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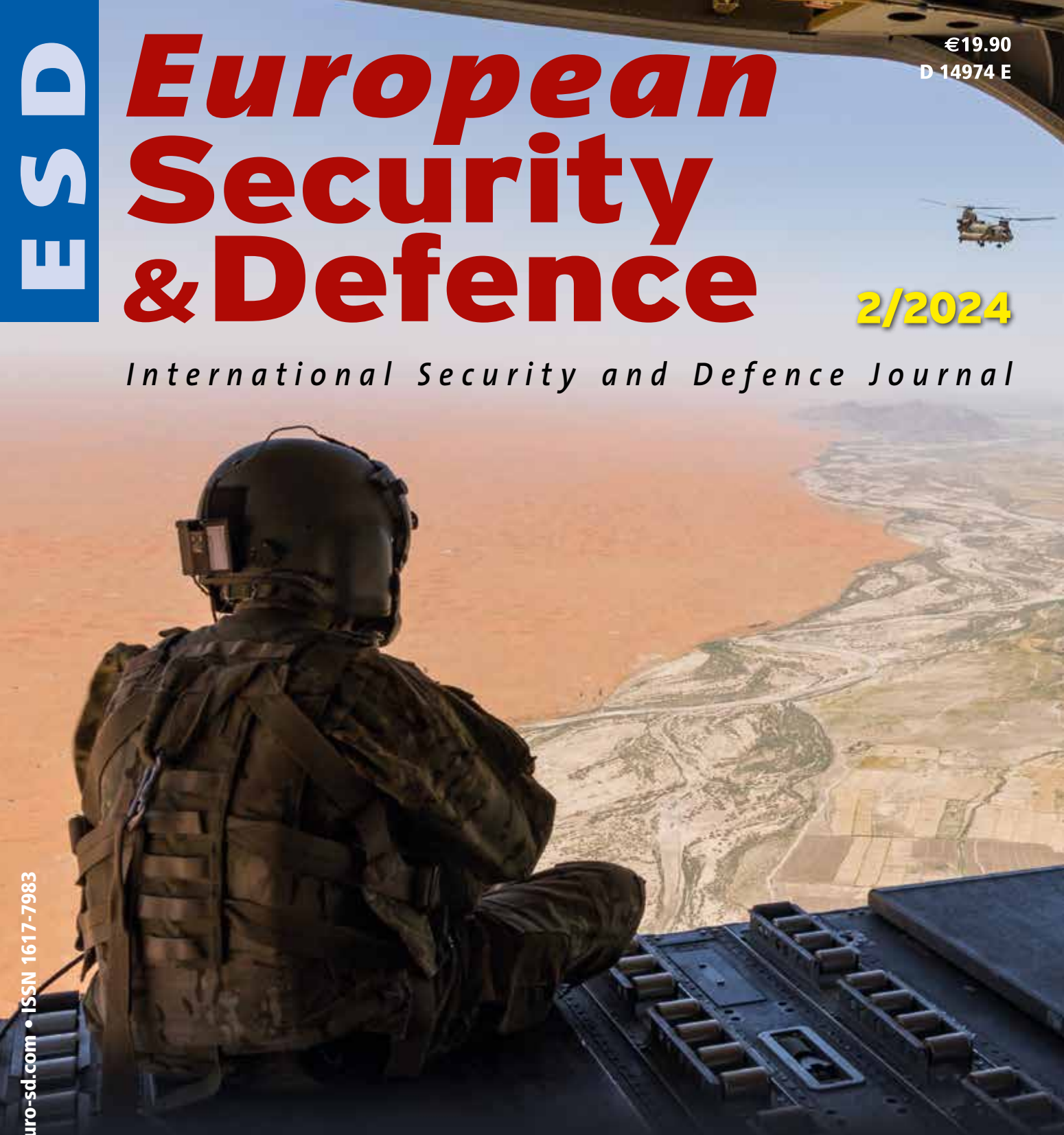

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Tides of wrath

While the Middle East managed to have a (relatively) quiet past couple of years, recent events have thrown the region sharply back into the spotlight, as a new cycle of violence has gripped the region.

The current round of bloodshed emerged out of Hamas' vicious 7 October 2023 attacks on Israel, which resulted in a reported death toll of 1,139, and were followed by Israel's brutal response, comprising aerial bombing and then a ground incursion into Gaza, resulting in a reported death toll of 25,105 and continuing to climb at the time of writing.

The overall security outlook in the Middle East began to deteriorate rapidly following the outbreak of the Israel-Hamas war, pulling in both states and non-state armed groups, and now risks becoming a wave of violence engulfing the entire region.

At the time of writing, the catalogue of cross-border violence in January 2024 has so far come to include:

- Ansar Allah (Houthi) attacks on Red Sea shipping,
- US and UK strikes on Ansar Allah targets in Yemen,
- Hezbollah strikes on Israel from Lebanon,
- Israel bombing Hezbollah targets in Lebanon,
- Israel conducting strikes against Iranian operatives in Syria,
- Jordan launching strikes on targets in Syria,
- Kurdistan Workers Party (PKK) militants attacking Turkish soldiers in Iraq,
- Turkey conducting strikes on PKK targets in Iraq and Syria,
- Iranian proxies attacking a US base in Iraq,
- The Iranian Revolutionary Guards Corps (IRGC) launching attacks on multiple targets in Iraq, including anti-Tehran groups, and an alleged Israeli "espionage headquarters", as well as strikes on militant groups in Pakistan and Syria,
- Pakistan responding with retaliatory strikes against militants in Iran.

Thus far, the majority of the cross-border strikes detailed here have been against non-state targets (the main exception here being strikes against Israel), however, tensions between Iran and Pakistan remain high, following the tit-for-tat exchanges of fire on one another's territory.

The exchange resulted in both countries momentarily severing diplomatic ties and recalling their respective ambassadors. In a similar vein, Iraq condemned the strikes on its territory, and also recalled its ambassador from Tehran. The IRGC was reported to be responsible for carrying out both sets of attacks, neither of which so far seems to have resulted in any tangible gains for Iran, and appear to have mainly served to damage relations with its neighbours. Evidently though, Iran seems to have been keen to quickly mend fences with Pakistan in the wake of the strikes, as on 22 January 2024 the two countries announced that they would return their respective ambassadors to their posts by 26 January.

One small ray of hope came in the form of Qatar's 16 January 2024 announcement that it had managed to broker a deal for the delivery of badly-needed aid into Gaza. The strip is currently in the midst of a humanitarian catastrophe, as residents struggle against cold, hunger and disease. Another potential source of reprieve is reported to be under negotiation, under which Israel could offer Hamas a two-month truce in exchange for release of hostages taken by the latter.

Hamas managed to seize around 253 hostages during its 7 October attacks, of which approximately 100 were released in exchange for a week-long truce in November 2023. Prime Minister Benjamin Netanyahu's government has come under considerable internal pressure to do more to free hostages still in Hamas' hands, including by making a deal with the group. This anger resulted in relatives of the hostages storming an Israeli parliamentary committee meeting on 22 January 2024, demanding their government facilitate the release of the captured. However, despite this internal pressure, Hamas-Israel mediation efforts from Qatar and Egypt, and US diplomatic pressure on Israel to scale down operations in Gaza, a negotiated settlement does not yet appear to be on the table. Currently, Israeli leadership seems set on pursuing a military solution to the conflict by maintaining high-intensity operations in the Gaza strip.

For the US and Western allies, this latest flare-up in the Middle East has been an unwelcome headache and a poorly-timed distraction from assisting Ukraine in its war against Russia. For their part, many Ukrainians have expressed worries that a regional war in the Middle East could result in fewer resources being diverted to Ukraine's war effort as Western allies are forced to juggle two major geopolitical priorities. Such fears are not unfounded, particularly in a US election year, where the frontrunner for the Republican nomination, Donald Trump, has previously criticised US spending on aid to Ukraine. It is therefore imperative for Western allies that the current situation in the Middle East can be stabilised quickly, before it has a chance to evolve into a greater regional conflict.

Mark Cazalet

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Cover Photo: A US Army Reserve CH-47 Chinook helicopter pilot deployed with Task Force Warhawk, 16th Combat Aviation Brigade, 7th Infantry Division surveys the landscape over the Registan Desert in Helmand Province, Afghanistan, on 21 June 2017.
Credit: US Army/Capt Brian Harris

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Defiant Houthis continue Red Sea attacks

(pf) Defying the retaliatory US and UK air strikes that were aimed at deterring them, the Yemen-based Houthi militia have continued to target shipping in the Red Sea and on 15 January 2024 struck the US-owned cargo vessel with an anti-ship ballistic missile.

Credit: www.mmy.ye

In a statement the same day US Central Command (CENTCOM) said the container ship, *Gibraltar Eagle*, reported no injuries or significant damage and continued on its way. CENTCOM added, however, that another anti-ship ballistic missile had been fired toward the southern Red Sea commercial shipping lanes earlier in the day but had "failed in flight and impacted on land in Yemen".

The previous day, 14 January, CENTCOM reported that an anti-ship cruise missile had been fired from Houthi territory in Yemen at the Arleigh Burke-class destroyer USS *Laboon*, which was operating in the southern Red Sea, but that the missile was shot down in vicinity of the coast of Hudaydah by US fighter aircraft with no injuries or damage reported.

Meanwhile, on 16 January CENTCOM reported that on 11 January, while mounting a flag verification mission, its naval forces had conducted a night-time seizure of a dhow conducting illegal transport of advanced lethal aid from Iran to resupply Houthi forces in Yemen.

"US Navy SEALs operating from [expeditionary mobile base vessel] USS *Lewis B Puller* (ESB 3), supported by helicopters and unmanned aerial vehicles (UAVs), executed a complex boarding of the dhow near the coast of Somalia in international waters of the Arabian Sea, seizing Iranian-made ballistic missile and cruise missiles components," CENTCOM stated. "Seized items include propulsion, guidance, and warheads for Houthi medium-range ballistic missiles (MRBMs) and anti-ship cruise missiles (ASCMs), as well as air defense associated components. Initial analysis indicates these same weapons have been employed by the Houthis to threaten and attack innocent mariners on international merchant ships transiting in the Red Sea."

This was the first seizure of lethal, Iranian-supplied advanced conventional weapons to the Houthis since the beginning of Houthi attacks against merchant ships began in the Red Sea region in November 2023.

"The dhow was deemed unsafe and sunk by US Navy forces. Disposition of the 14 dhow crewmembers is being determined in accordance with international law," CENTCOM stated.

These latest incidents drive home what an intractable issue Western military forces face in curtailing the Houthi attacks, the mere threat of which is forcing international shipping companies to reroute their vessels around Africa at considerable extra time and expense. The Western forces in the Red Sea region will have to mount a larger military operation to comprehensively protect shipping from Houthi attacks, while the degradation of the Houthis offensive capabilities in air and missile attacks like those mounted by US and UK forces on 11 and 13 January can be mitigated by further supplies of war materiel to the Houthis from their backers in Tehran.

For Iran, meanwhile, the Houthis provide the means of creating a significant headache for the West while Iranian forces remain at arm's length from any military action.

Hostile Houthi action against international shipping began in response to the Israel Defense Forces' campaign against Hamas militants in Gaza following Hamas' terrorist attack on southern Israel on 7 October 2023.

Sunak announces increased funding and security co-operation for Ukraine

(pf) During a visit to Kyiv on 12 January 2024 UK Prime Minister Rishi Sunak announced that the United Kingdom will provide GBP 2.5 Bn (EUR 2.91 Bn) worth of military funding to Ukraine in 2024/25: an increase of GBP 200 M over the previous two years.

Sunak also joined Ukrainian President Volodymyr Zelenskyy in signing a historic UK-Ukraine Agreement on Security Cooperation, which followed assurances made by the G7 nations at the NATO Summit in Vilnius last year that they would provide Ukraine with bilateral security assurances. The Prime Minister's Office noted in a press release that the UK is the first country to deliver a final agreement.

The UK-Ukraine Agreement on Security Co-operation formalises a range of support the UK has been and will continue to provide for Ukrainian security, including intelligence sharing, cyber security, medical and military

Credit: VZ X account

training, and defence- industrial co-operation. It also commits the UK to consulting with Ukraine in the event it is ever attacked by Russia again and to provide "swift and sustained" assistance for Ukraine's defence.

The GBP 2.5 Bn in military funding "will help to leverage the best of UK military expertise and defence production to ensure Ukraine's victory on the battlefield, including in critical areas like long-range missiles, air defence, artillery ammunition and maritime security", the Prime Minister's Office noted.

At least GBP 200 M of the funding will be spent on a major push to rapidly procure and produce thousands of unmanned vehicles for Ukraine, including surveillance and long-range strike unmanned aerial vehicles as well as unmanned surface vessels.

"The UK is already one of Ukraine's closest partners, because we recognise their security is our security," Sunak stated. "Today we are going further - increasing our military aid, delivering thousands of cutting-edge drones, and signing a historic new Security Agreement to provide Ukraine with the assurances it needs for the long term."

The closer UK security ties and increase in military funding will be welcome news for Kyiv, which has seen military aid from the United States blocked by Republican lawmakers opposed to it or holding it hostage over US border security concerns.

DARPA gives Aurora Flight Sciences green light to develop active flow control X-plane

(pf) The US Defense Advanced Research Projects Agency (DARPA) has selected Aurora Flight Sciences to build a full-scale X-plane to demonstrate the viability of using active flow control (AFC) actuators for primary flight control. The award represents Phase 3 of the Control of Revolutionary Aircraft with Novel Effectors (CRANE) programme.

While conventional aircraft of all types use a system of movable, external control surfaces for flight control, the CRANE programme's X-65 technology demonstrator breaks this century-old design paradigm for flight control by using jets of air from a pressurised source to shape the flow of air over the aircraft surface, with AFC effectors on several

surfaces to control the aircraft's roll, pitch, and yaw. Eliminating external moving parts is expected to reduce weight and complexity and to improve performance.

"The X-65 is a technology demonstrator, and it's distinctive, diamond-like wing shape is designed to help us maximise what we can learn about AFC in full-scale, real-world tests," Dr Richard Wlezien, DARPA's program manager for CRANE, was quoted as saying in a 3 January 2204 DARPA press release.

The X-65 will be built with two sets of control actuators – traditional flaps and rudders as well as AFC effectors embedded across all the lifting surfaces. This is designed to both minimise risk and maximise the programme's insight into control effectiveness. The X-65's performance with traditional control surfaces will serve as a baseline, while successive tests will selectively lock down moving surfaces, using AFC effectors instead.

Credit: Aurora Flight Sciences

"The X-65 conventional surfaces are like training wheels to help us understand how AFC can be used in place of traditional flaps and rudders," said Wlezien. "We'll have sensors in place to monitor how the AFC effectors' performance compares with traditional control mechanisms, and these data will help us better understand how AFC could revolutionise both military and commercial craft in the future."

The 7,000 lb (3,175 kg), unmanned X-65 will have a 30 ft (9.144 m) wingspan and be capable of speeds up to Mach 0.7 (864.36 km/h). Its weight, size, and speed – similar to a military trainer aircraft – make the flight-test results immediately relevant to real-world aircraft design.

"We're building the X-65 as a modular platform – wing sections and the AFC effectors can easily be swapped out – to allow it to live on as a test asset for DARPA and other agencies long after CRANE concludes," said Wlezien.

Aurora Flight Sciences, a Boeing company, has already started fabricating the X-plane at Aurora facilities in West Virginia and Mississippi; plans include building the airframe at Aurora West Virginia, followed by system integration and ground testing at Aurora's headquarters in Manassas, Virginia.

The X-65 is scheduled to be rolled out in early 2025, with the first flight planned for summer of the same year.

Spanish MoD orders 16 C295s configured for maritime patrol and surveillance

(pf) The Spanish Ministry of Defence (MoD) has ordered 16 Airbus C295 aircraft in maritime patrol aircraft (MPA) and maritime surveillance aircraft (MSA) configurations, Airbus announced on 20 December 2023.

The contract for the C295s, according to Airbus, is worth EUR 1.695 Bn.

The new aircraft will be used to strengthen the anti-submarine warfare capabilities of the Spanish Air and Space Force and the Spanish Navy as well as increasing and enhancing their surveillance, reconnaissance and search-and-rescue (SAR) capabilities.

An Airbus spokesperson responding to ESD on 3 January 2023 declined to specify the split between the MPA and MSA configurations between the 16 C295s being procured.

"The aircraft will be fully designed and manufactured in Spain, fostering the national industrial defence footprint and sovereignty," Mike Schoellhorn, CEO of Airbus Defence and Space, was quoted as saying in a company press release. "In particular, the Maritime Patrol version is the most complex C295 mission configuration to date: a major development project that will bring together the latest technologies to provide an operational advantage to our customer."

The contract also covers training systems, including a full flight simulator and mission system simulator, as well as an initial logistics support package.

Credit: Airbus

The C295 MPA will conduct the missions previously performed by the Spanish Air and Space Force's three P-3M Orion MPAs, which were retired at the end of 2022. Armed with torpedoes and other weapons, the type will be equipped to carry out anti-submarine warfare and anti-surface warfare as well as intelligence, surveillance and reconnaissance missions.

The C295 MPA will be highly connected and will be able to operate in a collaborative mode with other platforms in different domains. The aircraft can become a flying command-and-control centre, providing the Spanish armed forces with the versatility to carry out a wide range of missions, according to Airbus.

The C295 MSA is the natural replacement for the Spanish Air and Space Force's fleet of eight CN-235 VIGMA aircraft, which have been in service since 2008. It will be primarily equipped for maritime and overland operations such as anti-smuggling, anti-illegal immigration and anti-drug trafficking operations, as well as national and international SAR missions.

Berlin has lifted veto on Eurofighter sales to Saudi Arabia, German foreign minister indicates

(pf) Germany is now willing to end its veto on more Eurofighter Typhoons being sold to Saudi Arabia, according to comments made by German Foreign Minister Annalena Baerbock during a visit to Israel on 7 January 2024.

Credit: Crown Copyright

As one of the four Eurofighter nations Germany imposed the veto on further Typhoon sales to Saudi Arabia following the murder of Saudi journalist Jamal Khashoggi at the Saudi consulate in Istanbul in 2018 and due to human rights concerns as well as Riyadh's role in the Yemeni civil war.

However, as reported by Reuters and other media outlets, Baerbock stated to journalists in Israel, "We do not see the German government opposing British considerations for more Eurofighters for Saudi Arabia.

"The world, especially here in the Middle East, has become a completely different place since October 7," she added, referring to the date Palestinian militant group Hamas mounted a large-scale terrorist attack on Israel that prompted the current conflict in Gaza.

The Royal Saudi Air Force received 72 Typhoons between 2009 and 2017, all but one of which remain in service, but in March 2018 Riyadh signed a memorandum of intent to purchase an additional 48. Khashoggi was killed on 2 October 2018.

Among the Eurofighter nations (Germany, Italy, Spain and the United Kingdom), it was

Berlin – and especially the Green Party to which Baerbock belongs – that had opposed the Saudi Typhoon purchase.
Riyadh in the meanwhile has considered purchasing Dassault Rafale fighters instead.
Despite the lifting of the German veto, however, no firm contract with Saudi Arabia for more Typhoons is currently in place.

Slovakia receives its first two F-16 Block 70 fighters from Lockheed Martin

(pf) The first two F-16 Block 70 fighters for the Slovakian Air Force have been successfully delivered, the aircraft's manufacturer, Lockheed Martin, announced on 10 January 2024.

Credit: Lockheed Martin

Slovakia signed a letter of offer and acceptance (LOA) for 14 F-16s in December 2018 in a deal worth EUR 1.589 Bn and will be the first European country to receive the F-16 Block 70.
The purchase of new fighters as a replacement for its obsolete MiG-29 fighters has been one of Slovakia's acquisition priorities, as listed in the White Paper on Defense of the Slovak Republic in 2016.
O J Sanchez, vice president and general manager of the Integrated Fighter Group at Lockheed Martin, was quoted in a company press release as saying, "The delivery of the first two F-16 Block 70 jets to Slovakia signifies a crucial starting point in bolstering the country's defence capabilities. We are proud to be part of this endeavour and are committed to delivering a total of 14 jets to Slovakia.
F-16 Block 70 deliveries to Slovakia will continue through to 2025, with the first group of jets, known as a ferry cell, expected to arrive in Slovakia mid-2024. The aircraft are built at Lockheed Martin's facilities in Greenville, South Carolina.

Russian MoD cites major AFV deliveries following significant ramp-up in defence spending

(pf) The Russian armed forces received more than 3,700 AFVs throughout 2023, according to a Russian Ministry of Defence (MoD) end-of-year paper obtained by and reported on by TASS on 29 December 2023.

Credit: Kremlin

"Sufficiency level: over 84%. Shipped: over 1,500 tanks, over 2,200 armoured combat vehicles, over 1,400 rocket and artillery vehicles, over 22,000 unmanned aerial vehicles," TASS reported the document as saying.
The document added that the Russian armed forces had received more than 12,000 other vehicles, of which more than 10% – 1,400 vehicles – were armoured.
Meeting with Russian President Vladimir Putin at the Kremlin in Moscow on 28 December 2023, the CEO of Russian state corporation Rostec, Sergei Chemezov, claimed the enterprise had "been able to increase production several-fold" in both 2022 and 2023.
In particular, Chemezov told Putin that Rostec had been able to boost the production of munitions for firearms and artillery systems by 50 times and had "increased the output of light armoured vehicles and equipment by 5.5 times and tanks by 7 times".
In October 2023 the Uralvagonzavod factory, a Rostec subsidiary, announced that the Russian armed forces have taken delivery of a new batch of newly built T-90M and upgraded T-72B3M main battle tanks.
On 27 November 2023 Putin approved a major increase in military spending that will see around 30% of all fiscal expenditure – amounting to around RUB 36.6 Tn (EUR 370 Bn) directed towards the Russian armed forces in 2024. Russian spending on defence and security combined is set to reach around 40% of all budget expenditure in 2024.
This surge in Russian military spending amounts to an almost 70% increase compared to 2023, reflecting the fact that Putin is doubling down on his commitment to the war in Ukraine, no doubt hoping that discord among Ukraine's Western allies will see military funding for Kyiv start to dry up.

