires. Mines and obstacles were to be used to prevent an enemy force exiting the sack and tank heavy reserve forces prepared to attack into the sack and engage anything left after the artillery lifted.

Evidence suggests that this has occurred time and again in Ukraine. Ukrainian troops manoeuvring in their vehicles would encounter minefields much deeper than expected and the offensive would grind to a halt. A combination of artillery, rotary wing aviation, loitering munitions, and the occasional tank-led counter-attack, would proceed to inflict losses on the immobilised formation. Another application was in the use of massed fires on positions captured by the Ukrainians, which allowed Russian forces to regroup and then retake lost territory.

Grau and Bartles state that a motorised rifle battalion (MRB) would be expected to defend a frontage of 3-5 km with a depth of 2-2.5 km. The order of battle for a typical MRB is three companies mounted on BTRs, BMPs, or MTLBs, a mortar battery, anti-tank unit and other supporting functions for an approximate strength of 500 personnel. Each company commands two to four platoons, and each platoon consists of two to four squads. It is likely that the actual strength was slightly lower than this, and that a battalion was defending the upper limits of the area mentioned. An MRB platoon would typically consist of 32 personnel, three BMPs and a command section. It would be expected to defend a strong point with a 400 m frontage using positions for squad weapons, and firing positions for its BTRs or BMPs. The armoured vehicles would move between positions providing fire support for the dismounted infantry. The available evidence, such as videos and first-hand accounts, indicates that this force employment was observed and followed by Russian forces in some places.

FM 100-2-1 describes three additional elements in connection with prepared defence, but are not considered to be primary components mostly because they contribute to the overall success of the three above. These are: obstacles, anti-tank teams, and counter-attacks. The primary means of creating an obstacle for the Soviet forces was the landmine.

Sowing chaos

Each Soviet division included a mine-laying capability formed of tracked mine-laying vehicles with supporting engineers. If required, they could lay a three-row anti-tank minefield, 1,000 m long, in under 30 minutes. This would consist of mines positioned on the surface at a spacing of 4 - 5.5 m, providing a total minefield density of 750 - 1,000 mines per kilometre.

The modern Russian forces are able to call on vehicles such as ISDM 'Zemledeliye', the remote mine laying system that entered service in 2020 and uses a rocket-based mine dispersal system to sow 50 mines per vehicle, out to ranges of 15 km. An older system is known as the UMZ, or Universal Mine Layer. The original version developed by the Soviets was based on a truck and carried six launchers with 30 tubes each. It could be fitted with anti-tank or anti-personnel mines, and could lay between 180 and 11,520 mines without reloading, based on the desired nature of mine. For some time, Russian forces have also been able to deploy anti-tank and anti-personnel mines using the BM-27 Uragan 220 mm multiple rocket launching system. It carries 16 rockets, each of which is capable of carrying 312 PFM-1 anti-personnel mines, or 9 of the PTM-3 anti-tank mines. As such, a single Uragan could lay a minefield covering 0.24 to 0.81 km2. This minefield would

Credit: Russian MoD

The ISDM Zemledeliye can be used to re-seed minefields that have been depleted in combat, or to remotely confine the movement of enemy formations for further engagement with artillery.

Credit: Ukrainian MoD

A MOM-50 recovered from Donetsk is shown here. Instructions captured from a Russian soldier indicate that they could be used with a command detonation in combination with the OZM-72 bounding mine, or arranged with overlapping fragmentation arcs.

Credit: Ukrainian MoD

A Ukrainian soldier stands in the crater left by a Russian FAB bomb. The combination of FABs with the UMPK guidance kit made them more accurate and effective in blunting Ukrainian offensives.

have a low density, so it would be created by at least a battery of BM-27s. This system in particular was used to trap Mujahideen fighters in Afghanistan into valleys during assaults. Similar tactics were employed in Chechnya, and Soviet doctrine also envisaged launching the mines onto enemy formations.

An article deriving lessons from the War in Ukraine notes that the cost-efficiency of minefields increases with a greater density of mines. An axiomatic conclusion perhaps, but nonetheless interesting to observe the importance placed on this topic by Russian military thinkers. Using mathematical formulas, the author states that 300 mines deployed over an 800 m wide minefield would have a 66.3% cost efficiency against a BMP-2 sized target. This reflects the efficiency of a standard minefield against a common armoured vehicle. Now, consider the reality on the ground in Ukraine where it is rare for Russian units to lay minefields according to doctrine. They are, according to Nick Reynolds and Jack Watling from RUSI, frequently double or quadruple the depth of what was expected, and include multiple techniques such as double-stacked TM-62 anti-tank mines, and the use of improvised explosive devices.

The challenge of mines in Ukraine was further increased by the nature of the terrain and Russia's defences. The extensive trenches made obvious in satellite imagery were coupled with concealed positions in treelines and the use of terrain features to impact the available approaches. The Russian forces mixed mine types to complicate demining; one source indicates that OZM-72 bounding fragmentation and MON-50 anti-personnel mines would be used to defend approaches and paths to Russian positions, and other areas would be covered by a mix of PMN anti-personnel and TM-62 anti-tank mines. Drawings recovered from Russian soldiers suggest that OZM-72 and MON-50 mines would be deployed together, with the MON-50 command-initiated. OZM-72s have a lethal radius of 25 m, and the same drawings instruct the soldier to position them 30 m apart to ensure overlap of their lethal radius. Altogether, the depth of Russian minefields was greater than expected, the density of mines was greater than expected, and the nature of the terrain limited flexibility once a minefield had been encountered.

Tactical precision strike vs anti-tank teams

Minefields are not new, and neither is navigating them as part of an offensive operation. British forces fighting at El Alamein in 1942 resorted to manually probing for and lifting mines to create channels through German minefields. The Soviets made extensive use of mines and anti-tank guns at Kursk, with well-known results. However, it was rare for artillery fire to be corrected in real time by aircraft during WW2, and even less common for a single aircraft to achieve a first round hit on a moving tank. This meant that demining operations by hand could be conducted with some expectation of success, assuming that the enemy positions could be suppressed.

At the beginning of Ukraine's counter-offensive, demining was conducted by armoured vehicles such as the Leopard 2R mine breaching vehicle from Finland. It is understood that artillery fire to suppress Russian positions would be maintained for as long as possible, but could not always be sustained throughout an advance and mine-clearing phase. Furthermore, the mine ploughs that enable these vehicles to clear a path are only able to withstand so many mine detonations before they must be replaced. Added to this, the Russian propensity to use double-stacked TM-62s increases the likelihood of immobilising a heavy vehicle. Other systems such as the UR-77 Meteorit mine clearing line charge were also used, but their line charges were designed to defeat mine belts of a certain width, meaning that they needed to be reloaded to clear a path through Russia's deep mine belts in Ukraine.

Furthermore, all of these vehicles, and the vehicles conducting the offensive, were vulnerable to Russia's tactical precision strikes assets, which had effectively replaced the Soviet era anti-tank teams. Soviet anti-tank units were equipped with anti-tank guns such as the MT-12 Rapira and some anti-tank guided missiles (ATGMs). The lethality of these systems against heavier targets would not have been guaranteed, and the MT-12 in particular would have prompted counter-fire very quickly. Russian units in Ukraine, however, are armed with a variety of tactical precision strike assets that provide a much higher likelihood of achieving a first round hit. For example, in one defensive area, the Russian forces might have had at their disposal, the Lancet-3M loitering munition, the ground-launched 9M133 Kornet ATGMs, 9M120 Ataka ATGMs launched from Ka-52 helicopters, and drone-delivered munitions. These assets are complemented by the 2K25 152 Krasnopol guided artillery round when available, as well as 250 kg and 500 kg aerial bombs fitted with the UMPK guidance kit. Most of these weapons have a relatively high certainty of a first round hit, and sufficient lethality to immobilise or heavily damage all but the most protected Ukrainian vehicles.

Credit: Ukrainian MoD

Ukrainian units were forced to use sappers to clear paths through Russian minefields for limited infantry offensives.

Massed artillery fires with cluster munitions still play an important role for the Russians. However, the low force densities, enormous expanse of the Ukrainian battlefield, and restrictions on the use of artillery munitions mean that inflicting losses with artillery alone would be inefficient. This was especially the case after Ukraine had managed to degrade Russia's available artillery.

The eventual result of Ukraine's counter-offensive was the abandonment of demining vehicles and efforts to create routes through Russian minefields by hand. Teams of sappers would begin their missions at dawn and use night vision goggles (NVGs) to locate and remove mines. They used drones with thermal imaging to help locate mines warmed by the sun, but during these attempts they were targeted extensively by drones, artillery and snipers. The paths they cleared were used by infantry to conduct limited 'bite and hold' assaults against Russian positions, however they were often dislodged by counter-attacks. The combination of extensive and complex mine belts with tactical precision strike assets elevated the cost of breaching Russia's defences for the Ukrainian forces, and ultimately led to tactics that could not deliver the breakthrough that many were hoping for.

Credit: Russian MoD

A T-90M engages Ukrainian forces in the Summer of 2023. Russian forces used small packets of armour to inflict attrition on immobilised Ukrainian formations during the counter-offensive.

Counter-attacks

Russian forces counter-attacked to regain lost positions, or at times to simply inflict losses. Immobilised formations might be engaged by a pair of tanks, which Russian forces were willing to trade in exchange for causing Ukrainian losses. The counter-offensive did create issues for the Russians, however, and drove commanders to relocate units from other areas of the front to defend against Ukraine's advances. They would use pre-planned fires on their own previously-abandoned positions, and conduct small unit offensives with varying degrees of success.

The Russians also made the most of the opportunity presented by Ukraine concentrating forces and resources in the Donetsk and Zaporizhzhia oblasts, and conducted their own localised attacks. The end result was that Russia captured more territory than Ukraine in 2023.

In sum

Russia's forces in Ukraine have pursued a defensive doctrine that would have been familiar to Soviet soldiers in Europe circa the 1980s. They have exploited landmines to slow and degrade Ukraine's offensive power, and they used extensive mass fires to capitalise on the effects of those minefields, and counter any successful breakouts. However, the much greater proliferation of tactical precision strike assets would be alien to soldiers in the 1980s, and it has likely increased Ukraine's losses in a variety of ways. All in all, if Ukraine is to break through the Russian lines, it will need a lot more in terms of firepower and resources. Attacking prepared defences without an element of surprise and air superiority was always unlikely to yield significant results. Ukraine's allies must therefore seek new ways to arm its forces and ensure that the next counter-offensive achieves its goals. ■

Combat supply operations

Jean Auran

Military commanders have always been concerned about supplying their forces on the ground. Determining stock levels, providing, distributing, and replenishing constitute the supply function. This article focuses on combat supply operations in a NATO environment from a French perspective.

Supplying armies in the field has always been a concern for military leaders – supplies include all resources required to maintain and support troops in the field. Likewise, logistics can quite easily become a headache for commanders depending on the terrain, especially in mountainous or desert areas; sustaining forces becomes even more critical in expeditionary missions. This article will examine supply operations through the prism of NATO's policies and agreements.

Organising supply

Supplies in modern units are managed within sections and companies by sergeants and executive officers at the tactical level and by the S4, B4, G4, and J4 chain of all command posts. At its level, a battalion deploys with three days' worth of fighting supplies. This inventory consists of supplies (food, gasoline, ammo). At the brigade level, the Combat Support Service battalion manages the second line. At the upper level, divisional support areas or the Joint Logistic Support Group (JLSG) stores most of the resources in mobile logistic nodes.

When a NATO operation or mission is considered necessary, NATO members and partner countries voluntarily provide the personnel, equipment and resources required for the task. Nations that provide contingents for an operation are referred to as a troop contributing nation (TCN). The TCN handles the deployment of its troops with a first allocation, and during the stabilisation phase. Contracts are awarded, and certain nations assume functions for the benefit of the whole force. A nation may assume the function of logistic role specialist nation (LRSN) under specific circumstances. This was the case when France provided fuel to the 40,000-strong NATO Kosovo Force (KFOR) in 2000.

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Credit: NATO Battle group Lithuania

The primary military logistics instrument is the twenty-foot equivalent unit (TEU) ISO container. The Orion V is a 55 tonne heavy container hauler capable of handling containers weighing up to 29 tonnes.

The table below provides a summary of various categories of responsibility used by NATO:

NATO supply classes

NATO's supply classifications are widely accepted by most modern armies, and are split into five major categories:

- Class I: subsistence, health, morale, and welfare.
- Class II: equipment, vehicles, weapons, spare parts, medical and general supplies.
- Class III: fuel and lubricants.
- Class IV: fortification, construction, and engineering materials.
- Class V: ammunition, explosives, and chemical agents of all types.

RSN	Role specialist nation.
LRSN	Logistic role specialist nation. One nation assumes responsibility for providing or procuring a specific logistics capability and/or service for all or a part of the multinational force within a defined geographical area for a defined period.
LLN	Logistic lead nation. One nation, based on its capabilities, agrees to assume responsibility for organising and coordinating a broad spectrum of logistics support for all, or part of the multinational force and/or headquarters within a defined geographical area for a defined period. The LLN can also operate as an LRSN at the same time.
SN	Sending nation.
N-NTCN	Non-NATO troop-contributing nation.
TCN	Troop-contributing nation.

Credit: Armée de Terre

Combat rations are the solution for short-notice deployments; They are easily transportable and safe for around two years.