Boeing-built X-37B begins its seventh mission in space

(pf) The experimental Boeing-built X-37B autonomous spacecraft, also known as the Orbital Test Vehicle (OTV), began its seventh mission on 28 December 2023 when it was launched from Kennedy Space Center in Florida aboard a SpaceX Falcon Heavy rocket.
Operated by the Department of the Air Force Rapid Capabilities Office (DAF RCO) in collaboration with the US Space Force, the X-37B is designed to validate new technologies, foster innovation and push the boundaries of space exploration and utility. On its seventh flight the craft will test future space domain awareness technology experiments that are integral in ensuring safe, stable and secure operations in space.
The X-37B operates like a mini-version of its much larger Space Shuttle predecessor. It is propelled into space by a launch vehicle, performs its mission, and then descends back to Earth as a spaceplane.
"The X-37B government and Boeing teams have worked together to produce a more responsive, flexible, and adaptive experimentation platform," William D Bailey, the DAF RCO director, was quoted as saying in a Boeing press release. "The work they've done to streamline processes and adapt evolving technologies will help our nation learn a tremendous amount about operating in and returning from a space environment."

Credit: Boeing

Michelle Parker, Space Mission Systems vice president at Boeing Defense, Space & Security, added, "The technological advancements we're driving on X-37B will benefit the broader space community, especially as we see increased interest in space sustainability. We are pushing innovation and capability that will influence the next generation of spacecraft."
Since its inaugural launch in April 2010, the X-37B has consistently set new endurance records, surpassing the initial design mission duration of 270 days. Its sixth mission set a new record with a 908-day mission before returning to Earth in November 2022.
The X-37B had travelled more than 1.3 billion miles and spent 3,774 days in space at the time it was launched for its seventh mission.

Canada orders fleet of GA-ASI MQ-9B SkyGuardians

(pf) The government of Canada has signed a contract to purchase a fleet of MQ-9B SkyGuardian remotely piloted aircraft systems (RPAS), the system's manufacturer, General Atomics Aeronautical Systems Inc (GA-ASI), reported on 19 December 2023.
Although GA-ASI did not specify the contract value or the number of RPAS and ground control stations (GCSs) ordered, the Canadian Department of National Defence (DND) website states, "This project will acquire 11 long-range, long-endurance armed remotely piloted aircraft and six ground control stations along with associated equipment, weapons, infrastructure and in-service sustainment capability that will support up to three concurrent lines of tasking, domestic or international."
The DND has estimated the project cost at CAN 2.49 Bn (EUR 2.88 Bn).

Credit: GA-ASI

First deliveries are expected in 2028, with an initial operational capability set for 2027-2030 and a full operational capability due to be delivered between 2030 and 2033.
The SkyGuardian RPAS is interoperable with Canada's domestic missions and its continental defence missions through the North American Aerospace Defense Command (NORAD), as well as with Canada's closest allies – including the Five Eyes Alliance (FVEY) and NATO – for seamless integration with current and future Canadian defence, civil air, and ground assets, GA-ASI noted in a press release.
"Canada's vast territory and complex terrains, including in the Arctic, require a cost-effective multi-mission RPAS solution that can endure long periods on station, fly in harsh weather environments, and safely operate in all airspaces," Linden Blue, CEO of GA-ASI, was quoted as saying. "MQ-9B SkyGuardian delivers those critical capabilities. GA-ASI and Team SkyGuardian Canada are honored by this opportunity to become a key partner to Canada for the very long term in delivering these no-fail defence and security outcomes."
Team SkyGuardian Canada is a coalition of leading Canadian businesses – including CAE, MDA Ltd and L3Harris Technologies – that are working with GA-ASI on MQ-9B development, delivery and sustainment.
"Canada's investments in the RPAS Project and Team SkyGuardian Canada are a direct reflection of Canada's vested domestic interest in pursuing leading-edge RPAS technologies," GA-ASI stated.
The Canadian SkyGuardians will be stationed with the Royal Canadian Air Force's 14 Wing at Greenwood, Nova Scotia, and 19 Wing at Comox, British Columbia. They will also be operated from a forward operating location when supporting missions in northern Canada, while the ground control centre hosting the aircraft's flight controls will be located in Ottawa, according to the DND.
GA-ASI bills the MQ-9B SkyGuardian as "the next generation of RPAS, delivering exceptionally long endurance and range, with auto take-off and landing under SATCOM-only control", noting that the system will be able to operate in unsegregated airspace using a GA-ASI-developed detect-and-avoid system.
The first customer deliveries of the MQ-9B began in 2022 to the UK Royal Air Force, where the system is known as the Protector RG Mk 1, while contracts have also been signed with Belgium and the US Air Force (in support of Special Operations Command).
Meanwhile, the Japan Coast Guard began operating the MQ-9B for maritime operations from October 2022 and the Japan Maritime Defense Force has also selected the system for its medium-altitude, long-endurance (MALE) RPAS Trial Operation Project.
The MQ-9B also supported various US Navy exercises throughout 2023.

Finland takes up option to acquire more Patria 6×6 armoured vehicles

(pf) The Finnish Defence Forces (FDF) have purchased more Patria 6×6 armoured vehicles by redeeming the additional purchase option related to the agreement signed in June 2023, when Patria received a contract for 91 vehicles from the Finnish Defence Forces Logistic Command.
The agreement included a purchase option for up to 70 additional vehicles, of which the FDF have now redeemed 40. Vehicle deliveries are currently underway.

Credit: Patria

"The purchase is part of the multinational CAVS (Common Armoured Vehicle System) programme, which in addition to Finland includes Latvia, Sweden and Germany," noted Jussi Järvinen, executive vice president of Patria's Finland Division, in a company press release published on 4 January 2024. "During 2023 deliveries commenced also to Sweden and deliveries to Latvia have been underway since 2021. With close and excellent co-operation between the countries and Patria, the programme has proceeded quickly. The joint programme's research and development agreement was signed at the end of 2020 and since then the deliveries have already taken place in three countries in three years," Järvinen added.
The first tens of vehicles have already been handed over to the FDF's Pori Brigade, where operational training for conscripts will soon start.

Turkish Aerospace's Anka-3 UCAV makes maiden flight

(pf) The Turkish Aerospace Anka-3 unmanned combat air vehicle (UCAV) made its first flight on 28 December 2023.

Credit: SSB

A video of the UCAV's maiden voyage was published on the website of the Turkish Defence Industry Agency (SSB) the same day. Posting in X/Twitter, the president of the SSB, Professor Dr Haluk Görgün, stated, "We have introduced another national system with very high technologies to the sky. Our Anka-3 UAV will perform reconnaissance, surveillance, air-air and air-ground attack missions with its high payload-carrying capacity, tailless structure and low radar cross-section.
"As we enter a new year, we wholeheartedly congratulate all our engineers and technical staff who make us feel proud. We will continue to work towards full independence in our defence industry under the leadership of our President, Mr Recep Tayyip Erdoğan," he added.
According to a report by the Turkish news channel TRT Haber, the Anka-3 was airborne for 70 minutes, during which it reached an altitude of 8,000 ft (2,438 m) and a speed of 150 kts (278 km/h).

A tailless, jet-powered flying-wing design, the Anka-3 is intended to carry a 2,800 kg payload and have a maximum cruise speed of Mach 0.7 (864.4 km/h), an endurance of 10 hours and a ceiling of 40,000 ft (12,192 m).

The first Skynex air defence system has reached Ukraine

(gh) Posting his thanks on X (formerly Twitter) on 4 January 2024, Ukrainian President Volodymyr Zelensky made public the delivery of the first of two Skynex air defence systems to the Ukrainian armed forces.

The delivery – a timely one in that it focuses on air defence as a key Ukrainian priority – was supplemented by an undisclosed number of IRIS-T SLM missiles, two more TRML-4D air surveillance radars and other defence equipment.

"The German aid is helping to save lives and restore normal and just peace in Ukraine and throughout Europe more quickly," Zelensky said.

In its current 'List of military support services' Germany's Federal Ministry of Defence (BMVg) has confirmed the delivery and announced the supply of another Skynex system, based on a contract from December 2022. At the time the manufacturer, Rheinmetall, announced that two Skynex air defence systems with an order value of EUR 182 million would be delivered at the beginning of 2024, possibly with additional HX series logistics trucks for a further EUR 12 million.

Credit: Rheinmetall

According to Rheinmetall's description, Skynex is an open-architecture system that relies on cannon-based air defence and is therefore particularly suitable for close-range protection where guided weapons cannot be effective. The programmable 35 mm Advanced Hit Efficiency And Destruction (AHEAD) ammunition developed by the company for this purpose is significantly cheaper than comparable missile-based systems. Furthermore, it is not possible to influence or even deflect the 35 mm ammunition through electronic countermeasures. The successes of the Gepard 35 mm self-propelled anti-aircraft gun system in Ukraine underline the efficiency with which cannon-based air defences can protect against air attack, especially in relation to cruise missiles and unmanned aerial vehicles (UAVs).

The Skynex system essentially consists of the powerful Oerlikon Revolver Gun Mk3 with tracking radar and the Oerlikon X-TAR3D tactical acquisition radar, which are controlled via the Oerlikon Skymaster battle management system. The subsystems are integrated on all-terrain HX trucks with swap-body systems for Ukraine.

The second Skynex system is nearing completion at manufacturer Rheinmetall Italia, with its delivery scheduled for the near future.

First ECRS Mk2 radar installed onto a Eurofighter Typhoon

(pf) Engineers from BAE Systems and Leonardo UK have installed the first European Common Radar System Mark 2 (ECRS Mk2) radar, billed as the world's most capable combat air radar, onto a Eurofighter Typhoon test and evaluation aircraft ahead of flight trials, the two companies announced on 17 January 2024.

Credit: BAE Systems_Leonardo

The ECRS Mk2 radar, developed by Leonardo UK and integrated onto the Typhoon by BAE Systems, will fly from BAE's flight testing facility in Warton, Lancashire, this year.

The system, which is also colloquially known as 'Radar 2', features an innovative multi-functional array (MFA) that can perform both traditional radar functions, such as search and targeting, as well as electronic warfare tasks. "This means that the Typhoon will be able to locate and deny use of an adversary's radar with a powerful electronic jamming attack, while staying beyond the reach of threats," the companies stated in a press release.

A prototype of the radar has been undergoing ground-based testing in a unique test facility at Warton in recent months before being fitted onto test and evaluation aircraft BS116.

Andy Holden, Radar Delivery Director for BAE Systems' Air sector, was quoted as saying, "Equipping the aircraft with this prototype radar moves us a step closer to delivering new capability, which ensures Typhoon's role as the backbone of combat air defence for decades to come.

"We expect that this year we will be flight testing the radar, which will allow us to validate the results of ground-based testing we have undertaken at our Integrated Test Facility (ITF): the only facility of its kind on the UK," Holden added. "The ITF testing allowed us to 'fly' the radar for hundreds of hours without the need to put a jet in the air, ensuring our flight test programme is as efficient as possible and delivers what our customer needs."

The radar will now undergo further integration work inside the Typhoon final assembly hangar at Warton in advance of flight testing.

Ross Wilson, Vice President of Engineering for Leonardo UK's Radar and Advanced Targeting sector, was quoted as saying, "In parallel with the integration work on the prototype system as it approaches flight testing, the ECRS Mk2 production design has also been progressing apace.

"The radar's processor, receiver, and antenna power supply and control units have all been re-engineered to further enhance the capacity, capability, and performance of the Mk2 system in alignment with the new antenna and electronic warfare capability," said Wilson. "These production designs have all passed their critical design review phases, keeping the production programme on schedule."

Slovenia receives first of two C-27J Next Generation transport aircraft

(pf) Leonardo has delivered to the Slovenian Ministry of Defence (MoD) its first C-27J Spartan tactical transport aircraft, the company announced on 20 December 2023.

The delivered Spartan is the first of two C-27J Next Generation aircraft contracted following the Italy-Slovenia government-to-government (G2G) agreement signed on 17 November 2021.

Credit: Leonardo

Within the framework of the G2G agreement between the two countries, Leonardo and the Italian Ministry of Defence's Directorate of Aeronautical Armaments and Airworthiness (Armaereo) have signed two contracts over the last two years, each of which includes one aircraft plus logistics and training services. The selection of the C-27J by the Slovenian MoD meets a variety of operational needs in terms of transport and force projection capabilities for international operations. This is in addition to national missions such as rescue, disaster relief and firefighting duties.

General Jim Slife becomes US Air Force Vice Chief of Staff

(pf) US Air Force (USAF) General Jim Slife formally received his fourth star and was promoted to be the Air Force Vice Chief of Staff during a ceremony at Joint Base Anacostia-Bolling, DC, on 29 December 2023.
Commissioned through the Reserve Officers' Training Corps (ROTC) programme at Auburn University, Gen Slife has spent most of his air force career in special operations aviation assignments, including at Hurlburt Field in Florida, RAF Mildenhall in the United Kingdom and Cannon Air Force Base in New Mexico.
Gen Slife is a command pilot with more than 3,100 flight hours on the MH-53 helicopter and MQ-1 Predator armed unmanned aerial vehicle, among others. He most recently served as the air force's deputy chief of staff for operations, leading the development and implementation of policy directly supporting global operations, force management, training and readiness.


Credit: USAF

He has commanded Air Force Special Operations Command and held numerous joint leadership positions, including vice commander of US Southern Command, chief of staff for U. Special Operations Command, and chief of staff for United Nations Command and US Forces Korea.
As the USAF vice chief, Gen Slife will guide the Air Staff and assist Chief of Staff of the Air Force General David Allvin with organising, training and equipping 689,000 active-duty, Guard, Reserve, and civilian forces serving in the United States and overseas.
"Like Gen Allvin, he steps into his new role with an understanding of the challenges facing the force and a sense of urgency to address them," the USAF said in a press statement.
"We stand at the precipice of a different strategic environment," Gen Slife was quoted as saying. "[Chairman of the Joint Chiefs of Staff] General Brown called on us to accelerate change. Secretary [of the Air Force Frank] Kendall has empowered us to actually think about … what we need to have to be competitive for the next several decades."
Gen Allvin emphasised the value Gen Slife will bring to that problem set.
"[It's] the hardest thing we've done in a long time and maybe the hardest thing we do together," he said. "So having someone on the team who knows that and has done that … couldn't be better now for our force."

Phil Jasper appointed as president of Raytheon


Credit: RTX

(pf) Phil Jasper has been appointed as the president of Raytheon and will report to RTX President and Chief Operating Officer Christopher T Calio, parent company RTX announced on 4 January 2024.
Jasper, a 31-year aerospace and defence veteran, succeeds Wesley D Kremer, who will retire from the company at the end of the first quarter of 2024.
"Phil is a proven leader with significant depth of experience delivering defense solutions to the military customer," Calio was quoted as saying in an RTX press release. "His recent integration of RTX's connected battlespace solutions, a critical customer priority and growth driver for the company, is one of many business transformations he has led over his career. I am confident he will drive the newly restructured Raytheon business to accelerate performance to effectively meet customer commitments."
As president of Raytheon, Jasper, 55, will serve as a member of the RTX senior leadership team and will be responsible for leading the business and its product lines in missile defence, air-to-air missiles, fire control radars, and electro-optical/infrared systems.
In 2018 Jasper was named president of Collins Aerospace's Mission Systems strategic business unit, responsible for delivering military, government and civil solutions to help customers worldwide safely and successfully complete their most complex missions. He transitioned commercial aerospace technologies to the defence sector, delivering innovation in battlefield communications and networking solutions. In addition, Jasper designed, developed and integrated multiple mission-specific capabilities for military aircraft, including airdrop; refuelling; intercept; and guidance and control products and functions.
Kremer, meanwhile, has served in executive leadership positions since 2003 and was named a business president in 2015.
"Wes has contributed significantly to the advancement of missile defence systems for the US and its allies and played a critical role in structuring the Raytheon business in 2023," said Calio. "We thank him for his many contributions to RTX and wish him well as he retires from the company."

Colt CZ Group to purchase a 100% interest in Sellier & Bellot

(pf) The Czech Republic's Colt CZ Group has announced that on 18 December 2023 it executed an agreement with CBC Europe to purchase a 100% interest in Czech small-calibre ammunition producer Sellier & Bellot.
"Colt CZ shall acquire 100% of shares of Sellier & Bellot for the combination of the cash consideration in the amount of USD 350 M (EUR 319.6 M) and a new issue of Colt CZ common stock leading to a 27–28% CBC stake in the share capital of Colt CZ Group post transaction," the company announced in a press release.

Credit: Sellier & Bellot

The final size of CBC's shareholding in Colt CZ Group will be determined depending on the audited financial results of both companies for the year 2023. The acquisition, which will be financed through a combination of the company's existing cash resources and debt financing, is subject to regulatory approval in various countries and is expected to close in the first half of 2024.
A traditional Czech ammunition manufacturer, Sellier & Bellot ranks among the oldest engineering companies in the Czech Republic, its products having been manufactured under its trademark since 1825. The company has around 1,600 employees and its main production facility is located in Vlašim in the Czech Republic.
Colt CZ Group, meanwhile, is one of the leading Czech producers of firearms and ammunition for military and law enforcement agencies, as well as for personal defence, hunting, sports shooting and other commercial uses. The company employs more than 2,000 people worldwide.

NATO as a customer: an overview of the NSPA

Stacy Cummings

The NATO Support and Procurement Agency (NSPA) is NATO's lead organisation for multinational acquisition, support, and sustainment. We strive to obtain the best capabilities across all military domains at the best value – for NATO and Allied Nations – generating economies of scale while leveraging emerging and advanced technology.

The Agency also provides equipment and services to NATO member countries and its partners in all domains – air, ground, maritime, cyber and space. This support ranges from the multinational acquisition of complex platforms, such as aircraft, helicopters and uncrewed systems, to the provision of supplies such as fuel, spare parts and ammunition, or services including the maintenance of radars for air defence, or deployable infrastructure, transportation, medical and catering services.

Credit: NSPA

Stacy Cummings, NSPA General Manager.

Author

The NATO Support and Procurement Agency (NSPA) is NATO's lead organisation for multinational acquisition, support and sustainment in all domains. Based in the Grand Duchy of Luxembourg, with its main operational centres in France, Hungary and Italy, the Agency employs over 1,400 staff and oversees more than 500 contractors in support of NATO's missions and exercises.

To fulfil our mission, we work as a link between NATO members and industry to find the best capabilities, primarily through international competitive bidding. Our objective is to obtain the best service or equipment at the best price for the customer by consolidating requirements from multiple nations in a cost-efficient way through our proven multinational acquisition framework.

Our Agency has been operating since 1958, when the North Atlantic Council (NAC) formally approved the establishment of the NATO Maintenance Supply Services System, and its executive element, the NATO Maintenance Supply Services Agency (NMSSA). During the last six decades, we have successfully evolved from the support of only three main weapon systems and the supply of spare parts, to our current portfolio. Today we support more than 100 weapon systems across many different programmes, and we provide full multinational acquisition and logistical support.

NSPA currently manages a large number of key NATO and multinational projects throughout their lifecycle. One example is the Multinational Multi Role Tanker Transport Fleet (MMF), based on the Airbus 330 aircraft, which provides strategic transport, air-to-air refuelling and MEDEVAC capabilities to six Allies. The MMF is not only a prime example of co-operation between the EU and NATO and their respective agencies, but also illustrates how nations can cooperate by pooling and sharing resources to obtain access to state-of-the-art capabilities that would be difficult, or impossible to access individually. All the nations involved, regardless of size and the required number of flying hours, have access to these capabilities. The programme has developed a transparent and fair cost share mechanism based on flying hour costs, enabling smaller nations to join with assured access to an entire fleet of aircraft. The approach recognises the benefits of economies of scale, commonality and interoperability deriving from multinational acquisition of military off-the-shelf platforms.

NSPA also manages the acquisition of other complex multinational systems, from initial concept to capability delivery, product support and lifecycle logistics, and disposal. Another good example is the Alliance Future Surveillance and Control (AFSC), a multi-generational digital transformation programme designed to support multi-domain operations for decades to come. This programme represents NATO's largest and most complex capability development initiative to date, with NSPA managing the concept stage.

Another NSPA-led multinational programme involving European companies is the Next Generation Rotorcraft Capability (NGRC). Many of the medium-lift/multi-role assets currently in service across NATO Allies will reach their end of life cycle in the 2035–40 period. These existing inventories are based on designs dating back to the previous century. The NGRC programme will provide participating nations with options to replace their aged medium-lift assets, in a timely and cost-effective manner, while concurrently leveraging a broad range of recent advances in technology, production methods, and operational concepts.