Rations

Water, food, and rations are included in Class I. The Service du Commissariat des Armées (SCA) is responsible for providing this type of supply to units engaged in operations and/or on exercises. In this regard, STANAG 2937 is relevant because it aims to enhance interoperability of NATO military forces and partner nations' individual operational rations. A ration provides nutritional requirements for a complete day and typically includes three meals (usually breakfast, lunch, and dinner). It was estimated that the energy expenditure of military personnel would be approximately 3,600 kcal per day for 'normal' operations, such as peacekeeping, firefighting or construction work, and 4,900 kcal per day for special or long-range patrol forces. For standardisation of transport purposes, the rations are stacked on NATO-type pallets (1,200×1,000 mm).

Typically, armies around the world tailor their meals to national or ethnic tastes. Since 1986, France has used the Ration Individuelle de Combat Réchauffable (RCIR), designed to last for 24 hours with a validity period of two years; it includes two reheatable hot dishes and numerous freeze-dried products, including an energy drink and a solid fuel stove. Fourteen menus are available, including seven without pork. It also allows the soldier to avoid consuming the same meal twice a week. As much as 50% of French rations are labelled RSPO (Roundtable on Sustainable Palm Oil) and Marine Stewardship Council (MSC) for fish or come from organic farming or Fairtrade. The Commissariat des Armées is also working on the creation of vegetarian rations. The RCIR pallets are comprised of mixed cardboard boxes with seven different menus.

In 2021, the Pont de Cé military workshop produced 2.1 million combat rations. During the deployment of the French battalion in Romania, "Spearhead Battalion", 8,000 RCIRs were immediately dispatched with 45,000 litres of water. Special purpose rations are tailored towards specific circumstances; these include survival rations, emergency rations, specialised long-range patrol rations, Arctic/mountain/cold and hot weather rations, and other rations that may be required for extremes of environment or for SOF.

The French Army has deployed mobile kitchens on trailers or containers during prolonged missions. The élément lourd de cuisson 500 (ELC 500) is a containerised kitchen able to provide rations for 500 personnel, and for smaller detachments, the French Army uses the RD3000-ETRAC trailer. While Western armies delegate food supply to the private sector when possible, France has been working closely with the Économat des armées (EdA), which runs catering in Abéché, Djibouti, Koulikoro and N'Djamena.

The US tends to outsource catering functions in many areas whenever possible. As a notable example, KBR Inc. handles food at Camp Lemonnier in Djibouti, Isa Air Base and Naval Support Activity (NSA) in Bahrain, and Navy Support Facility (NSF) Diego Garcia in the British Indian Ocean Territory. The Defense Logistics Agency (DLA) has helped supply over 163,293 kg (360,000 lb) of food for the 2023 Thanksgiving celebrations, which included 28,945 whole turkeys.

Water

Water is necessary for both military operations and human survival. To provide its soldiers with clean water during World War I, the American Army dug multiple wells in the area of Bordeaux and Tours where their forces were initially based. More recently, a total of 15 million litres of water were used annually by the French Barkhane Operation in Sahel. There are various kinds of water, but the most crucial is for human consumption or Eaux destinées à la consommation humaine (EDCH), supplied by either mobile water treatment plants or the civilian market.

The French Army uses the Station de Traitement de l'Eau Mobile (STEM), developed by Equans France and Suez, which produces an average of 6 m3 per hour of consumable water that can meet the needs of 800 people. It also treats seawater (with salinity from 15 to 35 g/l), brackish water, or water with low degree of contamination by chemical or bacterio-

Credit: Jean François Auran

A French Army Renault Kerax truck with a fuel container semi-trailer.

logical sources. In recent operations, the French Army has also distributed water using Tetra Pak packaging.
On naval vessels, there are three types of water: freshwater, intended for human consumption; distilled water, for the engines; and distilled water with additives, used for the cooling and refrigeration. The water produced on board comes from the sea and is desalinated by reverse osmosis, before being treated and tested to check the concentration of chlorine, minerals, and salts.

Fuel

The mechanisation of land forces has generated enormous fuel requirements, but the resource is often challenging to find and complex to transport. A soldier during the Second World War consumed 6 litres of fuel daily, while an American soldier needed 100 litres during the Gulf War. For Operation Barkhane, the fuel used in Mali came from Chad, the Ivory Coast, and Senegal – a distance of around 1,000 to 1,500 kilometres from the source to the user.
In France, the Service de l'Énergie Opérationnelle (SEO) supplies the entire armed forces with 2,000 military personnel and civilian workers. Class III includes fuel, lubricants, oils (POL) and all fluids needed to run vehicles and aircraft. Class III contains further subcategories, and includes aviation fuel and lubricants, for example. This class demands a fleet of specialised vehicles, mainly because of the European agreement concerning international carriage of dangerous goods by road (ADR). Refuelling a military force has never been easy, as demonstrated for example by the deployment of Pakistani trucks to support ISAF in Afghanistan. In 2019, the French Ministry of the Armed Forces consumed 835,000 m3 of oil products at a financial cost of EUR 667 million. Aviation use accounted for around 50% of the total consumption, while the Navy's use accounted for around 25%.
NATO assumed responsibility for this subject several decades ago. There is a Petroleum Products Committee at the highest level, which is an advisory body responsible for all matters concerning petroleum products. NATO owns a pipeline network called the Central Europe Pipeline System (CEPS), which is more than 5,000 km long and crosses The Netherlands, Belgium, Luxembourg, France, and Germany. The Organisation established the CEPS to supply fuel to various air bases and depots for land forces in Central European member countries. In recent years, NATO forces have used a single type of fuel for both aircraft and land vehicles – the NATO-standard F-35 fuel – to simplify logistics and ensure security of supply.


Credit: US Army

Flexible fuel tanks allow users to create fuel depots within a short time. Earthen berms provide them with protection.

Today, fuel storage is typically provided by both solid (such as lined concrete) and flexible (such as impermeable textile) aboveground storage tanks in temporary depots. The French Air Force used temporary depots during operations in North Africa, particularly in Chad. Another example is the US onboard Amphibious Assault Fuel System, which allows offshore vessels to supply units located on shore as part of an amphibious operation.
The table below provides some common examples of fuel products distributed:

F-34/F-35	Jet fuels.
F-44	High flash point type jet fuel, XF-43, with a corrosion inhibitor additive and lubricity improver, S-1747, and anti-ice additive S-1745.
F-54	Diesel fuel, for use in compression ignition engines.
F-63	Jet fuel used for land vehicles instead of diesel.
F-67	Unleaded gasoline fuel used in spark ignition engines, including two-stroke engines.
F-76	A mixture of hydrocarbons from crude oil refining.
XF-81	Light marine diesel.

Ammunition

On the battlefield, ammunition is loaded using a palletised loading system or flat-rack system. Combat units tend to have sufficient dedicated transport vehicles to transport ammunition, the greater problem is the quantities of ammunition and propellant available in stockpiles. In theory, French ammunition stocks should meet the needs for a major conflict plus three years of training. However, a parliamentary report recently stressed that stockpiles of propellant charges are very low. France's artillery troops receive 20,000 propellant charges annually for training, which is equivalent to one week of the consumption observed in Ukraine. The time between order and delivery of ammunition also needs to be shortened – presently it can take between 10 to 20 months for a shipment of 155 mm explosive shells to be delivered, 24 to 36 months for 155 mm BONUS shells, about 24 months for MMP missiles and AASM kits, 36 months for Meteor missiles, and four to five years for Exocet missiles. Twenty-five NATO members have signed the European Defence Agency (EDA) project agreement for collaborative procurement of munitions. The project paves the way for two procurement tracks for: a two-year accelerated procedure for 155 mm artillery shells, and a seven-year project to buy several different types of ammunition. Thus far, 24 EU Member States plus Norway have signed on, and other NATO members have expressed their intention to join the initiative after finalising internal procedures.