In December 2023, we awarded a pioneering contract for the first Novel Powerplant Study to fulfil NGRC's requirements. The contract study was awarded to GE Aerospace, with work


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Credit: NSPA

An Airbus A330 MRTT of the MMR refuels two Eurofighter Typhoon aircraft of the Luftwaffe.

performed by its Defense & Systems organisation in the United States and Avio Aero in Italy. This achievement embodies NSPA's unwavering commitment to be the premier choice for NATO's multinational defence acquisition programmes, signifying a substantial leap forward in technology while enhancing the transatlantic defence industrial base.

Credit: NSPA

This diagram illustrates the key components of the Alliance Future Surveillance and Control (AFSC) programme.

The Agency also provides full life-cycle management support to the other key NATO capabilities, such as the Alliance Ground Surveillance (AGS), the Strategic Airlift Capability (SAC), the PATRIOT missile system and Boxer armoured vehicles, to name a few.

NSPA and the European defence industry

The level of demand that industry faces today is something we have not seen since the Cold War. This is paired with global supply chain challenges and the consensus formed around the notion that Allies and partners benefit from working together, opting for interchangeable and common defence systems, which help facilitate the effort to enhance industrial capacity, generating stable requirements with a common configuration.

Earlier in January 2024, the Agency signed one its most significant contracts for up to 1,000 PATRIOT Guidance Enhanced Missiles – TBM (GEM-T) supporting a coalition of nations including Germany, The Netherlands, Romania and Spain. The Agency awarded the production and delivery contract to COMLOG, a joint venture between Raytheon and MBDA. To support production and delivery, COMLOG will expand the production capacity of GEM-T missiles in Europe. This contract demonstrates that NSPA, as a primary enabler of the Alliance, can successfully deliver effective and cost-efficient multinational solutions to nations,

while reinforcing European industrial capacities. It also demonstrates the value of the transatlantic partnership and the benefits of consolidation of national requirements to the Alliance and industry.
Our Support Partnerships bring together member countries to aggregate their demand and allocate production capacity according to their priorities. Established upon the initiative of two or more NATO members wishing to organise common support and services activities, this unique mechanism enables the consolidation and centralisation of requirements reducing costs and logistics footprint and provides a common and efficient support base under a ready-to-go legal framework.
NSPA and the new security environment
In response to Russia's ongoing war of aggression against Ukraine, NATO has implemented a fundamental shift in its deterrence and defence posture, strengthening forward defence, enhancing battlegroups on the eastern flank and increasing the number of high readiness forces.
NSPA has been supporting this global effort, providing logistical assistance to NATO forces located on the eastern flank, including fuel, accommodation and other services on demand. In addition, NSPA has been assisting individual Allies with the procurement of materiel, such as winter clothing, rifle scopes, helmets, ammunition, medical equipment and logistics services including the provision of fuel.
Member countries engaged in collaborative efforts in defence before the current conflict, but the war has accelerated this trend. The Agency has identified the need to continuously adapt in response to increased and increasingly urgent demands. To assure the best possible support to NATO Allies and partners, the Agency has developed a strategy that balances efficiency, effectiveness and responsiveness.
Beyond interoperability, interchangeable and common systems among Allies represent a key NATO strength. Therefore, when nations pool and share resources and act together they achieve tactical, operational and strategic objectives in a more efficient and coherent way.
Cooperation with industry is one of NSPA's major strengths and enables us to develop state-of-the-art solutions and source the latest technologies for the Alliance. To successfully deliver these current and future capabilities for NATO and Allies, and gain access to the latest developments, NSPA engages and works closely with industry at different stages of the acquisition and sustainment cycles. We also organise 'industry days' by nation or by specific capability or domain to foster engagement with the private sector and brief companies on our procurement processes, opportunities and regulations.
Cooperation among European organisations and institutions is also equally important. The current security environment challenges us to be more efficient, effective and responsive. We are stronger together, as partners.

"It is by leveraging our synergies that we will be able to build collective strength."

In December 2023, I hosted an unprecedented trilateral meeting between NSPA, the European Defence Agency (EDA), and the Organisation for Joint Armament Cooperation (OCCAR). Our meeting focused on navigating the evolving security landscape and fortifying joint initiatives to optimise use of resources and enhance complementarity.
Our candid exchange focused on the impact of the current security environment on our respective roles and missions. We delved into strategic discussions aimed at identifying synergies and areas of collaboration. The emphasis lay on identifying common challenges and unlocking opportunities for strengthened cooperation. We also discussed pathways to bolster collaboration and coordination, addressing concerns regarding potential competition and overlapping capabilities, and identifying objectives for unified messaging when engaging with common stakeholders.
This meeting represented a step forward as we leverage past successes and continue to join forces towards enhanced cooperation, reinforcing our commitment to enabling and supporting nations across Europe and within the Alliance.
As NSPA embarks on a new year marked by increasingly urgent requirements, nations will continue to benefit from working together to jointly design and invest in common capabilities. Together, we will reinforce the Alliance's industrial capacities, particularly in Europe, to tackle current challenges and support NATO's deterrence, as we look forward to the end of global conflicts. This is where NSPA relevance to the Alliance is strongest. ■

Credit: NSPA

An in-flight USAF Boeing C-17 Globemaster III aircraft of the Strategic Airlift Capability (SAC) initiative fleet.

Saudi defence industry: capabilities and partnerships

Robert Czulda

Saudi Arabia is systematically investing in the development of its own defence industry and R&D capabilities. A remarkable 50% of defence spending is expected to be allocated domestically by 2030. This is an ambitious plan, and it remains to be seen whether the authorities in Riyadh will achieve their goal.

For decades, Saudi Arabia lacked any incentive to create a robust defence industry of its own. While some companies were established in the 1970s, its capabilities were primarily focused on assembly and maintenance rather than production, not to mention design. A key reason for this is that the government always had sufficient funds to acquire the latest solutions on the global market. At the same time, Saudi Arabia maintained a significant partnership with the West, which had no qualms with supplying Riyadh with substantial quantities of arms and equipment. According to PwC, between 2015 and 2019, Saudi Arabia predominantly imported from the United States (73%) and the United Kingdom (13%).

Saudi Arabia was the fifth-largest military spender in 2022 according to SIPRI (EUR 68 billion, a 16% growth compared to 2021), and is undergoing reshaping of its priorities. A decision to establish its own indigenous defence industry with a strong emphasis on R&D is due to a number of significant factors.

Firstly, Saudi Arabia's freedom to purchase weaponry has notably diminished. The United States is no longer eager to supply Riyadh with all types of equipment, with President Biden pledging to halt arms sales due to the controversial war in Yemen. Similar doubts over arms exports have also surfaced in Germany, where Riyadh faced challenges in procuring Leopard 2A7 tanks and additional Eurofighters (though in the latter case, the ban was lifted in early January 2024). Developing its own capabilities gives Saudi Arabia more flexibility in a volatile and unpredictable world, particularly as the country seeks to strengthen its political independence.

Credit: USAF/Tech Sgt Michelle Larche

Saudi defence industry is looking for air and missile defence technologies. Currently Riyadh is dependent on Western air and missile defence systems, such as the US PATRIOT pictured.

Second, Saudi Arabia, allocating approximately 7.4% of its GDP to defence, aims to emulate regional states such as Qatar and diminish its reliance on energy exports. At the same time, Riyadh is aware of unexpected fluctuations in the oil market. For instance, Saudi crude oil exports in August 2023 reached their lowest level in 28 months. The gradual departure from being a rentier state requires more careful budget management. Simply put, the era of indiscriminately spending billions of dollars has come to an end.

Third, Saudi Arabia is determined not to be left behind. Riyadh closely observes the successes of the United Arab Emirates (UAE), which has built its own defence industry from scratch in recent years and even developed an indigenous space programme, resulting in sending the first Emirati astronaut into space. EDGE represents the UAE's defence gem. For Saudi Arabia – perceiving itself a leader among Arab monarchies in the Persian Gulf – a domestic defence industry is also a matter of prestige.

Riyadh's vision

Saudi Arabia's ambitious concept has been presented in detail in a government strategy, "Vision 2030", which aims to foster a more diverse economy no longer reliant on revenues from the energy sec-

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Credit: SAMI

Pictured is the mobile radar for the Saudi Tracked Shahine air defence air defence system. The Shahine is a family variant of the French Crotale system, and will be due for replacement in the not-too-distant future.

tor. Released in 2016, this strategy announced the creation of thousands of highly-skilled jobs and an increase in Saudi Arabia's openness to foreign investments. As part of the strategy, there is an ongoing privatisation of state-owned assets, including leading companies, properties, and other assets. Consequently, Saudi Arabia aspires to improve its current position as the 19th largest economy in the world, to break into the top 15.

The defence industry is one of the pillars of this transition and in order to achieve its goals, Riyadh is insisting on a significant local workshare and investments from foreign partners. To this end, by January 2024, all foreign companies seeking business with the Saudi Government will be required to establish their regional headquarters in the country; this deadline is still in effect. Saudi Finance Minister Mohammad al-Jadaan was quoted by CNBC saying, "We definitely prioritise the companies that are bringing the value creation to where the value is consumed, that create high quality jobs for people in Saudi Arabia, Saudis and others, and that actually help us achieve our quality outcomes from our needs, whether it's services or goods at a better and more meaningful way."

Increasing the localisation rate — that is, the percentage of indigenous defence industries awarded contracts to supply the Saudi military and security forces — is one of the Government's main objectives. When "Vision 2030" was announced, Saudi Arabia had the third-largest defence budget globally. However, at the same time, only up to 3% of its procurements came from local companies, with the rest sourced from abroad. According to official data from the General Authority for Military Industries (GAMI), in 2020, the localisation rate was 8%, before growing to 13.7% in 2022, while by mid-2023, it was declared to be "close to 15%". The target is at least 50% by 2030. Moreover, Riyadh envisions a direct contribution from the defence industry of at least EUR 22.7 billion to the country's GDP by 2030. The total projected job creation by 2030 is 100,000 roles (both direct and indirect), and the total value of more than 70 investment opportunities arising from localisation and the supply chain is EUR 65 billion. Saudi ambitions to expand national industrial capabilities do not exist in a vacuum but are based on solid foundations. One such foundation is the economy. According to The World Bank figures, Saudi Arabia's GDP was approximately USD 874.16 billion in 2021, and grew to USD 1.11 trillion in 2022. It stands as the seventh-largest market globally in terms of foreign assets.

Saudi Arabian Military Industries (SAMI), a subsidiary of the Public Investment Fund (PIF), has been built up as a national champion. SAMI aims to be among the top 25 defence and security companies globally by 2030. The company has a comprehensive plan not only to be a major supplier of arms to the Saudi military and internal security forces, but also to be a regional hub providing various services, including repairs, overhauls, maintenance, production, design, and upgrades.

Capacity building

SAMI was established in May 2017 with the goal of reducing Saudi Arabia's dependence on foreign technologies and suppliers. SAMI has since evolved into a conglomerate of various companies, acquired through a process of domestic consolidation. For instance, in 2019, the Aircraft Accessories & Components Company, established in 1988, was acquired. The following year, SAMI acquired the Advanced Electronics Company (AEC) to establish SAMI Advanced Electronics and launched SAMI Composites. In 2023, SAMI acquired a 51% stake in the Saudi Rotorcraft Support Company (with Boeing retaining the rest). While the company does not rule out acquiring foreign companies, it is not a current priority.

With 341 employees in 2020, SAMI rapidly expanded to 2,500 just two years later and then to almost 3,600 workers. Further increasing employment, however, presents challenges as there is a shortage of Saudi engineers. To address this, in 2022, GAMI established the National Academy of Military Industries, capable of accommodating up to 2,000 students.

Between 2021 and 2022, SAMI's goal was to secure government contracts, while in 2023 and now in 2024, the company's priority is to develop indigenous capabilities. To achieve this, SAMI launched the Land Systems Industrial Park in Riyadh in February 2023, announcing on their website that they aimed to "localise defence industries and build local capabilities in the engineering and design of ground systems, testing, and further qualifying systems".

Credit: SAMI

The land division of SAMI is shrouded in mystery, with limited information available. The only known contract is a deal with EDGE. Saudi Arabia is expected to co-manufacture some vehicles in the future.

SAMI, which made its debut at the Dubai Air Show in 2019, has entered into at least 12 major joint ventures with foreign companies. These agreements grant Saudi Arabia access to valuable technological know-how. For instance, through a partnership with Safran, SAMI will expand its MRO (maintenance, repair, and overhaul) capabilities to include helicopter engine maintenance and repair skills, specifically for Makila 1 and 2 engines used in Saudi helicopters, including the Super Puma and Panther models.

In collaboration with Lockheed Martin, Saudi Arabia will have the capacity to manufacture THAAD launchers and canisters, as well as to establish a Sniper advanced targeting pod (ATP) repair centre. Riyadh will also host the country's Composites Manufacturing Center of Excellence following an agreement signed with Lockheed Martin in July 2022. ST Engineering's involvement will provide Saudi Arabia with autonomous solutions, while Turkey's Baykar will contribute to enhancing local expertise in electronic systems, mechanical parts, and aircraft structures. Additionally, Saudi Arabia will be able to locally produce Turkish Akinci UAVs.

Boeing is set to assist Saudi Arabia in establishing facilities and expertise for the maintenance, repair, and overhaul of helicopters. Simultaneously, a deal with Airbus Helicopters will provide Riyadh with essential helicopter airframe maintenance skills and bolster its repair capabilities for landing gears, engines, engine accessories, and rotor blades. To realise this objective, SAMI is currently constructing facilities at Malham, which will oversee activities related to helicopters, aircraft, and UAVs. These facilities are anticipated to become operational in 2024. Additionally, by 2026, facilities at Al Kharj are projected to become operational, focusing on production, assembly, and repair of light vehicles. Saudi Arabia has also forged industrial cooperation agreements with BAE Systems, Thales, L3Harris, Safran Helicopter Engines, John Cockerill, and Figeac Aero.

At the same time, the NCMS (National Company for Mechanical Systems), also headquartered in Riyadh, has finalised cooperation agreements with Turkish defence firms Roketsan and Aselsan. These agreements grant NCMS the rights to manufacture various types of munitions and sensors for UAVs. Both GAMI and SAMI are also making significant investments in cybersecurity. In October 2023, Riyadh launched a programme to develop indigenous communication systems, as well as autonomous systems for surveillance, reconnaissance, and combat. Technology transfer, including for armed UAVs, is also anticipated from China.

In October 2023, Seoul and Riyadh were reported to be in the "final stage of talks" regarding the procurement of air and missile defence systems. This is crucial for Saudi Arabia due to the ongoing missile threat from Yemen. It can be assumed that the agreement will also involve technology transfer, a priority for Saudi Arabia, as Riyadh is currently dependent on Western air and missile defence systems. At the same time, there are rumours that Saudi Arabia aims to collaborate with foreign partners in the field of directed-energy weapons.

Current strength

While the Saudi defence industry's portfolio is currently modest, SAMI's most significant project to date is the Al-Sarawat, a project related to the production of five new Avante 2200 class 104-metre corvettes in collaboration with Spain's Navantia (both companies established a joint venture named SAMINavantia). The deal was signed in 2018, with the final ship launched in Spain in December 2021. Specific details regarding SAMI's involvement are unclear, but it has been disclosed that the Saudi side provided the Hazem naval combat system, stated by Navantia to be "the first 100%

Credit: Navantia

Saudi corvette Al Jubail (828) is a leading ship of its class. The ship is based on Navantia's Avante 2200 design.

Saudi marine operations management system that was developed through the transfer of technology from Navantia."

Another product showcased by SAMI is the Roaya remotely-controlled weapon station for light vehicles designed to be equipped with either a 7.62 mm or 12.7 mm machine gun, or a 40 mm grenade launcher. The company also boasts the Mulhim battle management system designed for brigade-level units and below. It has been disclosed that SAMI is currently seeking a foreign partner to further develop this system. The land division of SAMI is shrouded in mystery, with limited information available, only mentioning that its offerings encompass wheeled and tracked combat systems, tactical logistics trucks, unmanned vehicles, as well as wheeled and tracked artillery systems.

The influx of technology may occur through collaboration with Hanwha, with a relevant memorandum of agreement signed in 2019, and EDGE. The deal foresees that Saudi Arabia will co-manufacture 149 NIMR Jais (4×4) wheeled vehicles, with Saudi industry tasked with integrating indigenous systems. If the contract expands, and Riyadh opts to acquire more vehicles, there is a likelihood that production would be moved, at least partially, to Saudi Arabia.

This is particularly plausible given the high demand for vehicles of this class. Potential users include not only the Royal Saudi Land Forces and the Saudi Arabian National Guard, but also other security agencies.

Saudi industry is also set to establish cooperation with Brazil, following the signing of a memorandum of understanding in August 2023. The deal involves several companies, including Embraer and Taurus, with rumours that the latter is considering opening a factory in Saudi Arabia. Within this framework, Brazil's Avibras has already signed a cooperation agreement with Saudi company SCOPA, founded in 1979 in Riyadh and a partner of both US and European companies in various industrial sectors. Cooperation with Brazil is expected to cover military vehicles for, artillery, ballistic and guided rockets, as well as equipment for the space sector.

Further plans

At present, it is difficult to determine whether the Saudis will fulfil their ambitions, which includes a plan to have exports account for 30% of their business. Building their own capabilities – both in terms of facilities and the knowledge of their engineers – will take many years, and alongside successes, there will undoubtedly be setbacks. On the one hand, they have the potential for this, including substantial financial resources. The UAE and its EDGE company provide the best example and can serve as inspiration.

Saudi Arabia is no less attractive as a partner for foreign defence companies. However, on the other hand, they lack experience, and their ambitions pose a potential threat to the current defence-industrial status quo. In other words, leading defence companies are willing to sell their products and solutions, but they will not be pleased with the emergence of a significant competitor in the market.

The Saudi portfolio is currently modest and relies primarily on replicative solutions. Nevertheless, it can be anticipated that new productions will be presented during the World Defense Show 2024, organised in Riyadh in February by GAMI, which was established not only to manage military procurements but also to oversee and promote the indigenous defence sector. SAMI is slated to have the largest exhibition space at the show, both indoor and outdoor. ■

Defending the Kingdom

David Saw and Conrad Waters

The Kingdom of Saudi Arabia (KSA) is faced with an extremely challenging strategic environment in which previous strategic certainties no longer apply.

For years, the economic and defence links between Saudi Arabia and the US were such that they constituted an implicit guarantee of support from Washington in the event of the Kingdom facing a serious threat. Instead of being a guarantee of certainty, KSA–US relations are now far more complicated than ever before, and that leads the KSA towards new strategic thinking and a change in diplomatic emphasis to try and improve their strategic situation.

The main stumbling block is that the government in Riyadh disagrees with the current US Middle Eastern policy of largely avoiding confrontation with Iran over its continuing nuclear programme. From the outset, the Biden administration demonstrated a colder relations with KSA than previous administrations, though relations began to warm somewhat following the Russian invasion of Ukraine in February 2022. The key to this of course, lay in the issue of oil, with Saudi Arabia able to move oil markets by increasing or decreasing supply, and with the Russian oil and gas industry sanctioned, the US needed Saudi Arabia's help to stabilise energy markets. At the time, Riyadh saw little need to respond to US requests; after all, high oil prices are rather attractive if you are an oil producing country. On the other hand, the KSA and other oil producers did assist in preventing the energy crisis that many feared following the sanctioning of Russia.

While relations between the KSA and US have recently shown signs of improvement, suspicion still remains in Riyadh regarding US intentions and the capacity of the Biden administration to cope with emerging crises in the region. How the future path of KSA–US relations evolve really depends on who wins the November 2024 US elections. Riyadh will therefore be closely following US domestic politics.

Credit: US Navy/Specialist 2nd Class Michael H. Lehman

The crew of the guided-missile cruiser USS Normandy (CG 60) seized an illicit shipment of advanced weapons and weapon components intended for the Houthis in Yemen, aboard a stateless dhow during a maritime interdiction operation on 9 February 2020.

A conflicted region

Within the region, Qatar remains a concern for KSA. The country has plenty of 'soft power' tools allowing it to punch above its weight as it seeks to gain regional and global influence. From a Saudi perspective, the political lobbying muscle that Qatar has been able to generate and sustain in Washington remains a concern. This also applies to the US tendency to look to use Qatari 'good offices' when it wants to contact Hamas or the Taliban for example.

In Yemen, the Shia Islamist Houthi movement, known as Ansar Allah (Supporters of God), represent a major security challenge for the Saudis. The group are effectively an Iranian proxy, receiving substantial support from the regime in Tehran. Today, the Houthis dominate the western part of the country (including a substantial stretch of border with KSA). Since KSA's March 2015 intervention in the Yemeni Civil War, Saudi Arabia has experienced attacks on its national territory by Houthi forces, with drone and missile strikes aimed at the Saudi oil industry and other high-value targets.

Since October 2023, the Houthis have targeted merchant shipping off the coast of Yemen in the Bab-el-Mandeb Strait and Red Sea, attacking a vital world trade artery leading to and from the Suez Canal. This has led the US, British, and others to deploy forces to the area to remove, or at least deter the Houthi threat comprising drones, missiles, cruise missiles and even ballistic missiles. The Houthi forces still have the ability to interdict maritime traffic, although there has been some effort to stop the supply of weapons to the Houthi by sea, and airstrikes have been launched against their missile launch positions.

As far as the KSA is concerned, the Houthis have posed a consistent security threat for quite some time, and the Biden administration's removal of the Houthis from the US list of foreign terrorist organisations soon after it took office in 2021 was an obvious annoyance to the Saudis. Now, after recent military operations against the Houthi, the US has once again

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Credit: USAF

US Air Force personnel visit an RSAF Eurofighter Typhoon squadron in Saudi Arabia in August 2023 during the Agile Spartan 23.2 multinational air exercise. The RSAF still has to decide whether to purchase more Typhoons or opt for something else.

placed the organisation on the 'Specially Designated Global Terrorists List.' The implications of this are less severe than being on the 'Foreign Terrorist Organisations List,' as it will not be a criminal offence for US nationals to support the Houthis. Moreover, the implications for the Houthis in being able to easily move funds around via the global financial system remain unclear.

Overall, the main Saudi strategic challenge remains Iran, as Tehran seems intent on becoming the dominant regional power. For its part, China has tried to broker a more relaxed level of diplomatic relations between Tehran and Riyadh, helped by the fact that it has strong commercial links with both states. This has led to some degree of improved diplomatic interaction, principally because neither Tehran nor Riyadh wish to see any escalation in tension that could lead to overt conflict. However, military action by Iranian surrogates against the Saudis, their allies or regional clients, can never be ruled out.

If we assume that Iran obtains a functional nuclear capability, then the security dilemma facing Saudi Arabia will be intense. Much will depend on who is the US president from January 2025 onwards and how the new administration intends to deal with Iran. That does not mean that the KSA will be out of strategic options, as there are plenty of possibilities it can explore.

For those who feel that it will somehow be possible to achieve a resolution of all of the disputes in the Middle East, this seems unlikely. The region remains divided by long-standing national, religious and ideological differences that cannot be easily bridged. The best that can be hoped for is that a measure of regional stability can endure.

Saudi airpower

The Royal Saudi Air Force (RSAF) does not wish to be totally dependent on a single foreign supplier for its primary combat aircraft systems. In an ideal world, it would be looking to continue its long-standing combat aircraft supplier-client relationship with the US and would hope to be working towards the supply of the Lockheed Martin F-35 Lightning II.

In the past, RSAF efforts to acquire top-of-the-line US equipment have been blocked by Israeli lobbying aimed at preventing the RSAF obtaining a high-end offensive capability that could be used against Israeli targets. This certainly complicated F-15 acquisition efforts in the past for example. However, relations between Saudi Arabia and Israel have significantly improved in recent years, especially since both are highly suspicious of Iran. It was felt that this situation might at some unspecified point in the future open the way to an F-35 acquisition. However, since the outbreak of the Israel-Gaza conflict in October 2023, overt links between Israel and the KSA remain in limbo, meaning that for the RSAF, the odds of acquiring F-35 appear low.

The decline in relations between the US and the KSA in recent years has put major combat aircraft purchases on hold, though there have been suggestions that the RSAF might be offered some form of evolved Boeing F-15EX solution as a logical capability expansion. The F-15 remains the most numerous combat aircraft in RSAF service as such they should be able to support additions to this force. However, it is doubtful whether the RSAF would wish to follow this path. Boeing remains a key supplier to the RSAF and would doubtless like to see the RSAF move forward on selecting the E-7 to replace its current E-3 AEW&C fleet, as this would certainly be a lucrative programme. In the meantime, the RSAF has acquired a couple of Saab GlobalEye AEW&C aircraft and has even apparently had talks with China regarding their KJ-200 AEW&C system. Should relations

Credit: Armée de l'Air et de l'Espace

A Dassault Rafale F4.1 standard aircraft of the Armée de l'Air et de l'Espace participating in a training exercise in December 2023.

between the US and the KSA improve, then the possibilities for the E-7 might greatly improve.

The potential RSAF acquisition that has generated the most interest is the long-awaited addition to the fleet of 72 Eurofighter Typhoon aircraft. A tranche of 48 more Eurofighters was to be acquired to allow the survivors of the Tornado fleet to be retired. The RSAF had previously purchased the Tornado IDS and ADV from the UK under the Al Yamamah programme, reflecting their preference for combat aircraft supplier diversity. Al Yamamah reinforced the position of BAE Systems as one of the major suppliers to the KSA and set the scene for the later Typhoon acquisition.

The acquisition of an additional 48 Typhoons was supposed to have happened by now, based on original plans, but came to a grinding halt as the German government, citing human rights concerns, blocked the sale. This ban was lifted by the German government in January 2024, but in the meantime, talks between Paris and Riyadh on defence acquisition programmes had already begun to take place over 2023.

France has been a significant supplier to the Saudi military for years, but has never been able to open the way for Dassault to win a combat aircraft programme. In 2023, a serious opportunity emerged for Dassault to finally succeed in selling combat aircraft to the RSAF. Serious conversations took place regarding the acquisition of some 54 Rafale aircraft, which would have been accompanied by the acquisition of a major air weapons package of Rafale-specific air-to-air and air-to-ground systems. This would have resulted in a massive training and support package as well. By the middle of 2023, the Rafale acquisition was increasingly seen as an inevitability and talks continued late into the year. Bearing in mind the complexity of such a programme, this was obviously a time-consuming process.

Now, given the German government's lifting of the ban on Eurofighter exports to KSA, Riyadh is faced with a bit of a dilemma, as they will have to take a decision on whether to acquire further Eurofighters, or the Rafale. This has future implications as well, since the Saudis are interested in becoming involved in the Global Combat Air Programme (GCAP) for a next generation combat aircraft involving the UK, Japan and Italy. There are clearly some difficult decisions for Riyadh to take, yet they are well positioned for some hard bargaining.

Land forces

The Royal Saudi Land Forces (RSLF) gained combat experience from their intervention in Yemen post-2015, and now the force faces serious decisions on how it shapes itself for the future. This depends on the type of conflict it expects to fight and the equipment it will need to prevail. The aviation element of the RSLF is certainly well positioned for the future, being equipped with the Boeing AH-64D Apache and the CH-47F Chinook, the Bell OH-58D and the Sikorsky UH-60L. Other parts of the RSLF are not so well provisioned, with lots of legacy equipment from multiple suppliers.

This is where local defence industry champion Saudi Arabia Military Industries (SAMI) could play a major role. It is official Saudi policy that 50% of national military expenditure is to be spent in the KSA by 2030. SAMI itself has the stated ambition of being one of the top 25 global defence companies. The company already produces ammunition, from small arms up to artillery calibres, truck and armoured vehicles, defence electronics and small arms. Rebuilding RSLF capabilities would certainly fit in with the transformational objectives of the KSA government to enhance local Saudi industry.

Credit: US Army

A RSLF M1A2S Abrams tank changes position during Exercise Eager Lion 22 in September 2022, a joint exercise in Jordan featuring the RSLF, Jordan and the US. The M1A2S is the RSLF's primary main battle tank.

The Saudi Navy

The Royal Saudi Navy (RSN) has always been heavily influenced by the country's geography. More specifically, the need to protect separate and lengthy coastlines has required the maintenance of two distinct fleets: a Western Fleet based at the Red Sea port of Jeddah and an Eastern Fleet headquartered at Al Jubail in the Persian Gulf. Despite the expense involved, the RSN has also typically been accorded a lower priority than the land and air-based arms of Saudi Arabia's defence forces, which has limited the RSN's aspirations. One consequence has been an excessive reliance on the country's allies – particularly the United States – to ensure the country's maritime security.

Until recently, the RSN has been comprised of warships of largely French and US origin. France has been the traditional supplier of choice for the Western Fleet; Naval Group delivered three sophisticated Al Riyadh air defence frigates early in the current millennium, where they joined an older quartet of French-built Madina class light frigates of 1980s vintage. Meanwhile, the Eastern Fleet is comprised largely of US-built missile armed corvettes and fast attack craft, also dating to the 1980s. These American ships were acquired under a large Saudi Naval Expansion Programme (SNEP) designed to counter growing Iranian naval power in the region.

In recent years, a further recapitalisation of the RSN's inventory has gathered momentum. Whilst this has partly been a reflection of the increasing age of many warships, it seems likely that lessons from the long conflict in Yemen have also been learned. The vulnerability of friendly shipping to asymmetric attack and the need to enhance capabilities to interdict enemy

Credit: US Navy

The RSN frigate HMS Makkah pictured in November 2020. In common with much of the RSN's Western Fleet, she was built in France.

seaborne supply lines have both served to demonstrate the importance of the maritime domain. The resultant programme of naval investment is sometimes referred to as 'SNEP II'.

By far the most important element of fleet renewal has been a growing strategic alliance with Spain's Navantia. This alliance is currently focused on the delivery of five Avante 2200 corvettes under a EUR 1.8 billion contract announced in July 2018. The new ships are slightly enlarged variants of the quartet of Guaiquerí class offshore patrol vessels previously supplied to Venezuela. However, they have a significantly enhanced combat capability, including the provision of a Mk 41 VLS. The first three members of the resultant Al Jubail class were handed over in Spain between March and December 2022. Combat system integration of the final pair has been transferred to Saudi Arabia, where the fourth ship (named Jazan) was accepted on 5 December 2023. The programme will be completed with the delivery of the fifth and final corvette before the end of 2024.

This shift of final commissioning activities to Saudi Arabia reflects a broader plan that envisages the transfer of technology to allow the country to build its own vessels. This will be carried out under the framework of a joint venture between SAMI and the Spanish shipbuilder. It is also part of the wider ambition of localising defence spending in accordance with the tenets of 'Saudi Vision 2030'. The Avante 2200 contract has already seen some tentative steps in this direction, for example through a joint development of the HAZEM combat management system. However, the new plans go much further, envisaging shared construction in Spain and Saudi Arabia. A memorandum of understanding covering the new arrangements was signed in November 2022 and it is ultimately expected to encompass completion of five multi-mission combatants.

If ratified, the agreement will mark a significant step forward in the indigenisation of local naval shipbuilding and support. This has previously been limited to the assembly of much smaller and less-sophisticated vessels, most notably the completion of HSI-32 fast interceptors by the local Zamil Shipyards in collaboration with France's CMN. However, it seems likely that both practical and political considerations will drive continued reliance on overseas shipyards for some time to come. One notable example is the acquisition of four Lockheed Martin-designed Multi-Mission Surface Combatant (MMSC) vessels being built at Fincantieri's Marinette Marine shipyard to a variant of the Freedom class (LCS-1) littoral combat ship design. As well as helping to cement the Saudi–US alliance, these vessels are urgently needed to reinforce their ageing US-built predecessors in the Eastern Fleet.

It is interesting to speculate to what extent the current investment in the RSN fleet renewal will increase Saudi Arabia's naval ambitions. Certainly, there have been recent signs that the RSN is willing to take a more prominent role in international maritime security operations across the region. However, the training and doctrinal hurdles inherent in developing meaningful 'real world' naval capabilities will be high. ■

Credit: Navantia

Avante 2200 class frigates pictured in various stages of construction at Navantia's San Fernando yard in the Bay of Cádiz in December 2021. Saudi Arabia's growing strategic partnership with Navantia looks set to transform the country's domestic naval sector.

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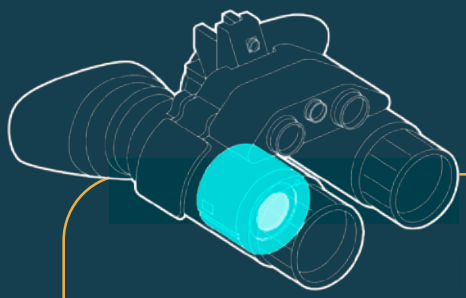

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How effective is modern vehicle armour against contemporary battlefield threats?

Sam Cranny-Evans

With weapon lethality at an all-time high, and many confirmed losses of modern land vehicle platforms across multiple battlefields, it is worth examining the extent to which current protection systems are up to facing the challenges of the modern battlefield.

In order to analyse the efficacy of modern armour on current battlefields, an analytical framework has been established. The goal of the framework is to provide a single set of criteria against which multiple case studies can be compared. The framework considers the following elements in combination:

- The modern survivability matrix: This variable provides a technical description of the dominant survivability matrix for each case study.
- Combat scenario: This variable provides context and will attempt to describe the predominant operating conditions of the case study.
- The threat: Analysis of the threat will seek to understand how the opposing side has sought to counter the survivability matrix in question.
- Mission success: Analysis of mission success and the ability of the survivability matrix to contribute to it will be based upon the perceived ability of the force in question to operate tactically and any resultant losses.
- The final element of the framework will consider the above to assess how effective the survivability matrix in question was within the defined scenario.

This analysis will draw on three case studies from modern warfare and the data used will be a mixture of quantitative and qualitative, drawing on vehicle and personnel losses where reliable and consistent figures can be found. This will be combined with a technical understanding of modern armour and anti-armour weapons.

Author

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Credit: Ukrainian MoD

This is an all too-common scene from wars featuring the T-72. The location of the ammunition can lead to catastrophic detonations in the event of a hull penetration. The Soviets were aware of this and concepts leading into the 1990s relocated the crew and ammunition.

The 'modern' survivability matrix

Modern vehicle armour is part of a survivability matrix, this means that all elements of a vehicle's survivability are connected and affect the way that armour has developed – it is not sufficient to simply look at the physical armour. The matrix consists of the vehicle, the armour that protects it, and any active protection systems it carries. This analysis also considers mission systems fitted to the vehicle, and its perceived accuracy and lethality. This is because a vehicle's survivability is not just decided by its ability to withstand a hit from an anti-tank guided missile (ATGM). It is partly decided by its ability to successfully enact its user's will onto an opponent and inflict losses in return for any engagement, whether successful or not.

In most cases, modern survivability matrices have been developed and deployed onto legacy platforms. The Merkava Mk IV, for example, builds upon the foundation of the Merkava Mk I that entered service in 1979. The Leclerc used by the UAE in Yemen was designed following studies initiated in 1972 and an initial concept proposed in 1982. This has had ramifications for almost every heavy AFV that is currently in operation and considered below. Most designers anticipated that the front 60° arc would need the greatest protection, leading to disproportionate weighting to the frontal arc. Consider this against the case studies below, every conflict has at some point involved urban warfare and 360° threat vectors leading to vehicle losses. It is likely that designers would take a different approach to survivability if starting from a clean sheet. It stands to reason that the 'modern armour' considered here is in some way operating at an inherent disadvantage compared to

threats that have developed free of any Cold War-imposed constraints.
So, whilst the survivability matrices considered here represent the leading edge of modern armour, they are in fact products of the Cold War that have been modified to carry cutting edge survivability solutions. There are, of course, more modern designs; the South Korean K2 and Japan's Type 10 are notable MBTs that have been developed inside the 21st century, but neither has been deployed operationally, making an analysis of their survivability matrix based upon combat experience impossible. It would, however, be possible to apply the theory of this analytical framework to them at a later date. In short, 'modern armour' is also working by and large within the constraints of perceptions of warfare in the 1980s, which means that adaptations to modern threats have been applied to existing designs, rather than built into the vehicles in question, which would be optimal.

Credit: Ukrainian MoD

This image illustrates the vastness of terrain in Ukraine. While there have been times where the fighting has been heavily urban as in Bakhmut and Mariupol, it has often taken place in open fields with very little in the way of cover. In this scenario, it becomes essential to employ combined arms for AFV survivability.

Case study: Ukraine's counter-offensive, 2023

Context

Ukraine's counter-offensive in 2023 was understood to have been intended to reach the city of Melitopol, with a stretch goal of pushing through Russian forces to the coast. The Russian forces had spent a considerable length of time preparing their positions to absorb and counter the offensive. They did so broadly according to their doctrine and an understanding of defensive operations that can be traced to the 1980s. The Ukrainians had received training from Western partners and it is now broadly understood that this failed to account for the conditions in Ukraine as well as the ability to conduct the large-scale (i.e., brigade-level) combat that would have been necessary for Ukraine to succeed, or achieve more than it did. The offensive had multiple aspects to it, but this article will primarily consider the use of NATO armour such as the Leopard 2, Bradley, and CV90 series vehicles.

Adversary armament and tactics

Russian defensive doctrine is composed of interconnected strongpoints that are fortified with trenches and obstacles. They do not form a continuous line, but the gaps between them are covered by indirect fires. A screening line of troops using anti-tank guided missiles (ATGMs) is expected to provide an initial blunting effect that forces the attacker to stack up, or deploy into an attacking formation early, thereby slowing the advance and providing a target for artillery and aviation. The majority of the defence is conducted by infantry with support from armoured fighting vehicles where appropriate. For example, Russian tanks were deployed in small squadrons of 2-3 vehicles to engage Ukrainian formations that had been slowed or immobilised by the screening force and minefields, often resulting in heavy losses on both sides.
Russia is by far the most capable adversary considered within this analysis and therefore the greatest test of modern armour. Its units deployed an array of equipment summarised in Table 1 below. Anecdotal accounts indicate that even during the largely successful Ukrainian offensive around Kharkov, Russian units were adept at forcing Ukrainian formations to stack up. When this occurred, Ka-52 helicopters would engage slowed or immobilised units using ATGMs. This tactic was repeated during Ukraine's counter-offensive. Other tactics include the use of massed MRL fire from the BM-30 Smerch and BM-21 Grad to saturate Ukrainian units with cluster munitions and re-sow minefields that had been partially cleared. Further conversations with Ukrainian soldiers indicate that the Russian use of FAB-500 bombs with UMPK guidance kits has been devastating to some Ukrainian operations. This is combined with the use of loitering munitions such as the Lancet-3M and first-person view (FPV) drones, combined with conventional semi-active laser (SAL) guided artillery munitions.
Furthermore, the Russians also built deeper minefields than expected, which created many challenges for Ukrainian units with scarce mine clearing resources, and trained to breach minefields according to Western doctrine. This was coupled with a very high density of mines and IEDs, as well as the

Table 1: A selection of weaponry employed by Russian troops in Ukraine

Name	Range	Penetration (RHAe)
9M133M-2 Kornet	8,000 m	1,300 mm
9M120M Ataka	8,000 m	950 mm
LMUR	15 km	Unclear - 25 kg warhead
Lancet-3M	Up to 50 km	Unknown
FPVs	1,000 m	300 mm*
UMPK-equipped bombs	60 - 80 km**	Significant wide-area blast damage

Notes:
*Assuming the FPV is fitted with a PG-7V type warhead.
**Ukrainian sources claim the range is shorter. It is understood to vary according to the bomb-weight and type.

Credit: Ukrainian MoD

An example of a heavily up-armoured Bradley in Ukraine. Not all Bradleys deployed to the country have carried this additional protection. However, they are reportedly more survivable than the BMPs and BTRs that Ukraine has relied upon.

practice of stacking anti-tank mines on top of each other to guarantee an immobilised vehicle. It is important to emphasise that Russian defences are centred around firepower and coordination between the motorised/mechanised rifle battalions, artillery, and aviation. The net result is a plethora of weapons that are brought together in a single battlespace with a high hit probability and considerable lethality. The challenge for Ukrainian units was always going to be immense and fraught with risk.

Ukrainian armour and tactics

Ukraine deployed a broad range of armoured vehicles during the offensive including Leopard 2s in various configurations up to the very capable Leopard 2A6, M2 Bradleys and CV90s, as well as Challenger 2s. They were accompanied at times by MaxxPro MRAPs and Soviet BMPs as well as some T-72s and T-64s. The Western platforms essentially represent the most survivable systems in service with Ukraine, and those that were most likely to be heavily used during the counter offensive.

The tactics used included preparatory artillery bombardments and the use of drones to provide overwatch and targeting of Russian troops and vehicles. Ukraine also deployed FPVs, however their impact on heavily protected vehicles is mixed at best, and may even be minimal insofar as catastrophic kills are concerned. The far greater impact of small drones was in their use to direct and correct artillery fire on Russian positions. The overall goal of Ukrainian tactics appears to have been driving Russian troops from their forward trenches, then taking and holding these positions, and then defending against a Russian counter-attack to retake the positions. In some places, the Russian defence was overly forward leaning when compared with its doctrine; a lot of effort was spent engaging Ukrainian advances as far forward as possible, as opposed to meeting them from within the protection afforded by the fortifications prepared in advance.

Losses

Assessing Ukraine's total losses in the counter-offensive is difficult. The New York Times reported that 20% of Ukraine's equipment had been destroyed in July, citing US officials. The personnel losses are also thought to have been high. In terms of western equipment, the pro-Russian source lostarmour has documented 16 Leopard 2s either damaged or destroyed. The evidence attached to those claims indicates that at least five continued burning at a low level after being hit. The same site has documented 41 immobilised or destroyed Bradleys, 13 Strykers, and 2 CV90s.

An indication of the survivability of western armour is provided by a report titled *Putting Medical Boots on the Ground*, which was published in August 2023 by the Global Surgical and Medical Support Group (GSMSG). The group's representatives in Ukraine examined the effects of the Kornet ATGM and were told that against light and lightly armoured vehicles such as the Humvee, BRDM, and M113, it often had devastating results. *"If the jet hit an unlucky individual they were generally vapourised. Other occupants of the vehicle were usually "blown apart" so it was likely a combination of spalling and fragmentation shredding the occupants as well as the blast wave literally tearing people apart. In addition, there was barotrauma to the brains and lungs of anyone who survived the other effects,"* a GSMSG representative told ESD via email.

The report notes that such attacks against this category of vehicles exhibited a greater than 75% fatality rate. In contrast, when the same missile hit a heavily armoured vehicle such as a Leopard 2 or Bradley, most crews reportedly survived. However, there were some examples of catastrophic impacts that immediately destroyed the vehi-

Credit: Russian MoD

The T-14 (left) and T-90M (right) are visible here during Russia's Army 2023 defence exhibition. The two vehicles represent Russia's approach to modern armour, and its perceptions of future armour requirements. The T-90M is made survivable through an extensive suite of ERA and at times an upper-hemisphere overhead cage for additional protection against drones and loitering munitions.

cle, the representative said. This supports other claims that Western armour was very survivable in the event of an ATGM strike, and lends credence to the assessment that modern survivability matrices are sufficient for the current threat landscape.