Credit: Eurenco

155 mm ammunition consists of shells and charges or combustible cartridge cases. Europe's stock levels are extremely low when compared to the demand seen in Ukraine.

Aside from procurement costs, maintaining various complex munitions in an operational condition can also come at a significant cost. In this regard, France annually spends an approximate EUR 2 million on SCALP missiles and EUR 7.5 million on the Exocet family.

With regards to other calibres of ammunition, NATO's primary focus for years has been the standardisation of small-calibre munitions. For the French Army, all NATO-approved 5.56 mm ammunition is compatible with their newly-selected HK416. However, NATO small-calibre standardisation is likely to face challenges as a result of the US Army's selection of a new cartridge, the 6.8 × 51 mm (.227 Fury) under the US Army's Next Generation Squad Weapon (NGSW) programme. Although very similar in terms of dimensions to the 7.62 × 51 mm cartridge, this SIG-developed cartridge is intended to operate at higher chamber pressures, translating to a flatter shooting profile, improved muzzle velocity and greater energy on target at typical engagement ranges. While improvements are broadly a good thing, a major actor such as the US selecting a non-standard munition can greatly complicate the work of logisticians.

The conflict in Ukraine has clearly shown the challenges of maintaining operational supply lines in wartime. While NATO's strength as a collective defence organisation lies in its ability to pool limited resources, the European Union is also making an effort to acquire or enhance its own production capacity. Training can also help to overcome supply challenges, and in this regard, exercises such as NATO's 'Capable Logistician' are crucial. ■

Towed artillery and dismounted mortar use in Ukraine

Tim Guest

Artillery of all kinds plays one of the most devastating and important roles in modern battle and while armoured, self-propelled (SP) platforms are increasingly being procured, towed guns, together with tubes of dismounted infantry mortars, continue to play a critical part in current conflicts.

This article shares thoughts on towed artillery and mortar systems primarily in the context of the battlefields of Ukraine.

Setting the scene

Lulled into a false sense of security after fall of communism, NATO, with its growing number of members, has experienced a relaxed and relatively peaceful period. For more than 20 years, while towed artillery and mortars played their parts in various confrontations and coalition-based encounters, they were eminently survivable, with friendly platforms facing little in the way of serious peer-to-peer counter-battery capabilities. As a result, this meant mobility of weapon platforms was not a decisive factor linked to survivability. Control of airspace also meant the unhindered deployment of towed guns via helicopter was possible, and it was reasonable to assume they could be placed in positions where they would remain for a long duration. Even after Russia first invaded Ukraine in 2014, then annexing Crimea and unleashing devastating counter-battery fire against Ukrainian artillery positions in the Donbas, the West's response has been dangerously slow in recognising that the potential for a major peer-to-peer conflict in Europe was, once again, a reality. Over the past five years or so, however, a realisation has driven a fresh analysis of artillery in the context of divisional warfighting against a peer adversary in Europe. The ongoing war in Ukraine confirms the need to confront this reality, urgently, and not simply with strategy and latest tactics, but also with the right equipment.

While the need to support small- or medium-sized troop deployments will remain, whether as part of a coalition or unilaterally, the threat now posed to Western Europe and NATO's eastern flank by a numerically and technologically formidable – and belligerent – Russia, means that support for divisional deployments from the most effective artillery assets, as well as other systems, is where focus is required. Deployed forces will need all the support they can get to be able to manoeuvre effectively, with longer-range guns destroying threats at range, as well as infantry needing the confidence of their own mortars providing effective fire support at shorter ranges and closer to the front.

Author

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

Credit: US Army

Pictured: Soldiers fire an M120 120 mm mortar system at Pocek Range in Slovenia, February 2023, during Thunder Mortar Gunnery, a readiness exercise. The versatility and relative simplicity of mortars ensures swift training to proficiency and an ability to reach targets other systems can't reach.

The death of the gun line – lessons from Ukraine

For some qualified thoughts regarding artillery in modern operations and on the use of towed artillery and mortars on Ukrainian battlefields, ESD turned to the Royal United Services Institute (RUSI) and Major Patrick Hinton RA, former Chief of the General Staff's Visiting Fellow in the Military Sciences Research Group at RUSI. Hinton shared his thoughts about what he calls, "the death of the gun line", noting: *"There has been a disaggregation and federation of how fires are happening from previous static gun positions. Today, dispersal and mobility are absolutely key, calling on whatever asset is in position and/or available at any one time, and in whatever way is best matched to*

engage a particular, designated target. So, rather than necessarily responding as a six or eight-gun battery, calling for fire is a lot less rigid. And when it comes to Ukraine, where there is a massive front on both sides and where so many different things are happening, differently, all the way along, it's hard to speak categorically; units have different bits of kit, there are different risk elements, command and control issues, and the use of artillery and mortars is largely based on the experience of on-the-ground commanders and battlefield realities."

One of the most important of those realities, according to Hinton, which is also something that was learned the hard way by Ukrainian gunners in 2014 in the Donbas, is, *"you've got to do your fire mission and be prepared to move fast, which is where the infantry's dismounted mortars – the lighter ones at least – have the advantage over towed guns of the artillery, which need to be hitched and un-hitched, and wheeled in and out of action. That's one immediate difference between the two"*. He added that trying to learn more about into- and out-of-action times, rather than sitting static in a forward operating base, is on *"everyone's agenda"*, with the ability to 'shoot and scoot' critical for survivability of both weapon platforms and crews.