This outcome was not limited to Western platforms; a RUSI report on Ukraine's counter-offensive indicates that gun-launched ATGMs fired against Russian tanks with Kontakt-5 explosive reactive armour (ERA) such as the T-72B3M often failed to defeat the vehicle, even with multiple hits. However, the efficacy of a lot of Russian and Soviet armour is undermined by design decisions around ammunition stowage. Every Soviet and Russian-designed tank after the T-55 employs a carousel autoloader in the centre of the vehicle carrying its ammunition, which tends to detonate when hit by an ATGM or APFSDS. By contrast, Western vehicles favour more protected magazines with ammunition either separated from the crew by armoured blast doors and blow-out panels fitted above the ammunition stowage. In Soviet tank designs, the turret crew is seated on top of the magazine, separated by a thin sheet of steel. Consequently, the turret can be separated from the vehicle by a magazine detonation. So, whilst the vehicles might be sufficiently protected to withstand multiple strikes, the post-penetrative effects will likely be a lot worse for the crews of Soviet and Russian-designed vehicles.

Assessment

Ukraine has failed to achieve the aims of its counter-offensive. It has reclaimed marginal amounts of territory from Russian occupation, but the strategic situation remained largely unchanged at the time of writing in late-November 2023. The Russians certainly suffered attrition, that is clear. However, the relatively small quantities of western armour and artillery supplied to Ukraine were unlikely to ever dismantle Russia's layered fires network and established defensive lines. From the density of the minefields to difficulties in massing fires in preparation of an attack, and the inability to conduct brigade-level operations, there is little that the added survivability of Western armour could add to the probability of success.

Within reason, Western armour was adequately suited to the lethality it faced during Ukraine's counter-offensive, but that was never going to be the deciding factor. A brief analysis of the 1991 Gulf War provides an indication of what might have been required to succeed. By February 1991, the Coalition forces had conducted a 6-week aerial campaign that targeted the infrastructure and command networks of the Iraqi forces. In the hours preceding the ground operation they conducted an enormous artillery barrage with hundreds of guns and rocket launchers. Thousands of shells and rockets were fired, many of them were cluster munitions and the intensity of the barrage was such that one participant recalled the ground shaking as he waited to advance. The subsequent advance met with resistance, but it also met thousands of Iraqis ready to surrender and defensive positions that were no longer effective. One Iraqi commander reportedly told his captors that of 100 guns in his division, 83 were destroyed by this targeted artillery barrage. There are undoubtedly multiple causes behind the Coalition's rapid success, but the massed firepower cannot be dismissed as a cardinal contributor.

So, what can be said of modern armour based upon Ukraine's experience? It is clear that when heavily armoured vehicles - Bradley, Leopard 2, CV90 etc - were engaged, the crew and dismounts had a reasonably good chance of surviving. The comparison with light vehicles is stark,

Credit: IDF

This image shows a large concentration of IDF armour during Operation Iron Swords. Combined arms tactics are critical to armour survivability, but its use and subsequent attrition depends to an enormous extent on an adversary's ability to locate and engage it at moments of vulnerability. A concentration such as this would have a very different outcome in Ukraine, for example, than it did in Gaza or Yemen.

as indicated by the GSMSG report cited above. It is also apparent that Russian armour, often protected by Kontakt-5 or Relikt ERA, was resistant to some of the more potent weapons deployed on the battlefield, thereby extending its ability to operate and inflict damage on Ukrainian troops. However, it also shows that the survivability matrices of Western platforms are not a panacea and do not guarantee success, despite their qualities when compared with Soviet-era platforms. Ukraine was unable to deploy sufficient firepower to blunt and defeat Russia's massed artillery assets, anti-armour helicopter sorties, and ATGM teams. As a result of this, its units became extremely vulnerable once immobilised in minefields they were not equipped or trained to breach. Russian aviation had to consider the possibility of Ukrainian air defences, which shaped how close they could get to the front line, but this did not prove decisive.

The bottom line is that modern armour is dependent upon effective combined arms cooperation and the use of sufficient, sustained firepower to achieve its objectives. It is unlikely to succeed when deployed in isolation against a determined and well-equipped opponent without these aspects in place. This point is axiomatic for anyone who has studied warfare since 1939, however, it is worth emphasising. The protection of a modern armoured platform is only as good as the system within which it operates. Modern lethality, which is essentially typified in all three case studies by Kornet, is considerable and likely sufficient to defeat almost any vehicle eventually. Where losses need to be reduced to a minimum, care around combining arms and concentrating firepower is critical. The remaining case studies will demonstrate this in different contexts.

Case study: Israel's offensive to isolate Gaza city, 2023

Context

Israel's deployment to Gaza following the atrocities of Hamas' 7 October 2023 attack came after close to a month of preparation. The quantity of troops dedicated to operations in Gaza is not clear, however, the Financial Times claimed that "35 battalions and four divisions" had been prepared as part of the "infrastructure" for a ground operation. The opening phases of the IDF's operation involved moving from the border with Gaza through fairly open terrain, into gradually more urban surroundings. The first thrust appears to have cut across the strip creating a corridor from the border to the sea; additional operations have been launched around the edges of Gaza City. The stated goal is the complete removal of Hamas and its military capabilities, as well as replacement of its political elements with an alternative entity to manage the Gaza Strip. At the time of writing in late-November, fighting was ongoing. For that reason, this section will not examine the overall success of the Israeli operation and look instead at select examples to illustrate the efficacy of Israeli armour.

Adversary armament and tactics

Hamas' military wing, al-Qassam, is variously attributed with a combat strength of as many as 30,000 personnel. Hamas forces are divided into offensive and defensive roles. The former is charged with maintaining rocket launches against Israel and will not be covered here. The latter is designed to either prevent or defend against Israeli ground incursions. They are arranged into five regional brigades and 140 companies, according to the IDF. The companies are understood to be further organised into platoons that are made up of three combat teams, which are the standard operating unit. The combat team is centred around an anti-armour capability that is typically, or ideally, supported by a sniper, medic, and a handful of fighters. This pattern appears to have been maintained in 2023, with the frequent addition of a cameraman to film engagements.

Armament includes the standard RPGs, assault rifles, some modern ATGMs and a greater number of older designs such as 9M14 Malyutka and 9M113 Konkurs, and some fighters are capable at deploying improvised explosive devices (IEDs) as part of their defensive lay down. The organisation was already capable of building and deploying shaped-charge type IEDs with various degrees of complexity in 2006, it should be assumed that the trend has continued. Hamas also has developed

Table 2: An overview of the more potent anti-armour weapons available to Hamas.

Name	Range	Penetration (RHA equivalent)
Yasin 105	150 m	750 mm without ERA, 600 mm with ERA.
9M14P1 Malyutka-P1	3,000 m	520 mm
9M113M Konkurs-M	4,000 m	800 mm
9M133-1 Kornet/ Delaviyeh	5,500 m	1,200 mm
SPG9	800 m (direct fire)	400 mm
IEDs	5-10 m	Depending on size and quality of explosives/shaped charge

Note: The penetration statistics do not always correlate with behind-armour effects and subsequent lethality.

Credit: IDF

Here a Namer and Merkava crew keep watch within their vehicles as their infantry search nearby buildings. The Merkava is fitted with Trophy and the Namer may be too. The system combined with good all-round protection makes the vehicles very difficult to destroy.

and manufactured the Yasin 105 tandem charge rocket, which is very often seen in videos of Hamas engaging IDF forces. The Yasin 105 bears very many similarities to the PG-7R tandem HEAT rocket that was introduced into service in 1988. It includes a 64 mm precursor charge positioned ahead of a 105 mm main charge. Hamas claims the rocket can penetrate up to 750 mm of steel armour that is not protected by ERA. Given the similarities to the PG-7R, it seems unlikely that the Yasin 105 was developed autonomously. Yasin 105 is not the most lethal weapon available to Hamas, which also has access to the 9M133 Kornet or its Iranian clone the 'Delaviyeh', supplied by Hezbollah. Details of some of the weapons available to Hamas are provided in Table 2. Note that a key difference between table 1 and 2 is the delivery method; a Russian Ka-52 is generally much more mobile and survivable than a Hamas anti-tank platoon. Especially when operating as part of a combined arms unit. Assessments in 2007 posited that Hamas would attempt to avoid fighting the IDF in the open and increase its level of resistance the deeper into urban territory that the IDF moved. It would combine IEDs with human shield tactics and suicide bombers to weaken the IDF and cause excessive casualties compared with the goal. The aim was to present an image of having defeated the IDF or frustrated its military objectives at least. It appears that this pattern was maintained in 2023 with initial engagements conducted in the more rural terrain outside of Gaza city, and the fighting then becoming heavily urban in focus as the Israeli forces gained ground. Observed tactics seem to include lightly armed teams using tunnels and terrain to emerge at close proximity to Israeli forces to conduct a brief engagement before retreating. It is notable that these teams very rarely carry more than one shot for an RPG-7 type launcher, indicating that they are not expecting a prolonged firefight.

Other tactics reported by the IDF include Hamas fighters deliberately swarming or 'hugging' their positions to make the use of close air support and other heavy firepower difficult. This tactic has resulted in the well-circulated videos of Hamas fighters placing explosives onto Merkavas. There is a singular report of the Golani Brigade's 13th battalion being engaged by a force of 30 Hamas fighters who used IEDs, ATGMs and drones in a coordinated attack in early November. The Hamas force suffered 20 casualties, according to a report in the Guardian.

IDF armour and tactics

The IDF deploys what is arguably one of the most survivable AFV families in the world in the form of the Merkava MBT and its Namer heavy APC. The two vehicles layer composite and steel armours with the Trophy APS. It is also possible that they carry some form of reactive armour, Israeli company Rafael for example, has designed ERA that is designed to counter kinetic energy threats. They also employ sophisticated digital battle management systems with a common communications architecture that has been implemented since 2012. Over time, this has evolved to enable the use of systems like Fireweaver, an AI-enabled sensor-to-shooter system that fuses the outputs of multiple sensors and shooters into a single network, allowing the commander to task effectors based on availability and suitability in real time.

The IDF's tactics in Gaza are led by armour and typically consists of armoured formations in company strength consisting of 2-3 Merkavas accompanied by a similar quantity of Namers and engineering assets in the form of the D9 armoured bulldozer. Additional fire support is provided by indirect fires, naval gunfire, drones, and close air support. There is a growing reliance on tactical precision assets such as the Spike guided missile and the 120 mm Iron Sting mortar round that has been used for the first time in Gaza. Nevertheless, IDF tactics are best described as firepower heavy, and most movements are dominated by the Merkavas. One IDF soldier recalled, "Face-to-face fights are rare. We don't

Credit: IDF

IDF armour is rarely left to fend for itself and typically works in combination with at least one form of additional fire support that can attack from a different angle. This might come in the form of artillery, drones, fixed wing aircraft, or helicopters as shown here.

Credit: UAE MoD

The UAE operates a modified version of the Leclerc. It is a very capable tank used to good effect in Yemen. However, as with other examples cited here, the UAE's armour was protected at all times by extensive firepower from the air, land, and sea.

see too many of them in person. Tanks will fire into buildings, and we will go to clear them. Usually the tanks get them."
The Merkavas provide a very important function for the IDF. For example, in the recovery of a battle-damaged vehicle they form a protective ring and use their firepower to enable recovery efforts. The vehicles are – at this stage in their service life – essentially designed to assume stationary positions in urban environments and provide fire support and suppression against hostile forces. They also act as cover behind which dismounted infantry operate and shelter when engaged. The IDF goal in Gaza is to eliminate Hamas' military capabilities whilst minimising its own personnel losses. This means that movement is conducted inside of vehicles as much as possible to prevent losses from sniper fire and IEDs. At times, it also appears that the D9 bulldozers are used to prepare large berms that Israeli armoured formations will occupy, which may be an attempt to deter vehicle borne IEDs as well as providing extra protection from attack.

Losses

Since the ground phase of the operation inside Gaza was started there had (at the time of writing) only been one confirmed loss of an IDF vehicle. This was reportedly a Namer, which was destroyed in the early stages of the operation leading to the loss of all 11 personnel onboard. However, the IDF released an article providing some insight into battle damage and repair (BDAR) operations. It indicated that the majority of damaged vehicles were driven out of contact to a repair centre and returned to combat. Some needed to be recovered, and it stated that some were beyond repair – those vehicles were salvaged for usable spare parts. The report provided no indication of numbers or types of damaged vehicles.
By late-November 2023, the IDF had reportedly suffered 66 fatalities – some of which were friendly fire – and an unknown quantity of wounded. Some analysis indicates that a force can expect 3 – 5 wounded for every soldier killed in combat, which suggests total IDF casualties in the hundreds. The IDF has also stated that hundreds of Hamas operatives had been killed by Israeli forces.

Assessment

Despite multiple videos released by Hamas showing engagements at close quarters with Israeli armour, there is not good evidence to support heavy losses. Moreover, the IDF had successfully entered Gaza city and claimed to have eliminated more than 80 Hamas commanders in the process. Overall, there is scant evidence of Israeli armour losses. The lone IDF report on BDAR indicates that vehicles were certainly damaged, some of them irreparably, but the losses were ultimately insufficient to prevent the IDF from achieving tactical success against Hamas and commencing efforts to dismantle its tunnel network.
The survivability matrix of Israel's armour undoubtedly contributed to its success in the opening phases of the operation and low combat losses. In addition to this, a key element was the IDF's liberal use of firepower and combined arms operations as a central tenet of its operations. So, whilst

Credit: US Navy/Ted Banks

The UAE's BMP-3 is valuable in the firepower it provides, but vulnerable in terms of protection and the location of its ammunition.

the armour is survivable, its survivability was enhanced by the protection and additional capabilities provided by air power, artillery, precision strike assets and regular intelligence updates. It stands to reason, especially when the assessments of Ukraine's operation are considered, that effective combined arms doctrine is a critical component of modern armour survivability. One might argue that modern armour is not designed to be survivable without it.

Case study: The Gulf Coalition in Yemen, 2015 onwards

Context

The Gulf Coalition was a Saudi-led force that deployed to Yemen in 2015 to support deposed President Abdu Rabu Mansour Hadi in Yemen's fight against the Houthi movement, which had attracted support from elements of Yemen's army. There are two armoured elements within the operation that will be considered; advances and engagements inside Yemen that were often led by armoured battle groups from the UAE, and cross-border raids into Saudi Arabia, which resulted in the loss of Saudi tanks and armoured vehicles.

Houthi forces had overthrown President Saleh and were in the process of capturing Aden, a port city at the tip of Yemen. The Houthis had been joined by defectors from the Yemeni Army and were equipped with tanks and other armoured vehicles. An initial deployment of UAE special forces saved the city from Houthi advances by directing air strikes against the armoured assaults. By August 2015 the UAE and Saudis were able to deploy a battalion-sized element of Leclercs, "dozens of BMP-3Ms", supported by 155 mm G6 howitzers and other fire support assets. The UAE-led battlegroup, which included around 1,500 Yemeni fighters, conducted a number of operations to recapture towns such as al–Anad and the Labouza military base around 30 km to the north of Aden.

Adversary armament and tactics

The Houthis were armed with anti-tank weapons provided by Iran such as the Delaviyeh/Kornet, Metis-M and RPG-29. The AM-50 anti-materiel rifle chambered in .50 BMG was also supplied by Iran. It is a single-shot rifle that has proliferated throughout the Middle East and is used by many of the forces that Iran supports. The Houthis have also deployed mines and IEDs that range in complexity. At least one example in 2021 was fitted with a passive infrared sensor connected to a radio controlled arming sensor, which reflects the more advanced IEDs deployed against western forces in Iraq. The Houthis also possessed armoured vehicles like T-55s and BMP-2s, but there is no clear evidence of them engaging Coalition forces.

The Houthis developed an array of tactics to delay and attrit coalition forces. One of particular interest included a single fighter in networked fox holes, each armed with different types of weapon. The fighter would move between the fox holes using each weapon in turn, thereby convincing the coalition forces that they were facing a much larger force. In addition, their tactics and techniques had been sharpened through a decade of war with the Yemeni armed force. They would prefer to use small groups of 3-5 fighters including at least one sniper, but would occasionally conduct set-piece battles to seize cities or larger objectives. This is broadly in line with tactics used by other decentralised insurgent organisations such as the Taliban and ISIS. Furthermore, it is understood that the Houthis received training and support from Iran which led to the introduction of Delaviyeh/Kornet ATGMs in 2017, which were supposedly unavailable to the Houthis before then. It is also notable that the 2015 portion of the operation at least, preceded the widespread use of small drones. In some sense, the coalition armour was saved from the effects of an additional challenging threat that has defined approaches to the Ukrainian and Israeli operations.

Analysis of earlier Houthi tactics from 2007 - 09 also indicates that they were capable of ambushing convoys, successfully attacking checkpoints and static forces, and small unit combat that could result in heavy casualties for both sides. They would also employ harassing fire using sniper rifles and mortars.

Coalition armour and tactics

The UAE and Saudi forces continued their operations with two offensives; the Aden force continued operations towards the Bab el-Mandeb straits, where it advanced 160 km in two weeks. Another force including a UAE armoured battalion and mechanised elements from Saudi Arabia, Bahrain, Egypt and Qatar advanced on Marib in the east of Yemen. It advanced 50 km in two weeks, but struggled to reach Sana'a as it encountered strong resistance in the deserts and mountains approaching the city.

The Leclerc and M1A2S were the MBTs of the UAE and Saudi forces respectively. The former combines advanced composite armours with steel and in some cases extensive suites of AZUR ERA and a soft-kill obscurant smoke-based active protection system. The Saudi M1A2S is protected with a combination of steel base armours and composite armour packs. However, its protection is focused on high risk areas – the turret cheeks and glacis – to a greater extent than an AZUR-equipped Leclerc. Therefore, ATGM engagements against the turret rear or side of an M1A2S often face much weaker defensive measures. The BMP-3 used by the UAE uses aluminium armour that is also concentrated on the frontal arc and designed for peer conflict with the US. Its critical flaw is the ammunition it carries for the 100 mm main gun, which is not built to high insensitive munitions standards. This means that a penetration of the armour and ammunition is likely to result

Credit: Islamic State video, via LiveLeak

This is an upscaled-resolution still from a video released supposedly by a pro-Islamic state media outlet in 2015. It shows the moment after an Iraqi M1A1 was hit with an ATGM.

Credit: US Army/Sgt Anthony Prater

The Saudi forces deployed to Yemen with variants of the M1A2 Abrams. However, the vehicles were often left exposed in border defence positions and engaged with ATGMs, which led to losses.

in a catastrophic explosion. The Saudis also deployed the M2A2 Bradley IFV, which is built from aluminium armour with hardened steel plates as an add-on. It is capable of mounting ERA, but it is not clear whether this was ever done for Saudi vehicles.

The total complement of Leclercs is believed to have reached 70 or 80 tanks that were deployed in squadrons of nine tanks for some operations. They appear to have been used in a variety of roles from offensive dashes to secure strategic locations, defensive operations to hold them, and in direct support of infantry. They operated alongside the BMP-3Ms and often in tandem with MRAP-type vehicles and M-ATVs. UAE forces were able to successfully secure Aden and the al-Anad air base to the city's north, the Leclerc played a leading offensive role in both operations. They were supported by BMP-3s that were occasionally up-armoured with bar armour to increase protection against RPG-7s.

Saudi forces were often embedded in stationary positions on the border with Yemen and also involved in patrols through Yemeni towns and countryside. Both forces supported their efforts with rotary and fixed wing aviation and were capable – at times – of good combined arms cooperation, although reports are mixed on this front and capabilities inevitably varied by unit.

Losses

There are no definitive indications that any Leclercs were lost during these operations. One may have been penetrated by an ATGM, but the type is not known. If the report is accurate, the missile penetrated the frontal armour and killed the driver. The tanks are also thought to have survived IED and RPG strikes. However, there are several indications that the Houthis became adept at shooting the Leclerc's prominent sight, external fittings and fume extractor using AM-50 anti-materiel rifles. At least one BMP-3 was catastrophically destroyed, reportedly on the road between Aden and Abyan. The website Lostarmour indicates that 6 M1A2S tanks were destroyed in 2015, and the total reached 14 2021. However, the available indications are that some were engaged whilst in stationary positions on the border with Yemen. The same site reports the loss of 36 Saudi M2A2 Bradley IFVs in 2015 and 59 in total by 2021. The conditions of their loss vary, but some were engaged with an ATGM, an encounter that a Bradley is unlikely to survive. Some video footage from these engagements indicates a concerning trend for the tanks to cook-off over an extended period of time once hit. In one instance, this begins within five seconds of the missile striking the vehicle, which is unlikely to have allowed the crew time to escape. Total Sudi losses may be as high as 3,000 personnel according to an article in The Independent from 2016, whereas the UAE had reportedly lost 108 personnel by 2020.

Case study addendum: Iraqi losses facing ISIS

The Iraqi Security Forces (ISF) fought ISIS with a similar mix of equipment to the Saudi forces. Their MBT was the M1A1, a predecessor to the M1A2S and a mix of M113 APCs with more modern MRAPs and M1117s. The ISF suffered heavy losses from frequent ambushes and concentrated attacks against isolated and unsupported outposts. In the battle of Mosul, its Abrams losses were so severe that the country's President ordered the ISF to stop using them inside the city. As is the case for the Saudi M1A2S, videos of ATGM engagements against Iraqi M1A1s indicate a tendency to cook-off very shortly after an engagement. Whilst both vehicles store ammunition behind armoured blast doors and blow-out panels, the extent of the cook-off and resultant blaze would at least result in an effective mission-kill of the vehicle. In many cases, ISF armour was unsupported, or reliant upon coordination with Western partners for air and indirect fire support. This indicates, along with Saudi losses, that the use of armour in cases where it can be isolated and engaged without the protection afforded by air support, is unlikely to produce favourable results.