Hinton noted that another issue highlighted by the war in Ukraine, no matter what the platform, is that, *"Everything around the systems has changed. Loads of towed guns and mortar systems have been gifted to the country and what has developed around them – such as the use of UAVs/quadcopters for targeting and adjustment of fire – has been a step change from the norm. In the UK, for example, using UAVs/quadcopters is something we've not really done; we only have a few UAVs, as we insist on them being highly certified and technical. As a result, we've not undertaken adjustment-of-fire training off the likes of a DJI Phantom-type of commercial drone platform."*

Other challenges faced by towed guns and mortars in Ukraine, is that of ammunition, logistics and resupply. According to Hinton, *"Ukrainian Forces are being given many different types of systems, and some ammunition works with some platforms, though not with others, and this has made their logistics chain incredibly complicated. It seems they now have at least 14 different artillery systems, from 155 mm and 152 mm towed, e.g., M777 and 2A65 Msta-B, respectively, to smaller calibres, like the towed 105 mm Light Gun, but each with different operational and maintenance requirements."*

Hinton added, *"This is where the simplicity of mortars offers effective advantages; slightly more disposable, with lots of them available and more able to adapt on the go. And whilst these advantages might come with the loss of a bit of range, it's not that significant. There is, of course, a logistics chain for the mortars, too, but this will be somewhat smaller than for towed guns. Whilst 61 mm and 81 mm mortars are man-portable, they're not light by any means, as anyone who has ever had to carry a mortar baseplate will attest."*

Towed boost for Ukraine, but not without challenges

When it comes to towed systems on a real peer-to-peer battlefield, challenges have been highlighted through the use of the M777 155 mm towed gun in Ukraine, gifted in quantity by the US, Australia and Canada. In one major tranche of equipment from the US, cited by the DoD,

Credit: General Staff of the Armed Forces of Ukraine

105 mm Light Guns are among the towed artillery proving effective in Ukraine, despite losses. These were gifted by nations, including the UK.

Credit: USAF/Staff Sgt Shawn White

Pictured: several 155 mm M777 towed howitzers being loaded onto a C-17 Globemaster III, as part of security assistance from the US to Ukraine. One advantage of towed systems is their relative light weight compared to heavy SP guns, making them easily air transportable.

were 126 155 mm M777s, along with 126 'tactical vehicles' to tow them, accompanied by up to 411,000 155 mm artillery rounds. For crews in Ukraine, just five days of training has made them proficient on the system, in part due to their existing gunnery skills using legacy systems such as the 152 mm 2A65 Msta-B, and others, but also, from interviews with crews, because many seem to have found the M777 relatively easy to master. Not only that, the system's accuracy and range – reaching out beyond 20 km with conventional rounds, or 30 km with extended-range shells – has also boosted the morale of Ukrainian infantry relying on indirect fire support at the front.

The M777 has been very effective in hot spots and expeditionary conflicts where adversaries have not been as capable as the Russians. In terms of counter-battery and detection capabilities in Ukraine, however, the gun's positives have made it a priority target for the Russians, who have had a degree of success in destroying a fair number of them. Indeed, its towed nature and lower mobility compared to SP systems has highlighted this weakness as an existential problem against a peer adversary, despite it being a formidable system when firing optimally. Reports suggest that more than 50 of the roughly 190 M777 howitzers gifted to Ukraine since the start of the conflict have been destroyed, although some of these were in a storage facility awaiting dispersal to operational units. Major Hinton argued that, *"Whilst manufacturers might profess to the system's prowess on the testing grounds, on the real battlefield these guns simply may not survive contact. In fact, in Ukraine some one third of the Ukrainian Forces' artillery, including M777s, is out of the line for repair at any one time, which is a significant number".*

Towed effectiveness in Ukraine

That said, the M777 has nonetheless proven popular with its Ukrainian crews and been extremely effective on many occasions during the conflict to date, including in scenarios such as the Kharkiv and Kherson counteroffensives. Hinton's RUSI peers, Jack Watling and Nick Reynolds, in their report, 'Stormbreak: Fighting Through Russian Defences in Ukraine's 2023 Offensive', include a discussion and description of Ukraine's counteroffensive against Russian forces along the defensive Surovikin Line, including tactical actions around the villages of Novodarivka and Rivnopil, bordering Donetsk and Zaporizhzhia Oblasts, and in which Ukrainian M777s played an important role. A short extract describes the Ukrainian offensive beginning in late May:

"…with a protracted period of preparatory artillery fires. For the Rivnopil sector, batteries of M777 155 mm howitzers had been assigned to support the effort, setting up their firing positions to the northwest. Usually, Ukrainian howitzers would have to displace 2–15 minutes from opening fire, depending on their distance from different threat systems. This time it was clear that Ukrainian intelligence had accurately marked down Russian firing positions, and with the greater range afforded by the 155 mm guns, the Ukrainian gunners quickly caused Russian artillery to be pulled back. Since the targets in this phase were largely in the close, the Ukrainian artillery established a steady rhythm of strikes with little need to displace. There was a sense of elation among the crews and the infantry watching the fire. For months, each gun was strictly limited in the number of rounds available. Ukraine had been trying to conserve its ammunition to stockpile for the offensive. Now there was freedom to fire and when calls for resupply were made additional rounds were promptly delivered."

On mortars

Of the many systems gifted by overseas nations, mortars and towed guns have been amongst some of the most crucial. However, as Major Hinton told ESD, while the platforms might have arrived, not every package (unlike the DoD-cited tranche mentioned earlier) contained ammunition for the weapons. While perhaps an oversight, but more likely this was due to the lack of stocks in the West. On training aspects of these donated systems, Hinton added, *"with all the towed platforms and mortar systems gifted to Ukraine, training, (as well as maintenance), in their technical and operational use has been an essential requirement; as you would expect. For mortars, with their smaller crews and being much less complex systems with fewer moving parts than towed guns, like the M777, training is a much simpler process and takes less time. Tactics for both, on the other hand, have been left largely to Ukraine's in-the-know troops on the ground".*

Hinton's final thoughts on these two weapon systems in the Ukrainian theatre offered certain differences regarding their use: *"Don't forget, with mortars, their highest firing angles enable rounds to be dropped just a few hundred metres in front of the firing position, though with potentially lengthy times of flight, and their range capabilities overall are much less than towed artillery. And whereas towed guns will provide indirect fire over typical ranges to targets*

Credit: USMC/Cpl Ryan Schmid

Pictured: USMC 81 mm mortar during a training exercise at Marine Corps Air Ground Combat Center, Twentynine Palms, California, June 2023. Towed artillery and mortars complement each other on the battlefield.

between 10–20 km using conventional ammunition, it can also be used, should the need arise, as a direct-fire weapon, something for which the [towed] mortar is unsuited. Indeed, in Ukraine, tanks have sometimes been used for indirect fire and howitzers for direct fire," he said, concluding, *"so lots of operational and tactical variations and inventive use of weapon platforms has been going on, as needs must, and orthodoxy has, effectively, melted away".*

While infantry-portable mortars are generally unsuited for direct fire, exceptions to the rule exist. In this vein, Poland has supplied the LMP-2017 60 mm light mortar to Ukraine, including just prior to the invasion. This was designed to be handheld and hand-aimed, although low-angle, almost-direct fire would only be considered in the most extreme circumstances.

Homegrown mortar footnote

While many nations have donated dismounted mortars of various calibres together with appropriate ammunition to Ukraine since the start of the war, it is worth mentioning a homegrown Ukrainian development, first seen in early 2023 and more recently mentioned by the General Staff of the Armed Forces of Ukraine and reported on the Ukrainian *Militarnyi* Military Portal in late November.

The weapon in question is a Ukrainian-made 30/40 mm, bi-calibre 'mini-mortar', made by an unnamed private company, which can launch both 30 mm and 40 mm grenades used by automatic grenade launchers. While not a 'true' mortar, it nonetheless provides Ukraine's soldiers with an option for close-range indirect fire support. Prior to being handed over for operational use, the weapon was tested by Ukraine's 108th Territorial Defence Brigade, and deemed successful, including in terms of consistent accuracy.

Final thoughts

Artillery remains the most effective means of bringing down a huge weight of fire onto a target, or target area, and has been a battle-winning asset in many conflicts. While the towed component may be more vulnerable than armoured, SP systems, which are steadily taking over, their advantages include low cost, simplicity, and a relatively small mass. This also makes them more readily transportable by air, as well as deployable to final gun positions by helicopter, where circumstances permit. So, while there has been significant attrition of towed systems in Ukraine, their contribution has still been immense and there remains a place for them, even in an extremely harsh battlespace. Mortars, too, play an essential role and can, with their high firing angles, can reach targets within closer ranges than artillery rounds. Their relative simplicity, versatility and ability to lay down high rates of fire, are just some of the attributes making them an essential complement to an effective fighting force. ■

Credit: General Staff of the Armed Forces of Ukraine

A soldier of Ukraine's 108th Territorial Defence Brigade with a bi-calibre 30/40 mm mini-mortar.

The metals war has just begun

Juan M. Chomón Pérez

On 9 August 2022, the Biden administration signed the CHIPS and Science Act into law. The act was intended to boost semiconductor manufacturing in the US, decreasing its reliance on foreign suppliers. Since then, the global competition for semiconductor production and the supply of rare earth metals has only heated up.

During President Xi Jin Ping's recent state visit to the United States on 15 November 2023, the leader of the Chinese Communist Party took barely a minute after taking the floor to announce his concern about global supply chains. It was no coincidence that just over a week earlier he had announced the tightening of controls on exports of rare earths, which are effectively monopolised by his country. This announcement became a reality one month later, in December 2023, when the Beijing government banned the export of technology to extract and separate these metals.
The Chinese reaction to the US CHIPS Act denying the Asian giant access to certain microchips – and the technology to manufacture them is a continuation of the controls enacted over the past five months on gallium and germanium, which have led to a de facto export ban and, more recently, to an announced control of graphite exports. The trend of this trade and technology war seems clearly marked by chips versus rare earths, or rather, chips versus critical metals, in a tit-for-tat exchange.

Credit: White House Press Office

President Biden signed the CHIPS and Science Act into law on 9 August 2022 in response to growing tensions over Taiwan and as part of his overall 'Build Back Better' strategy.

De-globalisation is here to stay

The alarm over de-globalisation is gradually awakening Western countries. The fractious global management of COVID-19, the lack of unanimous international condemnation of the war in Ukraine since early 2022 and now the conflict in Gaza, together with an evolving trade war with China, are shaking liberal democracies out of their soporific slumber of security and dreams of unlimited growth.
US hegemony must now contend with technological, economic, and diplomatic threats, in addition to its usual military threat portfolio. The global South is moving ever closer to the BRICS bloc, as demonstrated by more than 20 new official applications and five new members (Saudi Arabia, Iran, Ethiopia, Egypt, and the UAE), dwarfing NATO's enlargement of two new members (Sweden and Finland). The petrodollar's domination is under threat as several OPEC+ countries such as Russia, Venezuela, Iran, and Brazil increasingly conduct trade with alternative currencies. Even traditional US allies such as Saudi Arabia are now selling their oil to China in CNY. World trade is gradually turning 'red' as the total volume of Chinese exports continues to rise. China is enabling this trade via alternative 'made in China' economic structures. For the first time in recent history, most Chinese cross-border payments are in CNY. China has already developed its own alternative to the SWIFT system, the Cross¬-Border Interbank Payment System (CIPS) and has similarly taken the lead in developing a Central Bank Digital Currency (CBDC) framework in conjunction with the Bank for International Settlements (BIS), while still pushing their own 'digital Renmibi' (also referred to as 'e-CNY') currency.
These are times of realpolitik. In this emerging new Cold War, China has already taken several technological leads: in hypersonic glide vehicles, methane-fuelled rocket engines, Thorium-based molten salt breeder reactors, and cellular network technology. It has also made significant progress in other key technological areas, such as electromagnetic projectile weapons (railguns and Gauss guns), and micro-satellite constellations. Even in fields less directly relating to the defence and aerospace fields, such as machine learning (ML), artificial intelligence

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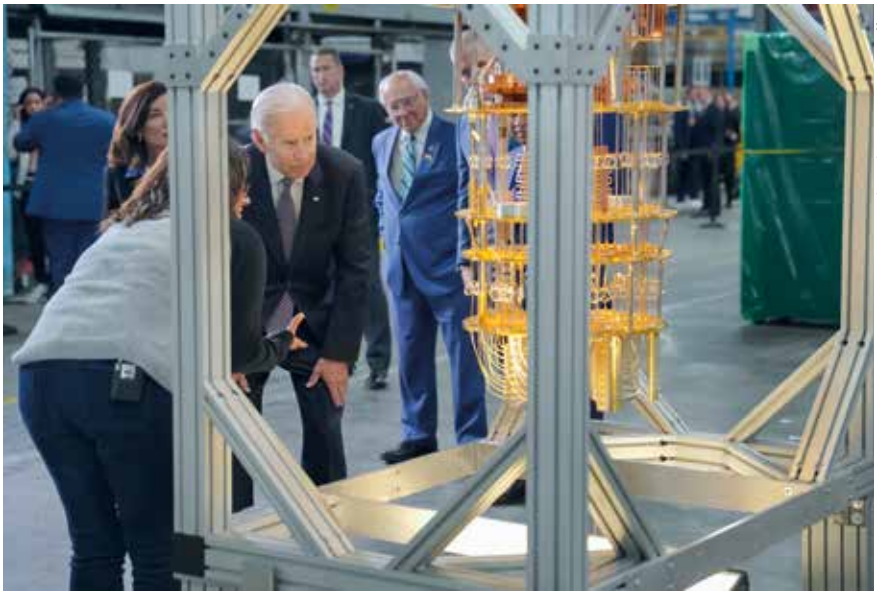
(AI), and voice recognition technologies, China has gained notable momentum. The Chinese iFlytek app already has 700 million users, roughly twice as many as Apple's Siri. In general, these are Western technologies that have been copied and improved. China may not have invented the wheel, but it's certainly working to perfect it.

The primacy of material factors

The US, Europe, and Japan have just begun efforts to halt China's advance, focusing most recently on microchips and the requisite high-end equipment to manufacture them. Disruptive technologies such as AI, which could tip the balance of technological power, depend on some of these chips. Yet all semiconductors are just an abstract entelechy without a physical basis to realise them. If chips are the brains of electronics, then rare earth metals and other critical elements such as lithium and cobalt can be said to form the neurons. A fundamental asymmetry exists at between these two responses – microchip production equipment can be developed, but raw materials and the supply chains needed to extract and process them, at demanded scale and at costs the market can bear, cannot simply be wished into existence.