Assessment

The 2015 and 2016 offensives of the Gulf Coalition were largely successful in driving Houthi forces out of Aden and preventing an immediate collapse of the Yemeni government and anti-Houthi resistance. The initial mission for which the armoured vehicles were deployed was therefore successfully achieved, even if the remainder of the campaign is seen to have failed.

In circumstances where the Coalition forces were vulnerable – stationary guard posts on the Saudi-Yemen border for instance – the Houthis were able to exploit this with successful engagements using ATGMs. This tends to be disregarded as a tactical as opposed to technical shortcoming, however it is worth noting that survivability of Israeli vehicles in stationary positions was improved with the addition of Trophy. UAE vehicles are ostensibly more survivable based on loss counts, but it is impossible to assess whether they were engaged in as heavy fighting as the Saudi forces. Finally, it is abundantly clear that a non-state aggressor is capable of delaying and degrading modern armour. The use of the AM-50 against the sights of the Leclerc and external fittings was unlikely to turn the war in the Houthis favour, but it would have degraded vehicle availability and combat readiness.

It seems that in many cases, Saudi armour was acting alone - either without supporting infantry - or without the wrap-around capabilities of combined arms. There are many accounts of isolated Saudi outposts and armoured columns being destroyed or overrun by well-organised Houthi attacks. However, in cases where Saudi forces were supported by Apaches or close air support, the Houthis usually lost the engagement. This reinforces the assessments from the two previous case studies.

Conclusion

From the fields of Ukraine to the cities of Gaza and Iraq, or the deserts and cities of Yemen, this report has examined (briefly) the performance of the best-protected armoured vehicles in the world. It shows that losses are common and should be expected when adversaries are capable of deploying advanced anti-armour weapons such as the Kornet or Yasin-105. It indicates that armour can be survivable and lethal if properly protected by layered matrices including an APS and reactive armour. However, it also reveals the limits of modern armour.

In the cases where combined arms tactics have not been used or platforms have been deployed in isolated packets without supporting fires, attrition is high. This is a recurring theme and cannot be dismissed. This hypothesis is not new, nor is it exciting. However, it should form a central pillar of every discussion around armoured warfare. The excited reporting ahead of Ukraine's counter-offensive was rarely tempered with a sober discussion of the need for combined arms and overwhelming firepower when approaching prepared defences. The Israeli offensive into Gaza was overshadowed by propaganda, with many assuming the IDF would suffer unacceptable losses because of a failure to account for the effects of armour coordinated with massed fires and close air support. Iraq's losses in Mosul showed the risks of engaging a well-prepared and driven opponent using heavy armour without infantry, and the Saudi losses on the border with Yemen demonstrate that static armour does not make for a deterrent if it is not supported by sensors and systems that enable it to shoot before an opponent.

At a technical level, it is worth returning to the statement made at the outset of this report. Many of these vehicles have been modified to meet existing threats rather than built to counter them. This means that in some cases, they are perhaps facing modern threats at a disadvantage. For instance, how much more survivable would a T-72B3 be if it could redistribute its frontal armour to its sides or relocate its autoloader into a turret bustle? ATGMs are clearly problematic, however ERA and an APS offer a solution that is challenging for them to negate. Small drones are everywhere and can have dramatic effects if deployed en masse, however they have been covered only briefly here. The reason for this, is that beyond deploying grenades into the open hatches of vehicles that might already be disabled, FPV drones face a lethality problem; until they can deploy larger warheads, it will be difficult for them to make a real impact against heavy armour. Their effects are far more pronounced in correcting artillery fire or targeting the unprotected aspects of a force.

Overall, this study indicates that armour requires a matrix of elements to have an effect against modern threats. At the inner levels, advanced composite and reactive armour combined with an APS is fast becoming essential. Beyond this, good sensors and battle management is key to coordinating efforts and sharing data between platforms. However, all of this will come to little if it is not part of a combined arms formation operating with full supporting firepower from the land, sea, and air. This conclusion should be clear to most, however, it is an important one to re-emphasise in an attempt to move capability discussions away from a comparison of gun size and armour thickness, to one of combined arms effectiveness.

Awaiting the Lithium dawn

Mark Cazalet

As the green transition begins, militaries are left weighing the benefits of a transition from internal combustion engines (ICEs) to hybrid electric vehicles (HEVs) and even battery electric vehicles (BEVs). The defence industry has already begun to promote some of these technologies and to showcase what is currently possible. However, the big question remains – is making the switch viable right now?

On the face of it, there are a lot of positive benefits up for grabs by militaries through a transition to HEVs and BEVs. These range from to lowering the vehicle's thermal and acoustic signatures, helping to decrease average detection distances by being cooler and quieter, to improving the vehicle's 'silent watch' capability (the ability to keep a vehicle's core mission systems operating without running the main engine), to extended vehicle range and budgetary savings through reductions in demand for hydrocarbon fuels. However in engineering, benefits rarely come for free, and electric vehicles are no exception.

Economic factors remain a critical consideration for operating a vehicle fleet, and benefits such as fuel savings would need to be weighed against the short-term procurement and training costs, as well as the longer-term spares and maintenance costs of running such a fleet. Aside from economic factors, there are some much more immediate physical and engineering factors which need to be considered when looking at BEVs in particular.

As such, before dealing with HEVs, we will first compare the two opposite ends of the spectrum – all-electric BEVs and conventional ICE vehicles, as this will help to highlight the strengths and weaknesses of battery technology as it exists currently.

Credit: AM General

A CG render showing AM General 'Humvee Charge' hybrid electric vehicle. A lower acoustic signature, exportable power, and extended range compared to ICE vehicles are a few of the potential benefits of adopting hybrid electric drive.

Battery impact on payload capacity

Perhaps one of the most important figures in when making logistical considerations is payload capacity, a figure which can be derived by subtracting the vehicle's curb weight (how much the vehicle weighs when empty) from its gross vehicle weight rating (GVWR) – the latter represents the total design weight of the vehicle which cannot be exceeded, and includes passengers, fuel, and cargo.

To use a representative example, if an ICE-powered truck (assuming a rigid body truck for the sake of simplicity) has a curb weight of 9 tonnes, and a GVWR of 30 tonnes, then the vehicle can hold a maximum of 21 tonnes of non-towed payload. However, some of this weight has to account for the fuel and the driver, along with any spare parts or necessary supplies. So if we assume a value of approximately 800 kg in fuel, along with 100 kg for the driver, and 100 kg for a spare tyre plus some supplies, we are left with a useful payload of 20 tonnes remaining for carrying cargo. Since the Lithium-ion (Li-ion) batteries commonly used for electric vehicles have vastly inferior energy density compared to hydrocarbon-based fuels (both in gravimetric and volumetric terms), a BEV truck will necessarily be significantly heavier than an internal combustion engine (ICE) vehicle of the same approximate automotive performance. This added weight quickly begins to eat into payload capacity, as we see in the rough, back-of-the-envelope calculations below.

In gravimetric terms, diesel fuel provides approximately 12,600 Wh/kg, while a lithium-ion battery (depending on the individual design) can range from around 300 to 500 Wh/kg. As such, at first glance, it would seem that a Li-ion battery pack would need to be around 25-42 times (depending on the exact battery design) heavier than the equivalent amount of energy in hydrocarbon-based fuel. However, this potential energy doesn't quite translate perfectly into real-world usable energy, since there are efficiency losses to heat in burning hydrocarbons which need to be factored in. Using diesel as our example, this fuel has a peak efficiency of around 50% in optimal conditions. Since these conditions will not be met all the time, we will assume an average efficiency of 45%. To feed this back into our energy density calculation, we end up with an effective energy density of about 5670 Wh/kg for the sake of this thought experiment.

Assuming this ICE truck has a diesel fuel capacity of 940 litres, this would weigh 800 kg, and we will assume a representative range of 700 km at full load with this fuel capacity. This results in an effective total energy of 4,536,000 Wh required to drive a 30 tonne vehicle for 700 km, and

this is the figure a BEV truck would need to aim for to match the ICE truck's range. BEV batteries are much more efficient, with a charge/discharge efficiency of around 95% to 98%. Assuming the best-case latter figure, to translate this into an effective energy density figure for a 500 Wh/kg battery, we would get 490 Wh/kg. Thus, in order to reach the 4,536,000 Wh required to drive 700 km, a hypothetical BEV truck would need 9,257 kg worth of battery – over 11.5 times more in 'fuel' than the 800 kg of the ICE vehicle. This would naturally cut into the vehicle's available payload capacity, leaving only around 10 tonnes for payload, compared to 20 tonnes on the ICE truck.

There are several options for designers looking to overcome these problems using available options. The first is sacrificing range, since this would allow weight savings on the amount of battery required. To go back to our hypothetical BEV truck example, if we were to halve the range requirement, we could halve the battery capacity, and our hypothetical all-electric truck would be able to go from carrying 10 tonnes of cargo for 700 km to carrying 14.6 tonnes for 350 km. While this is an improvement, it also limits the truck to shorter journeys. A perhaps better solution is to limit BEV logistics vehicles to serving as tractors for semi-trailers, rather than as rigid-body trucks. Since towing a load is easier in terms of energy requirements than carrying the same load directly on the platform, this would greatly help to close the performance gap between ICEs and BEVs for many typical day-to-day applications.

Neither option is ideal. Many militaries are likely to require both rigid-body trucks for numerous applications, and a long-haul capability is desirable in wartime conditions, particularly when operating in austere environments. Limiting BEV logistics vehicles to niche roles also provides the problem of reducing fleet commonality, which would necessitate more types of spare parts, storage, and training for how to repair and maintain them.

While the added weight already poses problems for logistical vehicles, this problem only increases in magnitude when considering battery electric drive for armoured fighting vehicles (AFVs). Most such vehicles already operate very close to their GVWR, due to their armour taking up much of their theoretical payload capacity allowance. While many modern AFV designs have a built-in margin for future growth, this margin is often relatively modest, typically in the order of a few tonnes. This gives AFV designers very little room for manoeuvre when considering adapting existing vehicle designs to battery electric drive. Aside from this added weight, there is also the impact of added volume to consider.

Credit: Scania

A Scania electric tractor with semi-trailer. Several companies including Scania and Tesla have entered the electric truck space. However, the regional-distance designs revealed thus far have all been tractors with semi-trailers. Scania has already revealed a rigid body electric truck for shorter-range urban deliveries, and is working on a regional-distance version.

Battery impact on volume

A further consideration are the volume requirements of batteries. Once again, they are less efficient than their hydrocarbon-based counterparts. In volumetric terms, diesel has an energy density of 10,722 Wh/L, reducing to an *effective* energy density of 4825 Wh/L after factoring in efficiency losses of 55%. This can be contrasted to around 750 Wh/L for Li-ion batteries used by BEVs, reducing to 735 Wh/L when factoring in efficiency losses of 2%.

To bring this back to our previous comparison, to reach the 4,536,000 Wh of energy required to drive a 30 tonne vehicle 700 km, the ICE truck requires roughly 940 litres of fuel. By contrast, to attain the same range, a BEV truck would need batteries

Credit: US Army/Stephen Baack

Advanced Ground Mobility Vehicle_(US Army; Stephen Baack)
Caption: General Dynamics Land Systems' Advanced Ground Mobility Vehicle on display at the Renewable Energy Rodeo and Symposium at Fort Bliss, Texas, in June 2010. The vehicle is hybrid-electric capable with in-hub electric drive. Hybrid vehicles for military purposes have been quietly under development for many years.

occupying about 6,171 litres of space – over 6.5 times more. However, this comparison is not entirely fair, since there are a lot of automotive components an ICE vehicle possesses which a BEV equivalent would not need. Typically this would include the ICE engine, gearbox, clutch/torque converter, fuel tanks, drive shaft, differential, and any transfer cases. All of these components together occupy quite a large volume inside the vehicle, which can effectively be regained for battery storage space.

The space savings would be especially pronounced if the BEV uses in-hub motors, since mounting the drive motors inside the wheels would provide even greater in-board volume savings for battery storage. However, in-hub drives can expect a lower life expectancy compared to in-board motors due to their direct exposure to terrain shocks and the elements. They also represent a point of vulnerability to enemy fire, which could result in a mobility kill of the target vehicle. Added to this, in-hub motors would represent a very large increase in the unsprung mass of the vehicle, which in turn would require a more capable suspension system and shock absorbers (likely further increasing weight) to compensate for the added upward inertial force of heavier wheels, and is likely to result in overall worse handling characteristics. The effect would be especially pronounced when travelling over rough terrain.

The added inertial load of in-hub motors would likely have additional effects when on AFVs, such as greater difficulties stabilising cameras and weapons while the vehicle is in motion, making accurate fire on the move more difficult to achieve. This could also result in incompatibility with weapon stations and turrets designed around current typical vehicle vibration limits, and may require special modifications to cope with the higher inertial loads on the wheels. As such, while in-hub drives may make it easier to find space for battery storage without adding to volume requirements, they are not necessarily the most desirable solution.

Using a conventional in-board motor to drive one set of wheels would be an alternative, but if all-wheel drive is a requirement, in typical BEV designs the various axles need their own motors powering them, with their own transmissions. This in turn would cut into space that could have been used for battery storage, meaning the designer would need to find the additional space elsewhere. Having said this, electric motors can be fairly small, and most BEV transmissions are single-speed, so both can be fitted into a fairly compact package compared to their ICE equivalents. As such, the final impact of multiple motors and transmissions on internal volume would likely be relatively minimal.

In sum, while the difference between ICEs and BEVs is not quite as pronounced when dealing with volumetric energy density as it is with gravimetric energy density, this gap nonetheless has the potential to pose serious problems of its own. If the space cannot be found by just replacing ICE drive components, new space would need to be found, which would likely impact final vehicle dimensions and thus automotive performance.

Increasing vehicle dimensions is a complex prospect. Making the vehicle wider would render it unsuitable for some roads, and complicate manoeuvring in tight spaces, as well as possibly put the vehicle outside of common rail carriage limits. Making it taller would also limit access in some areas, such as roads passing under low bridges. Making it longer would be easier, but would increase the turning circle, making it harder to manoeuvre in tight spaces.

Finding some additional volume may pose less of a problem for logistical vehicles, yet it becomes a nightmare for AFVs, which already struggle with internal volume even in the best cases. Indeed, the search for ever-more internal volume has been one of the major driving forces behind why today's AFVs are often many times larger than their Cold War equivalents. Beyond volume, the case for military BEVs looks weaker still when factoring in the real-world environmental conditions a BEV may face.

The role of temperature on battery performance

While battery efficiency is very high under optimal conditions, it varies greatly depending on the ambient temperature. Fan Yang et al noted in their June 2018 paper in Nature that the driving range of a BEV using Li-ion batteries can drop significantly under both high and low temperature conditions, as summarised in the table below:

Ambient temperature	Loss of range (local driving)	Loss of range (highway driving)
-18°C	57%	40%
35°C	27%	10%

As the table shows, these losses can be quite considerable, particularly in cold weather. To bring this back to our hypothetical BEV truck – if it needed to drive 700 km in cold weather conditions of -18°C, we could anticipate needing approximately 14,533 kg of battery, thus cutting further into the useful payload. The alternative would be stopping to recharge, but this would result in highly variable mission timescales in different environments. This is far from ideal for military planners.

Added to this, battery degradation over time also poses a significant problem to BEV overall efficiency. This happens as a function of both how often the battery is charged and discharged, known as 'cycling capacity loss', and time, known as 'calendar capacity loss'. As noted by Yang et al, average ambient temperatures play a significant role in both, but particularly in calendar capacity loss, with greater degradation noted in hot climates compared to cooler climates:

Geographic Location (average temperature)	Annual calendar capacity loss after the first year	Annual calendar capacity loss thereafter
Alaska (-2.7°C)	4.4%	1%
Hawaii (24°C)	9.6%	2.2%

As such, the 98% efficiency figure cited earlier represents an EV's peak performance at the start of its life, under optimal temperature conditions. The real world is rarely as forgiving. Consequently, our hypothetical BEV truck could expect a significant reduction in range in realistic conditions over time, with the speed of degradation varying by geography and climate. This would impact life cycle costs, with replacement batteries becoming necessary to maintain performance. Yang et al cite the agreed-upon maximum battery degradation limit as being 30%, and noted that according to their data, this would translate to BEV batteries requiring replacement every 5.2 years in Florida's warm climate, and every 13.3 years in Alaska's cold climate.

Given that most military vehicles can be expected to spend the majority of their life outdoors, in a variety of weather and temperature conditions, this is not ideal. There are engineering solutions to this problem, such as the use of heating, ventilation, and air conditioning (HVAC) systems to cool or

heat the batteries to their optimal operating temperature as needed. However, these add a degree of complexity and cost, and would primarily help when the vehicles are being used, rather than when they are left parked outdoors in an inactive state.

BEVs look to remain light over the short term

Given the above problems, it would be easy to write off BEVs as un-viable for military applications entirely, but things are not so straightforward. Speaking to representatives of GM Defense at IDEX 2023 in February, ESD was told that given where battery energy density currently sits, BEVs are viable, but mainly at the lighter end of the military vehicle market. According to Jim Khoury, then Assistant Chief Engineer at General Motors, the approximate dividing line for viability currently sits at around 5,443 kg (12,000 lb) – if the vehicle is lighter than this, batteries become a viable option, while if the vehicle is heavier, hydrogen or hybrid electric propulsion are the more viable options.

Khoury also noted that battery energy density has tended to increase every 2-3 years, and said that he estimated battery energy density would double within 10 years. According to Khoury, one effect of this doubling, is that it will raise the dividing line at which BEVs become viable, from their current level, to approximately 7,257 kg (16,000 lb). This latter figure is a large increase in relative terms, yet in absolute terms it remains far shy of the kinds of weights needed for implementing battery electric drive on medium-weight armoured vehicles, which normally range from 15-40 tonnes, let alone heavier vehicles such as main battle tanks, which are typically over 45 tonnes at the lighter end. As such, it would appear that the prospects for heavier BEV AFVs remain very limited over the medium term.

When ESD spoke to Jensen Chew, Product Director for Powertrain Electrification at ST Engineering, he agreed that this divide was likely to remain, with BEV technology used for generally lighter vehicles, and HEV for heavier vehicles, albeit only for the near-term future. Jensen stated that over the longer term, we will start to see full electric drive used for various vehicles ranging from light to heavy, wheeled and tracked. Jensen foresees this coming as a result of both continued research and proliferation of electric vehicle technology globally, and as the result of simultaneous scaling down of R&D of ICE engines.

Credit: GM Defense

Shown here is the GM Defense concept BEV known as the electric Infantry Squad Vehicle (eISV), which weighs just under 2,232 kg. For at least the next decade, BEVs are likely to remain on the lighter side. However, advances in battery technology are expected to gradually permit heavier designs to become viable.

Here Jensen touches upon an often-neglected point – that ICE engines will require continued development to match evolving efficiency requirements and emissions standards. As the investment funding and research efforts drift increasingly toward BEV technology, there is likely to come a point where ICE engine development effectively halts at large scales, giving BEV technology a greater chance to catch up and even overtake.

For the time being, however, there appears to be consensus in industry that current with current battery energy densities, hybrid drive currently represents a more viable approach to the heavier end of the AFV segment. Since HEVs primarily rely on their ICE to provide most of their power, their dependence on batteries is far lower. As such, HEVs comparatively have to sacrifice a much lower portion of their payload capacity and internal volume than BEVs. At the same time, HEVs can make use of their batteries to supply power when needed, providing a 'silent watch' capability, and allowing the vehicle to switch to electric drive when a lower acoustic signature is required. These characteristics lend themselves to military applications much more easily than current BEVs.

However, this does not mean that HEVs will necessarily reign supreme for the long-term. While HEVs are the more viable option for heavier vehicles today, many of the advances to be made in improving HEVs, will directly improve BEV viability at the same time. Examples include advances in battery chemistry, the development of energy-dense solid-state batteries, and the development of regenerative power systems. Over time, these advances may eventually tip the scales in favour of BEVs in all weight categories.

The promise of regenerative power

To close the power density gap with ICE vehicles, there are a number of measures which BEV and HEV manufacturers are looking into, with a particularly important development in this area being regenerative power. This technology has been used in Motorsport since around 2007, most famously on Formula 1 cars since 2009 in the form of a kinetic energy recovery system (KERS). This system works by recovering energy from the vehicle's wheels during braking, and storing it for later use, such as supplying additional power and torque to the wheels when needed. Typically this energy would be stored in a battery on F1 cars, but it's also possible to use supercapacitors or a flywheel to achieve much the same result.

The technology began to make its way into the commercial hybrid vehicle market and public transport applications shortly after its adoption by motorsport, referred to by the generic term 'regenerative braking'. On hybrid vehicles the benefits are clear – by harvesting some of the energy that would otherwise be wasted during the braking process, regenerative braking provides the vehicle with what is essentially free energy, and can be used to top up the battery slightly, increasing its available power and thereby improving range.