China's industrial foundations are based on its land; it manufactures its products with the minerals it extracts and with the metals it refines. By contrast, the Western neoliberal economic consensus of the past few decades has shown no qualms about outsourcing the critical mining and refining portions of supply chains, and with them the bothersome labour costs and pollution they generate. It is therefore no accident that critical elements such as cobalt, lithium, manganese, tungsten, antimony, bismuth, graphite, fluorspar, vanadium and germanium are now under effective Chinese monopoly, with either the amount of ore mined, or the elements processed accounting for more than 50% of the world total.

Since August 2023, China has banned the export of Gallium and Germanium, and announced controls on exports of rare earths beginning in November 2023. These materials are essential for high-performance semiconductor production, modern weapons systems, fibre optics, and various 'green' technologies such as solar panels, wind turbines, and high-performance batteries. These restrictions should not be read as hasty retaliatory reactions, but rather as well-analysed efforts with a strategic purpose. Under this model, China's efforts are aimed at crippling the supply of elements critical to the aforementioned technical fields, in order to establish its own market dominance.



Credit: White House Press Office

President Biden touring IBM facilities in the US as part of CHIPS Act campaign. Despite the CHIPS and Science Act intended to protect US manufacturers from a Chinese-induced semiconductor shortage, the legislation does not address the sourcing of the underlying minerals needed for high-end microchip fabrication.

The Asian giant has cited national security reasons that allow it to restrict its exports without breaching World Trade Organization (WTO) regulations. In this case, the control mechanism is based on the obligation of exporting companies to obtain a specific licence. This supply restriction represents a massive blow, given that China is currently responsible for suppling of 94% of Gallium, and 83% of Germanium available on the market. As such, the Chinese Ministry of Commerce has essentially turned off the global tap of these elements, and threatens to do the same with rare earth metals, while retaining its monopoly.

Learning from the past

During the peace dividend years, the West has forgotten lessons learned in the Second World War, when securing supplies of war

Credit: US Army/Courtney Bacon

Soldiers from the US 101st Airborne Division using the recently fielded Enhanced Night Vision Goggles (ENVG) system from L3Harris. Night vision systems are just one example of the used US military's numerous high-tech systems reliant on rare earths.

materials was essential. Today, anaemic Western arsenals, understocked further though material donations to Ukraine and insufficient resupply and production cadence, serve as a painful reminder of these lessons. Yet Ukraine was not the West's first reminder of the importance of these critical war materials – two decades ago, demand for Germanium, used by the US military, skyrocketed due to the Iraq War. The demand for this material, used in various high-end optical applications including thermal imagers, night vision goggles and missile seekers, rose from 5,000 tonnes in 2003 to 30,000 tonnes in 2007, and had more than tripled in price over this period.

It has taken China roughly two decades to create the supply chains for many of these minerals, and it could take the West another two decades to get them back, especially since China does not appear inclined to give up its control. Going further, it remains to be seen whether the West would be willing to bear the ecological, health, and social costs for processing these coveted metals, as China has. Beyond the strategic leverage it enjoys, China's dominance means that is has a major influence on the prices of these commodities on the market.

China's rare earths strategy of monopolising the refining process and buying the raw material cheaply can be likened to that which the seven major Anglo/American companies, known the 'Seven Sisters', used to obtain and maintain their oil monopoly between 1940 and 1970. Between them, Exxon, BP, Chevron, Shell, Mobil, Texaco, and Gulf Oil held, an approximate 85% monopoly on the oil market, comparable to that enjoyed by China today in rare earths. These companies bought up as many oil wells as possible outside their territories and then moved the extracted crude oil to their national refineries. In a similar manner, China now concentrates critical metal refinement domestically, a technical art perfected over the years to the point of mastery. Yet despite being rich in mineral resources itself, it also seeks to obtain ownership of third countries' resources while preserving its own. In part, this is being pursued through its Belt and Road Initiative, recently renamed as the 'Global Development Initiative'.

Credit: TMY350, via Wikimedia Commons

The Mountain Pass Mine is the US' last active rare earth mine. Environmental concerns led to both the US and the EU reducing mining operations. The net result was to effectively move this environmental damage geographically to China, as the country increased its own mining and refining, often using obsolescent and highly polluting techniques.

The war for metals has just begun

In this slow awakening to de-globalisation, Western attempts to regain control over the periodic table has been sluggish. The timid measures taken by Europe and the US so far have failed to correspond to the reality of the new political-industrial conflict. Although both have defined a list of critical and strategic materials, there is currently no list of critical defence metals. Meanwhile, countries' stockpiles of war materials continue to dwindle, despite renewed efforts to increase production. Defence industry leaders such as Gregory J. Hayes, CEO of Raytheon, stated in June 2023 that "We can de-risk, but not decouple" with respect to manufacturers' dependence on China.

The US Inflation Reduction Act (2022) and the European Raw Materials Act favour the development of mining projects as well as the acquisition of metals extracted and refined on their own soil. However, they do not protect these entrepreneurs from the price fluctuations and market manipulation that China's subsidised monopoly enables. Liberal democracies are quickly reaching the limits of their capability to react in the face of a new model of autocracy that embraces global capitalism while exploiting liberal institutions. For instance, although China is a key member of the WTO, it does not hesitate to intervene in its markets on national security grounds, as seen with the ban on exports of metals which feed the West's technological ambitions. Nor does it hesitate to use its 97 major state-owned enterprises to project power beyond its borders.

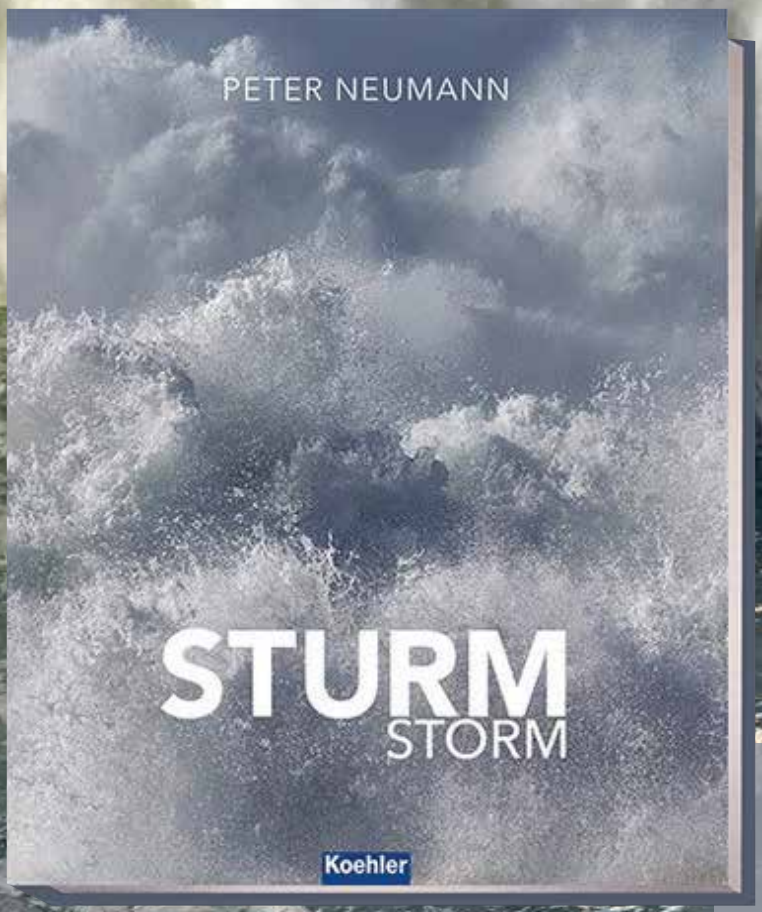
The reality is that most Western-aligned countries cannot support a fully integrated domestic supply chain for rare earths, so cooperation is critical for any strategy to succeed. Yet multinational cooperation adds a major layer of complexity and more points for failure. Developing effective strategies also requires adapting long-term strategic thinking, as China employs. However, the short-term election cycles inherent in most Western democracies does not allow for planning far beyond the four to six years a leader is typically in office. Right now, it is incredibly difficult for the West to effectively compete against China's dominance while operating under the rules and norms of democracy and liberal capitalism. Pulling supply chains out of the web of globalisation may effectively mean playing by the same rules as China.

The institutions created after the Second World War were designed to promote a model of globalisation that is now crumbling, and the West cannot continue to labour under the illusion that it can successfully combat illiberal actors under these same neoliberal institutions. Developing a successful strategy would likely require the US and EU to return to a socio-economic model where the state manages and protects critical industries and resources, and where the security needed to protect liberal values trumps economic benefits.

The war for metals has just begun, and the recently-initiated subsidy battle to convince European or American companies to remain in their territories instead of leaving for East Asia shows us one of the fronts in this new Cold War. It is a front where control of supply chains will be the lynchpin for assuring access to technologies that can tip the balance of power and push the global geopolitical map back towards the values the West wants to uphold and proliferate. Any progress in this slow war is unlikely to come quickly or cheaply. ■

STURM

STORM



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The 19th NATO Life Cycle Management Conference

"The NATO LCM Conference is the only place in the world where you can meet people discussing life cycle management" – Conference delegate, 2024

The 19th NATO Life Cycle Management Conference (LCM) took place in Brussels on 23-24 January 2024. The conference was attended by more than hundred delegates coming from more than eighteen nations. When you see those figures, you might wonder how can they do this? The LCM community is based on several different actors which I will try to describe in the following before giving an overview of the conference this year.

There are three important pillars that support LCM. First there is the NATO Main Group (MG) AC/327. From the very beginning, this group has taken LCM on board and used ISO 15288 as the basic document for the work in the MG. The MG has established several Working Groups (WGs), and it is the work of those WGs that produce all NATO LCM documents to be used by NATO as well as industry, if the industry wants to eligible for defence contracts. WG members work on a voluntary basis in their free time, they are not paid by any for doing this work. It is due to the nations willing to support their meetings in Brussels, that the work is done.

The second pillar is industry, represented by the NATO Industrial Advisory Group (NIAG) and by the NIAG Industrial Interface Group (NIIG). It is vital to maintain a close relationship between government representatives and industry. In a rapidly changing world, it is deeply important that both parties are kept up to date on the evolution of various facets, especially with regard to the IT domain. This requires mutual trust.

The third pillar is Mittler Report. From the very beginning of the NATO LCM programme, and after the North Atlantic Council (NAC) endorsed LCM to be used by NATO and the agencies in 2005, Mittler Report proposed that it, together with the MG AC/327, should be responsible for establishing a NATO LCM conference. However, it was Mittler Report who took the risk as none of the players in the LCM community had any idea of whether or not the endeavour would succeed. The 2024 conference convincingly demonstrated that the decision taken in 2006 was the right one.

The 2024 conference was organized in four blocks. The first block concentrated

Credit: Riccardo di Stefano

on the LCM business in relation to NATO. A speaker from the NATO Support and Procurement Agency (NSPA) gave an overview of how LCM was an integral part of the In-service Support (ISS), Supply Chain Management, Maintenance, Repair and Overhaul, Engineering Services, Technical Documentation (interactive), and Disposal. Then, a speaker from the NATO Defence Investment Division highlighted the NATO Policy for Systems Life Cycle Management, C-M(2005)0108, and stated that it is NATO policy that Nations and NATO Authorities apply the principles of systems life cycle management as laid out in the policy document. Finally, a speaker from NIAG and NIIG explained how they provide industrial liaison to AC/327 LCMG, industrial advice, viewpoints, and expertise, as required.

The second block was kicked off by a speaker from Leonardo outlining the use of Artificial Intelligence (AI) in relation to condition-based maintenance and predictive maintenance. This was followed by a Systecon speaker explaining how machine learning strengthens the LCM-analysis toolbox. Later, a Millog Oy representative discussed the use of AI in incident management benefits from data analytics to anticipate and prevent possible software defects or problems before they occur. The final speaker was from Contextere, and highlighted that despite automation, digitisation, and predictive planning initiatives, the reality is that industrial workers make 'minute to minute' decisions that impact productivity, safety, and ultimately cost.

In the third block, an NSPA representative explained the major LCM activities performed by the NSPA in support of different categories of UAV systems, as well as the challenges related to each system. Then a presenter explained how to meld advanced analytics, machine learning, and intuitive AI tools making them accessible actionable for the users. It was followed by a presentation (Raytheon EAGLE) on how an integrated support plan can deliver speed through additive manufacturing. This block was closed by a presentation from MBDA and TÜBITAK BILGEM about the scientific approach to reliability in product design by using the advantages of performing reliability tests and use of physics of failure models to understand failures.

The fourth and final block focused on the use of vehicles. A speaker from Trout Gmbh outlined how their use in challenging scenarios, such as navigating in rugged terrain, can result in various issues. Sensors are used to collect data and an AI process is used to ensure the availability of the vehicle and make life cycle costs easier to calculate. The last presentation came from a Roketsan representative, and suggested a framework to meticulously align product life cycle stages with project management phases, leveraging the adaptability of Disciplined Agile methodologies, and introduced a cross-functional dashboard to facilitate efficient product management. This presentation tied it altogether as business agility is the key to bridge Product Life Cycle and Project Management.

During the whole conference, four exhibitors were present, including Raytheon Intelligence & Space from the USA, Systecon from Sweden, TFD Europe Ltd. from the UK, and Patria ISP Oy from Finland.

Based on this participant's experience, the conference was a laudable success. It was organised in a highly efficient manner, the selection of presenters and presentations were excellent, and last, but not least, the delegates were highly motivated, as seen in the lively Q&A sessions.

The 20th LCM conference will take place on 21-22 January 2025 in Brussels – don't miss it!

Credit: Riccardo di Stefano

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