Credit: Mark Cazalet

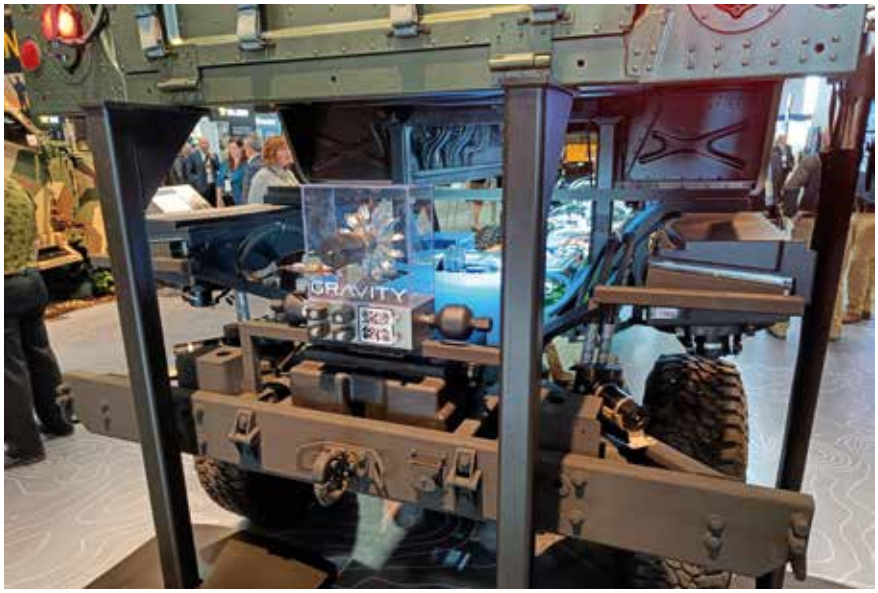

Image shows the turbine generator for the 'Gravity' system, with its paddle-shaped blades for catching the high-pressure fluid sprayed from the accumulators.

Going a step beyond regenerative braking, a US company known as Gravity Driven has developed a means of recovering energy from the vehicle suspension system, simply known as 'Gravity'. This system operates by using a series of hydraulic shock absorbers which are modified to be more akin to pistons – moving upward or downward to pump fluid at pressure via the top and bottom of the cylinder. The cylinder is combined with fluid tubes and valves to create a closed-loop circulation system for fluid under high pressure.

Whenever the vehicle's wheels move up in response to vehicle tilting, unevenness in the terrain, or back down from the return force of the vehicle suspension, their movement drives the piston along with them. The up and down action of the piston forces some of the fluid into one of two fluid accumulators. Once these accumulators have reached a predetermined pressure level, they discharge the pressurised fluid, spraying it onto the paddles of a turbine generator, which is rotated by this force, producing energy, thereby recharging the vehicle. The manufacturer has claimed that this system is capable of increasing an electric vehicle's range by as much as 40%.

Credit: Mark Cazalet

The 'Gravity' system integrated with a 'Humvee Charge' was displayed at AUSA 2023. Note that in this setup, the system's piton has been mounted within the vehicle's coil spring suspension, with the latter providing return force to move the piston back down.

It should be noted that unlike the fairly common hydro-pneumatic suspension, the 'Gravity' system itself does not use a pneumatic component, as it is intended to complement the host vehicle's suspension rather than replacing it outright. Therefore the vehicle's existing suspension (whether based on hydro-pneumatics or a mechanical spring) would provide the return force to lower the wheels to their original position.

An advantage of this system over regenerative braking is that the system does not require the vehicle to brake, and thus can be done during while travelling at a fairly constant speed. However, one side-effect of this setup is that the frequency at which the system can recharge the vehicle is inherently tied to the degree of travel of the suspension, since it is this motion which charges the fluid accumulators. This means that in theory the 'Gravity' system should function even more effectively when travelling over rough terrain than on smooth roads, since in the former case, the suspension would experience comparatively more travel per unit of distance traversed.

On the subject of regenerative power systems, ST Engineering's Jensen noted, *"regenerative power recovery technologies to close the gap between all-electric and ICE drives is good technology. However, technologies, no matter how promising need to be industrialised for ease of manufacture as well as to be affordable. This will be the most critical stage of any new technology to ensure adoption."*

Starting the transition

The 'Gravity' system was showcased on a HEV configuration of the 'Humvee Charge' developed by AM General and Qinetic, which was displayed at AUSA 2023. When ESD asked about the viability of a HEV or BEV for the US Army, an AM General representative noted that although an all-electric HMMVW may not be something the US Army is actively pursuing at the moment, such a vehicle could find an initial usage niche in the US Army National Guard, whose domestic mission profile would mean lower barriers to entry for the adoption of a HEV or BEV than the regular Army. Indeed, here, the AM General representative touched upon an interesting point. Many of the critiques of adopting BEVs (and to a much lesser extent HEVs) into military service have centred on some of the

challenges they would face on the frontlines, particularly when operating in austere conditions and exposed to enemy fire. However, most major militaries have large vehicle fleets dedicated to non-frontline tasks many of which in practice rarely leave their home bases. Alongside National Guard or Territorial Army units, in regular service these can include airfield re-fuelling vehicles used by air forces, resupply vehicles used by navies, fire engines, mobile generators, some utility and staff vehicles, along with various types of transporters or loaders not tied to frontline units. Some of these vehicles could make good candidates for an earlier transition to hybrid or electric drive than their frontline counterparts, decreasing the fuel requirements of daily operation for armed forces.

While vehicles in the aforementioned roles may be the first tentative steps into the BEV world for militaries, it is likely that they will not be the last – with recent concept vehicles AbramsX and StrykerX both featuring a hybrid electric drive, and both conceptually intended for service on the frontlines.

Overall, there are many good reasons to begin the transition to HEVs, not least because the power demands of modern mission systems are beginning to reach levels where traditional ICEs are having trouble keeping up, as noted by Jensen, *"Whilst batteries have a lower load capacity, concurrently, the battlefield electrical loads have been increasing to the extent that traditional alternators and batteries start to have challenges in keeping up with the demand. This is where Hybrid Electric Drive vehicles have an advantage. In terms of payload, from a vehicle design perspective, it is about tradeoffs and balancing between battery capacity (size) versus payload."*

Credit: GDLS

The StrykerX (left) and AbramsX (right) concept vehicles unveiled by GDLS in October 2022 both featured hybrid electric drive.

Addressing safety concerns

Battery safety has been another sticking point in the adoption of BEVs into military roles, particularly given that Li-ion batteries have become notorious for being liable to rapidly ignite when punctured. By contrast, the diesel fuel used by many military vehicles is very difficult to ignite naturally, typically requiring compression, which makes it relatively safe even when

Credit: Mark Cazalet

A scaled-down model of GM Defense's 'Ultium' solution integrated with a vehicle platform. The approach taken by GM Defense is one of a large integrated battery housing, containing 12 smaller modules for an SUV-type vehicle.

exposed to enemy fire. In fact, it has even been used as a form of protection on some vehicle designs, such as the BMP-3, which features a self-sealing fuel tank in front of the driver's position, to provide additional protection in case the main armour is penetrated. However, battery safety has not stood still.

On the subject of battery safety, Jensen noted, *"the current approach for the use of Li-ion batteries is with five different levels primarily to address safety. This starts with battery type & chemistry selection, followed by the level of monitoring and intervention by the Battery Management System. The preceding two would have defined battery selection and after which the focus is on the Thermal Management System of the battery which we go beyond just the traditional ethylene glycol type cooling before we look at battery containment and finally platform configuration. The last two [levels] will address battlefield threats."*

Other manufacturers have likewise taken multiple precautions to ensure battery safety. Khoury stated that GM's battery technology has been modelled to survive an 18g crash, and fire prevention measures are present both at the battery module level and at the vehicle integration level.

While it remains to be seen how effective these measures will prove their worth on a real-world battlefield, the initial signs are that manufacturers are taking the issue very seriously, and seeking to use multiple means to ensure that catastrophic battery fires – whether from thermal runaway or penetration by hostile fire – are prevented. An important, related question is how BEVs and HEVs should be repaired when damaged.

Modularity and field repairability

In most current vehicle designs shown so far, the batteries are built into the floor of the chassis, effectively forming a structural part of the vehicle. This is a good way to maximise the amount of batteries which can be fitted into the available volume, however, it is not necessarily the best approach for field repairability or the ability to rapidly 're-fuel' the vehicle. In the latter scenario, smaller 'hot-swappable' battery packs may be a more desirable choice for BEV users, as they would allow a crew to swap out spent battery packs for fully charged ones, negating the need to spend precious minutes recharging.

Yet opting for a 'hot-swappable' battery design may come with some design trade-offs, such as a lower overall range because some volume would need to be sacrificed to make each battery module removable. It would also likely drive up production cost, as it would require a more complicated design, with the requirement that the modules are crew accessible. A further question to consider would be whether the user would prefer a smaller number of larger modules which can be hot-swapped using specialised heavy-lifting equipment at a base, which may entail a smaller volume and complexity penalty, or a larger number of smaller modules which can be hot-swapped by soldiers directly in the field, which may entail a larger volume and complexity penalty.

Choosing between maximising available power and the convenience offered by hot-swappable batteries is a difficult choice. Jensen shared his thoughts on the different use-cases for each, *"In my view, hot-swap capability and high power density are just as important. This is because it is about how the users use their vehicles. As an example, if we juxtapose the manner in which a non-expeditionary force versus an expeditionary force operates, with the assumption that it is BEVs, battery hot-swap may make more sense to have vehicles on a continuous operation cycle for the former, whereas an expeditionary force may prefer integrated batteries but operating at a higher voltage for fast charging."*

Credit: Mark Cazalet

A scale model of GM Defense's 'Ultium' battery module. Essentially this is an aluminium block housing 24 smaller pouch-type cells. Theoretically, such a module would be small enough to allow for hot-swap to be an option, if this were a direction the company decided to go in.

Adoption of one design over the other would have a direct impact on vehicle repairability and life cycle costs, with integrated battery vehicles more likely to need to be sent back to the factory for repairs to damaged battery modules, since the manufacturer would be more likely to have the tools and skills needed to remove and repair or replace the damaged integral battery pack. By contrast, hot-swappable designs would lend themselves to better repairability, since damaged modules could be easily swapped out for spares. Additionally, hot-swappable designs would allow

for simpler upgrading – if a standardised battery format is used, older models could be rapidly swapped out for newer, higher-density models without the need to send the vehicle back to a factory to replace an integrated pack.

Either way, manufacturers have an incentive to pick one approach, as a standardised design would allow for cost savings on the manufacturing side, leveraging economies of scale. As such, perhaps a compromise between the two designs is a safer approach. For instance, BEVs could use an integrated battery pack to store the majority of their power, but also have one or two small hot-swappable battery modules in case emergency power is needed in the field. This would allow for both efficient use of available volume, while also allowing a degree of field-repairability and redundancy. For instance, if the integrated battery on a BEV becomes damaged or simply runs out of charge in the field, the vehicle in question would have the option of making its way back to base under the power of hot-swap batteries borrowed from other vehicles in its platoon.

Times change

Even within the last few years, battery technology has come a long way in terms of power density and safety. One must remember that in many ways battery technology is still relatively nascent. It took decades of continuous development for ICEs to enjoy the levels of power and efficiency that they enjoy today, and similar levels of effort will no doubt need to be expended to get BEVs where militaries would like them to be.

Nonetheless, external factors such as mission system power demands, and the requirement for a silent watch capability, are already pushing militaries to look beyond traditional solutions such as auxiliary power units. Power demands are likely to increase further as directed energy weapons (DEWs) such as high-energy lasers (HELs) and high-power microwaves (HPMs) start to become adopted, along with active protection systems (APSs) and jamming systems for defending against small unmanned aerial vehicles (UAVs) and loitering munitions continuing to proliferate and increasingly becoming a standard part of a vehicle's protective suite. Added to this, exportable power is also likely to become a greater requirement as manned-unmanned teaming (MUM-T) becomes more commonplace, with manned ground vehicles increasingly operating alongside UAVs and unmanned ground vehicles (UGVs).

Additionally, as the civilian world increasingly transitions toward HEVs and BEVs, and R&D into ICEs begins to decline, military vehicles are at risk of being left behind. Many vehicle manufacturers have both civil and military product lines, and tend to seek synergy between the two where possible. As the civil sector increasingly transitions to HEVs and BEVs, manufacturers would likely incur significant costs by keeping open ICE vehicle production lines and supply chains just for militaries, which tend to make infrequent, low-volume orders, and represent a relatively small market share compared to the civil automotive sector. Such costs would in all likelihood be passed on to the customer, likely decreasing ICE affordability and increasing through-life costs over the long term.

In sum, while BEVs may not yet be ready for mass adoption by militaries in all vehicle classes, there are certainly some roles where militaries could look to make the switch, particularly with vehicles expected to serve primarily on or near domestic bases. Closer toward the frontlines, HEVs represent a good compromise between ICEs and BEVs, providing added power to run power-hungry mission systems, along with improved signature management for greater survivability, and generating overall fuel savings for the vehicle fleet, while continuing to benefit from advances in battery technology as they come.

It may be perhaps a few years too soon to herald the arrival of the lithium dawn for military vehicles, but over the next decade this is very likely to change. Yes, current BEV technology leaves a lot to be desired from a military perspective, but this is changing fairly rapidly, driven in large part by the civil automotive sector. Militaries are not immune to industrial or economic pressures, and the trends driving the rest of the world to electric vehicle adoption are not going to disappear. Sooner or later then, the electric AFV era is likely to arrive in earnest, and now is a good time to start preparing for it. ■

Credit: BAE Systems

BAE's ACV C4UAS prototype, proposed for the USMC's Advanced Reconnaissance Vehicle (ARV) programme. The vehicle is a good example of the massive growth in mission systems seen on contemporary designs, with the vehicle equipped with optoelectronic sight, 360° cameras, radars, a UAV, and what appears to be either an omnidirectional UAV jamming system or possibly a direction-finder.

Examining the future of C-UAV and C-RAM

Sidney E. Dean

The battlefield threat posed by small and medium unmanned aerial vehicles (UAVs), as well as by precision artillery continues to evolve. Both are driving a demand for counter-UAV (C-UAV) and counter-rocket, artillery and mortar (C-RAM) systems, and there is a good degree of overlap between the two. Intense research and development efforts are necessary to devise technologies capable of effectively countering these evolutionary – if not revolutionary – threats.

The threat spectrum today is quite broad and includes medium-sized reconnaissance and strike aircraft, as well as smaller-to-micro-sized UAVs. A portion of these medium-to-small aircraft are purpose built for military applications, but recent conflicts have demonstrated that commercial and consumer-oriented civilian UAVs can be readily reconfigured for combat and combat support missions. The tactical UAV category (often referred to as the 'Small Tactical UAS' (STUAS) category in the US) has become especially ubiquitous in recent conflicts, in part because of their low cost, high availability, and relative ease of use. In 2021, the then commander of US Central Command, US Marine Corps (USMC) General Kenneth McKenzie, considered the spread of tactical UAVs as "the most concerning tactical development" since the rise of improvised explosive devices (IEDs) during the Iraq conflict. "I think what we are seeing is the rise of a new component of warfare," McKenzie said.

His assessment rings true. In the intelligence, surveillance, targeting and reconnaissance (ISTAR) role, small to very small UAVs can approach enemy formations with a relatively low risk of detection, providing information about troop movements or conducting spotting, fire correction, and post-strike battle damage assessment for artillery. Electronic reconnaissance and offensive electronic warfare (EW) are additional missions for UAVs. In the attack role, even commercial-off-the-shelf (COTS) hobbyist small UAVs can be configured to either carry and release ordnance over enemy forces, or to act as loitering munitions (LMs; often referred to as 'suicide drones' or 'kamikaze drones') carrying explosive payloads all the way to impact. Such LMs can patrol a given sector until sighting a sufficiently valuable target of opportunity. They then effectively transition from a surveillance drone to a precision-guided munition (PGM).

Credit: DARPA

Concept of an integrated sensor and effector network of ground vehicles and a UAV to coordinate defence against an attacking swarm.

Ukraine – the greatest drone war

Conflicts over the past two decades have highlighted the increased role of UAVs by armed forces worldwide. The dramatic impact of ad hoc reconfigured COTS systems was first fully registered a decade ago during the ISIS/Daesh insurgency in Iraq (although various other irregular forces discovered their utility around the same time). A new intensity has been reached in the ongoing war in Ukraine, where UAVs and artillery feature among the most important weapon systems deployed on the battlefield. Tens of thousands of UAVs have been launched over the past two years, making this a drone war on a scale never seen before. Fixed-wing, global navigation satellite system (GNSS) and inertial navigation system (INS) guided, medium-sized UAVs, such as the Iranian Shahed 131 and 136, strike fixed infrastructure targets, while those equipped with optronic infrared (IR) sensors – such as the Turkish Bayraktar TB2 – can attack mobile military vehicles with guided bombs and missiles. Ukraine's domestically-developed AQ 400 Kosa UAV has sufficient range to reach Moscow with a 32 kg payload, or shorter distances with a 65 kg payload. Kyiv plans to increase production to 500 units monthly.

In much greater numbers, small UAVs have targeted soldiers in foxholes and trenches, where they were largely shielded from other battlefield threats. Attacking as a single unit and also in swarms, revamped COTS-based quadcopters have also been able to destroy armoured vehicles up to and including main battle tanks (MBT). Many small UAVs are radio remote controlled via a radio frequency (RF) link. This includes so-called first-person view (FPV) UAVs, which

effectively function as improvised LMs – the onboard camera provides the operator with a pilot's eye view, enabling very precise targeting decisions, even flying the aircraft through doorways or into open vehicle hatches. Notably, RF-controlled drone operation does not require a great deal of training; the COTS systems are designed for ease of use, and any nation with a teenage population raised on video games will have a large pool of potential pilots. More sophisticated aircraft, often purpose-built for the military, use GNSS and/or INS to fly pre-programmed reconnaissance or strike missions with minimal direct supervision. Some LMs can display autonomy in targeting, thanks to onboard databases that permit positive identification of legitimate targets. This can allow them to perform their strikes even if the radio link with the control station is jammed.

Escalating threat level

Ukraine aside, leading armed forces are investing heavily in unmanned technology. In addition to performance upgrades such as improved range and endurance, the great-

Credit: US Army/Aaron Duerk

While drone swarming technology may be relatively nascent at present, these capabilities are developing rapidly.

Credit: USAF

The Mavic 2 UAV produced by Chinese firm DJI is a high-end COTS system with a high-resolution 20 MP camera.

est focus is on using artificial intelligence (AI) to enhance autonomy. Improved AI integration will ultimately have two major operational consequences.

Swarm attacks

Swarm operations are already a reality, but are relatively nascent, and images from Ukraine represent only the beginning. The US Armed Forces have been rather open regarding plans to exponentially enhance the capabilities of autonomous swarms (while various foreign powers are certainly pursuing the same goals more quietly). The US Army has tested swarms composed of dozens of small UAVs during exercises over the past two years. In some experiments, the swarm was able to carry out reconnaissance and attack operations autonomously, following pre-programmed objectives.

According to Major General Walter Rugen, currently Director of US Army Aviation, the goal is to enable hierarchical "wolfpacks" of UAVs to operate without direct human supervision, with one aircraft assuming the pack leader role, controlling operations of other units; preselected aircraft would assume control should the leader be neutralised. Such wolfpacks should ultimately be capable of performing sophisticated multi-task operations, with each unit carrying out a specific task – such as reconnaissance, communications relay, suppression/destruction of enemy air defences (including through EW), or direct attack of the primary target – contributing to the overarching mission goal. The other service branches of the US armed forces are conducting similar experiments.

Resilient navigation

Closely related to the issue of autonomy is the quest for redundant and jam-proof navigation systems. Just as PGMs are frequently outfitted with multiple navigation systems such as GNSS, INS, and image-based or terrain-following navigation, future UAVs will likely have redundancy which includes interference-proof navigation options. Similarly, future UAVs will require multiple targeting systems to deal with various passive or active countermeasures. Targeting options could include optical and infrared, laser, or – depending on the size of the UAV – radar. Onboard defensive EW systems to minimise the impact of jamming, preserve communications links, and interfere with enemy targeting would further enhance UAV survival and increase the likelihood of mission completion.

Precision and saturation artillery

Using the chessboard analogy of warfare, UAVs have emerged as the knight on the modern battlefield, capable of manoeuvring in a unique manner, and overcoming obstacles in the process. As the war in Ukraine is demonstrating, artillery remains the queen of the battlefield, striking straight, but over long distances. Whether engaging static or mobile targets, military or infrastructure, tube and rocket artillery has demonstrated the conflict's deadliest sustained effects. Here, too, major efforts to upgrade range, precision and lethality are underway in all major armed forces. Rockets, artillery and mortars (RAM) constitute a major threat to both static installations and manoeuvre forces, with the threat potential increasing in the coming decades. As such, the imperative to improve and field C-RAM systems is increasing.

C-UAV and C-RAM requirements

Traditional missile-based air-defence systems are well suited to downing larger to medium-sized, sophisticated military UAVs and LMs on the larger side of the spectrum, such as the Shahed family. However, they are not a viable option

Credit: USMC

Major components of the USMC's LMADIS (Light Marine Air Defense Integrated System) C-UAV are the 360° RPS-42 radar mounted on an MRZR light tactical vehicle (shown here) and the man-portable Modi II jamming system.

for C-UAV operations against small UAV threats. Even when the latter can be detected within the engagement zone of very short-range air defence/ short-range air defence (VSHORAD/SHORAD) systems, their ability to be employed in large numbers would quickly drain (V)SHORAD magazines, leaving the protected units vulnerable to attack by more sophisticated aircraft or missiles. The asymmetry of cost also makes traditional air defences a financially unsustainable solution against such threats. To get a sense of the extent of this asymmetry, in May 2023, CBS News reported that a single FIM-92 Stinger family missile costs over USD 400,000 – by contrast a typical off-the-shelf small UAV such as a DJI quadcopter costs only a few hundred dollars.

To date, RF jamming continues to be the most widespread (and arguably most effective) weapon against small UAVs. RF interference works by disrupting the aircraft's navigation and control systems, either by blocking reception of the command signal from the control station, or by blocking satellite navigation frequencies to disrupt GNSS guidance. Depending on the strength of the jamming system, effects can be scaled both in intensity and in terms of the width and depth of the targeted airspace. Both sides in Ukraine deploy extensive jamming to defend their own positions from enemy aircraft, and to suppress enemy UAV capabilities ahead of offensive operations. Powerful electronic warfare systems can be mounted in fixed positions or vehicle-mounted for easy relocation. Lower-echelon tactical units are outfitted with portable jammers, while tanks and other combat vehicles have been photographed with jammers atop their turrets.

However, EW-based countermeasures have some weaknesses. Frequency hopping can often be a simple and effective means to circumvent RF jamming. Also, as

Credit: US Army

The Stryker-mounted DE M-SHORAD combines a 50 kW class laser and a multi-mission hemispheric radar to detect, track and classify threats.

Ukrainian strikes on Russian EW sites have demonstrated, the jammer's signal can be triangulated, allowing them to be located and targeted by artillery, or air-launched bomb or missile strikes.

Increased autonomy and introduction of redundant navigation systems is expected to diminish the impact of RF jamming in the future, but this will not be an absolute. Some drones will continue to rely on RF datalinks for remote control, for receiving tasking updates, or for relaying situational awareness data back to their operator. GNSS will continue to be an important navigational tool, even when additional interference-proof navigational systems become more widespread.

Jamming may still negatively impact UAV effectiveness even when it does not fully disable vehicle control or navigation. EW technology is expected to continue to advance, improving signal strength, range and effectiveness as well as using smaller portions of the electromagnetic spectrum in order to minimise collateral impact on friendly systems. The Pentagon plans to routinely field jamming capabilities at lower echelons, specifically at the platoon level, and is already experimenting with EW systems mounted on light infantry vehicles such as the USMC's MRZR. Other armed forces are pursuing a similar course.

Improved jamming alone cannot counter balance the expected enhancement of tactical UAV capabilities and operating concepts. Additional kinetic technologies are being actively pursued. Some of these measures may also be able to protect ground forces and installations from rocket, artillery and mortar (RAM) attack. Such C-RAM systems can have a large degree of capability overlap with the C-UAV role, making systems capable of undertaking both missions an attractive proposal.

Credit: Epirus

Leonidas prototype HPM mounted on the Stryker armoured vehicle demonstrates the ability to defend the manoeuvre force with microwave weapons.

High-energy laser systems

One major avenue of research for C-UAV and C-RAM is focussed on high-energy lasers (HEL). Several advantages frequently cited regarding HELs, and indeed other directed energy weapons (DEWs) is the so-called 'unlimited magazine'. Unlike missile launchers or air-defence guns, a laser can – within reasonable limits – operate as long as the energy supply is maintained.

Operating costs are also significantly lower than those of kinetic weapon systems. Here again the US Armed Forces have been making systematic progress toward testing more powerful vehicle-mounted laser systems. In October 2023, the US Army awarded Lockheed Martin a contract to develop and deliver prototypes of the Indirect Fire Protection Capability-High Energy Laser (IFPC-HEL). According to the Army, the truck-mounted objective weapon system is designed to protect fixed and semi-fixed sites from UAVs, cruise missiles, RAM threats, as well as "[manned] rotary and fixed-wing threats". The prototypes are to be delivered by 2025.

To protect the manoeuvre force, the US Army has been pursuing DEWs under the Directed Energy Manoeuvre Short Range Air Defense (DE M-SHORAD) programme. Four Raytheon-designed prototype systems mounted on Styker armoured vehicles were delivered to the Army in January 2023 to equip a platoon-sized test and evaluation unit. The 50 kW laser weapon is designed to defeat UAVs up to size class 3 (600 kg), as well as RAM threats. The user assessment phase was slated to continue through early 2024. Intermittent reports stated that the system was proving effective against UAVs but that "challenges remain" regarding the C-RAM mission. Smaller 10 kW and 20 kW systems are also being evaluated on pallets and light vehicles, but their effectiveness is limited to smaller UAV classes.

There are various suggestions regarding how a HEL could most effectively neutralise a UAV or artillery projectile with current tests demonstrating success in disabling the motor of smaller UAVs. The simplest approach would be to burn out or blind the targeting or homing system of the aircraft or projectile. This would work best against a remote-controlled or autonomous UAV equipped with optical sensors. However, this would do little to divert an artillery round from its ballistic flight path. It is important to consider that the ultimate goal is to develop considerably more powerful tactical lasers in the 1 MW range or higher. The higher the energy output, the faster any single target can be defeated or disabled. Optronics and control systems are also being improved to improve the speed with which a target can be acquired, as well as the ability to keep the beam focused on one particular spot of the target; the latter will be particularly decisive in disabling RAM projectiles, which must be accomplished by burning through the casing to reach and detonate or deflagrate the warhead.

Despite ongoing developments, several questions still remain regarding laser utility for C-UAV and C-RAM. Difficulties relate to the need to project sufficient energy onto the target and keep the beam focused long enough to disable the UAV or incoming ordnance. While lasers currently being tested are considered potentially strong enough to down an unmanned aircraft or burn through the casing of an artillery shell, laser weapons still face challenges. Beam integrity deteriorates with range, since the beam gets wider as it gets further from the source, and can also be degraded by inclement atmospheric conditions. These factors can therefore limit the effective range of a HEL. The US Department of Defense cites an effective range of approximately 1 km for today's DE weapon systems. However, battlefield conditions – including smoke from burning vehicles, detonating ordnance, as well as deployment of obscurants – can interfere with beam integrity even at shorter ranges.

Finally, the manoeuvrability of UAVs and the speed of rocket and artillery projectiles pose significant challenges to keeping a laser beam on target for more than a few seconds – especially when operating in an

Credit: AFRL

Artist's concept of the THOR HPM system capable of providing long-range defence of fixed or temporary installations.

Credit: Aurora Flight Sciences

The armed MIDAS interceptor can shoot down up to 16 UAVs per flight.

environment with many line-of-sight blockers present. Even if future HELs are powerful enough to disable a target within such a short timeframe, the need to focus on each target for several seconds makes lasers vulnerable to swarm attacks. If, for example, a laser can engage a rocket 30 seconds before impact, and requires only five seconds to target and destroy each warhead, an enemy could overwhelm the C-RAM system by launching at least seven projectiles simultaneously. While tactical HELs could ultimately contribute to the C-UAV and C-RAM operations, it seems unlikely that they alone will be the most effective solution.

Microwave weapons

Another promising C-UAV concept is deployment of high-power microwave (HPM) weapons. HPM energy can destroy sensitive onboard electronic components, disabling navigation and control systems and forcing drones to the ground. A single nanosecond-long pulse can be sufficient to down entire drone swarms simultaneously. As with lasers, the US military considers this a priority technology. "This is going to provide us the best opportunity to get after larger swarms that come your way because essentially, you're looking (at) technology, that if it continues to move, can potentially fry the electronics in these UASs," said US Army Maj. Gen. Sean Gainey, head of the Joint C-UAS Office (JCO), during the August 2022 Space and Missile Defense Symposium in Huntsville, Alabama.

Among other initiatives, there is a second IFPC leg, the Indirect Fire Protection Capability-High Power Microwave (IFPC-HPM), which is focused on developing and testing an HPM weapon. In January 2023, the technology company Epirus received a contract from the Army's Rapid Capabilities and Critical Technologies Office (RCCTO) to deliver prototypes of their Leonidas HPM system. The award followed several rounds of system demonstration, where Leonidas was reported to have outperformed competitors in defeating drone swarms and other electronic systems. The first prototype was delivered on 1 November 2023. According to Epirus, Leonidas' digitally beamformed antenna can alternately create a focused beam that disables a single target within a crowded airspace.

Epirus' CEO, Leigh Madden, added that the system's software can process input from Blue Force Trackers and IFF transponders to ensure that HPM pulses are directed around friendly forces. In October 2022, Epirus and General Dynamics Land Systems unveiled a mobile variant of Leonidas mounted on a Stryker armoured vehicle, referred to as 'Leonidas Mobile'. The Army hopes to transition IFPC-HPM to an acquisition programme of record in 2025, following prototype evaluation of the weapon system.

Other HPM systems are currently being evaluated. These include the Tactical High-power Operational Responder (THOR) technology demonstrator developed by the US Air Force Research Laboratory (AFRL) specifically for the C-UAV role. The system can be fully stowed within a 6 m ISO container, and in its ready state the steerable dish antenna of the microwave effector is visible atop the container roof. The system can be air-transported by a C-130 transport aircraft and set up and made operational by two people within 3 hours; its energy is drawn from a grid. It has been tested against single UAVs since 2021, and eliminated an entire drone swarm during the first-of-its-kind test in spring of 2023. "THOR was exceptionally effective at disabling the swarm with its wide beam, high peak powers, and fast-moving gimbal to track and disable the targets," said programme manager Adrian Lucero from the

Credit: US Army

US Army's LIDS (low, slow, small, unmanned aircraft integrated defeat system) integrates the Raytheon Coyote UAV and KuRFS radar with a Syracuse Research Corp. EW system and Northrop Grumman's Forward Area Air Defense Command and Control system. To date the Army has ordered systems to equip more than two divisions.

AFRL Directed Energy Directorate. Additional testing of THOR in the base-security role is planned for 2024.

However, the Air Force has already begun transitioning the technology to the private sector. In February 2022, the Air Force awarded Leidos Inc. a contract to develop "a next-generation counter-electronic weapon system". According to AFRL, it will build directly on the technology demonstrated by THOR, but will add enhanced capability, reliability and manufacturing readiness. Staying with the Nordic theme, the new HPM weapon system is designated 'Mjolnir' after Thor's hammer. "Because THOR was so successful, we wanted to keep the new system's name in the family […] Mjölnir will focus on creating a detailed blueprint for all future C-UAV HPM systems with enhanced range and technology for detecting and tracking UASs," said Lucero.

HPMs also have the potential to be used for the C-RAM mission, where the defeat mechanism would involve disabling precision guidance systems or possibly even the fuzes used by their targets. This would likely be (at least initially) restricted to fixed or semi-fixed installations, given the current sizes of sufficiently-powerful systems. A study released by the Air Force Research Laboratory in July 2021 – titled Directed Energy Futures 2060 – postulated that DE weapons, including HPMs and HELs, could ultimately form a de facto "force field" around high value targets, repelling not only UAVs, but also RAM threats and missiles.

Kinetic solutions

In August 2022, the JCO's Gen Gainey stated that the US military would need to start "leaning toward" kinetic options as UAVs become increasingly autonomous and less reliant on communications links. "If you're focused only on an EW system and they've evolved past whatever you're denying with that EW or non-kinetic capability, we got that kinetic effector that can then provide that capability," Gainey said during a speech at the Space and Missile Defense Symposium in Huntsville, Alabama.

Turret-mounted 30 mm guns firing air-burst munitions using proximity fuses have shown the greatest promise so far in testing. Northrop Grumman is developing a family of advanced programmable air-burst munitions (PABM) for chain guns. These include guided medium-calibre 30 mm and 50 mm munitions with in-flight trajectory guidance, assisted by sophisticated target identification algorithms on the platform side, promising enhanced effectiveness against drone swarms. For defence of infrastructure targets, a modified Phalanx system would seem suitable against UAVs of most size classes. Machine guns remain an option of last resort, though Ukrainian soldiers have used truck-mounted automatic weapons – including World War I Maxim guns – to good effect against small UAVs. However, they are not an ideal solution.

Armed interceptor UAVs

Today, UAVs seem well positioned to serve as armed interceptors. Over the past decade or more, some quadcopters have been armed with nets, shotgun shells, and other ordnance suited to disabling hostile quadcopters. Kamikaze-type interceptors have also been fielded, and those presented so far have included both hit-to-kill and warhead-equipped models.

Recently presented systems include the Modular Intercept Drone Avionics Set (MIDAS) quadcopter developed by Aurora Flight Sciences and Anduril Industries' Roadrunner-M. The MIDAS is equipped with modular rails capable of accommodating various payloads. These include a projectile weapon capable of firing multiple rounds, potentially allowing the defeat of up to 16 small UAVs per mission. Target cuing utilises ground-based radar, as well as onboard optical sensors. The modularity of the system permits upgrades necessary to counter future threat developments. By contrast, the manoeuvrable, jet-powered Roadrunner-M is a 'kamikaze-type' drone, which flies at high-subsonic speed and is armed with an explosive warhead, initiated by what appears to be a laser proximity fuze. It intercepts targets by flying close enough to them for the warhead to activate. Anduril states that it would be especially suited to defeating Shahed-type UAVs, as well as larger systems, including manned aircraft. US DoD budget documents for 2024 reveal that the US Special Operations Command (SOCOM) is acquiring the system.

In a similar vein, the tube-launched Coyote UAV, developed by RTX, has been proposed as another 'kamikaze-type' C-UAV solution. The vehicle which can be deployed from the ground, air or sea, and is equipped with an active radar seeker and high-explosive warhead, enabling it to identify and defeat hostile UAVs. The Coyote has demonstrated its ability to operate in a coordinated swarm of up to 24 aircraft, giving the system the potential to directly attack enemy UAV swarms in large-scale 'swarm-on-swarm' aerial engagements. The Coyote can also be equipped with various payloads including an EW suite or a high-power microwave emitter, permitting non-kinetic engagement of unmanned threats.

Lockheed Martin has developed another tube-launched UAV, designated MORFIUS, which is equipped with what appears to be an IR seeker, as well as an HPM payload

Credit: Northrop Grumman

Northrop Grumman's Mk310 PABM munitions are optimised for the C-UAV role.

designed to counter UAV swarms. MORFIUS is intended to fly relatively close to its targets, before engaging them with its HPM payload, which, according to Lockheed Martin, is capable of projecting a Gigawatt of microwave power. A particular advantage of UAV-mounted HPMs is their ability to engage enemy swarms well in advance of friendly forces, before the hostile drones are positioned to initiate their own attack.

No silver bullets

In June 2024, the JCO is due to host its next technology experiment at White Sands Missile Range, New Mexico. The exercise scenario is built around an adversary's attempt to overwhelm US C-UAV defences through massed attacks by swarms of up to 50 UAVs, making it the largest scale demonstration of its kind. Given the scale of the attack, the exercise is expected to rely heavily on EW systems, said Col. Michael Parent, JCO acquisition chief who added, "Let's face it, kinetic is challenged because we talked about [defeating] 20 to 50 [UAVs]."

However, as noted earlier, drone autonomy can limit the utility of EW-based C-UAV systems. This will become more acute in the coming years as UAVs become increasingly autonomous and are shielded against electronic attack, including hardening of systems against microwave energy. In the words of Gen. Rainey, "There is no silver bullet. No one system is going to be able to defeat all these threats." As UAVs become more sophisticated, future defence efforts must rely on an integrated system of systems. Just as air and missile defence is now layered, an effective C-UAV solution requires multiple overlapping capabilities in order to avoid gaps in coverage. This is the approach the US Armed Forces are currently pursuing. HPM weapons such as THOR and Mjolnir are, for example, expressly referred to as complementary to laser, kinetic and explosive countermeasures. This approach will likely be pursued by any nation capable of financing a full-spectrum C-UAV arsenal.

To be clear, jamming and microwave weapons capable of covering broader sectors of airspace and engaging large numbers of enemy systems simultaneously will be vital elements of future C-UAV arsenals. UAVs that do not succumb to this first line of defence must then be engaged directly. A broad spectrum of mutually supportive weapon systems including laser, vehicle-mounted and man-portable projectile weapons, as well as airborne systems, must be included. If fielded in sufficient quantity and optimally deployed, such a layered mesh could form a tight shield, minimising the chance of enemy UAVs slipping through the gaps and inflicting strikes on friendly forces.

In any case, the C-UAV mission currently seems somewhat more feasible than an effective C-RAM solution, in large part due to the greater range of effector options. Even if the guidance system of PGMs could be neutralised by jamming, laser dazzling/optical 'burn-out', or microwaves, the inertia of various munitions in the final stages of a ballistic flight path (such as artillery shells) may ultimately require kinetic solutions to ensure they are successfully stopped. These will need to be deployed with sufficiently deep magazines and extended engagement ranges in order to protect against intensive and prolonged artillery barrages. As for the AFRL's prediction of a "force field" style umbrella repelling RAM threats in the coming decades, many experts believe this will remain confined to the realm of science fiction for years to come.

Keep it short

Thomas Withington

The ongoing war in Ukraine underscores just how hotly contested the airspace over the tactical edge will be in future conflicts.

There are no firm definitions for very short-range air defence (VSHORAD) or short-range air defence (SHORAD), though a 2019 official UK publication entitled 'Joint Air Defence' provides some useful thresholds. The document states that SHORAD systems typically engage targets at below 18.5 km range, while VSHORAD systems engage targets at under 5.6 km range. Informally, however, a common practice among air defence analysts and industry is to take the convention of describing effectors with a maximum engagement range of ≤10 km as VSHORAD, and effectors with a range of >10 km to 20 km (sometimes even going up to 25 km) as SHORAD.

VSHORAD effectors typically include surface-to-air missiles (SAMs), including the man-portable air defence system (MANPADS) sub-category, and cannon or gun-based anti-aircraft artillery (AAA). SHORAD systems by contrast only use SAMs as their effectors. Looking ahead, directed energy weapons (DEWs) such as lasers may supplement the typical effector mix in the VSHORAD range band, and possibly in the SHORAD range band further down the line. A US Congressional Research Service report published in June 2023 entitled the 'US Army's Manoeuvre Short-Range Air Defence System' highlighted the force's search for a 50 kW laser to this end.

The combined (V)SHORAD bands are inherently tactical. Assets such as SAMs and AAA, and their associated sensors, are typically deployed to protect point targets. A battalion or brigade headquarters, would be two examples of a point target, as might a tactically important bridgehead. Given (V)SHORAD's tactical nature, it will also provide an umbrella of coverage above units at the tactical edge. Doctrinally, it is vital that (V)SHORAD assets are mobile as they must be able to move as land forces manoeuvre, continuing to provide protection from aerial threats. Assets need to be capable of engaging or sensing when mobile as the air picture will be continuously changing when tactical units are moving and engaging.

Credit: DRS RADA Technologies

Rada Electronic Industries has seen the company's S-band (2.3 GHz to 2.5 GHz/2.7 GHz to 3.7 GHz) MHR multi-mission hemispheric radar outfit US Army General Dynamics' Stryker family of wheeled armoured fighting vehicles, and teamed with kinetic effectors and optronics, to provide a mobile VSHORAD capability.

(V)SHORAD Command and Control (C2) systems must take account of this, as must the communications networking short-range air defence assets. However, it may prove impractical to provide wired links between SHORAD assets at the tactical edge. Instead, tactical radio links will need to be survivable in the face of determined hostile electronic jamming. Furthermore, the links must be capacious enough to carry data pertaining to the potentially dense air picture. Data are likely to include visual imagery, the recognised air picture (RAP), including tracks, plots and Identification Friend-or-Foe (IFF) information. This traffic will be accompanied by voice, cartographic and text-based information.

Complicating matters further is the plethora of aerial threats the manoeuvre forces must contend with. Broadly speaking, these threats include unmanned aerial vehicles (UAVs) and manned fixed- and rotary-wing aircraft. UAVs and conventional aircraft are joined by surface-to-surface and air-to-surface missiles (SSM/ASM) and air-launched ordnance. Countering rockets and artillery tends to be the mission of specialist dedicated counter-rocket, artillery, and mortar (C-RAM) assets and is not routinely folded into the VSHORAD mission, since many VSHORAD systems are not capable of undertaking the C-RAM mission effectively. Dedicated C-RAM systems, however, are typically capable of serving as effective VSHORAD.

Sensors

SHORAD forces will typically use optronics and radar to detect, identify, track and help engage aerial threats. Passive radio frequency (RF) capabilities also increasingly have a role to play. Passive RF systems, such as direction-finders, will seek to detect and track an aircraft by using only the latter's emitted radio signals. Manned aircraft employ an array of electromagnetically dependent systems while radios, radars and identification friend or foe systems all transmit RF signals. Electronic support measures (ESM) can listen in to detect these transmissions. By using two or more antennas, an ESM can triangulate an aerial target via the latter's transmissions.

Author

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PROTECTING YOUR MILITARY INFRASTRUCTURE

Much is discussed today regarding the urgent importance of radars for detection of the rapidly growing Drone and UAV/UAS threat. With the ever-increasing number of drone attacks on military infrastructure, the time is up for an effective solution to detect and counter this threat.

INCREASE IN DRONE ATTACKS ON MILITARY BASES

A drone attack Monday December 25th, 2023 targeted a military base in northern Iraq used by U.S. and anti-jihadist coalition forces, U.S. and Iraqi officials said, in the latest such incident. The number of attacks targeting the coalition, which deployed troops to Iraq to fight the Islamic State group, has surged since the start of the Israel-Hamas war on October 7.

In this incident a drone was launched towards a base close to Irbil airport, in Iraqi Kurdistan, Yehia Rasool, the Iraqi prime minister's spokesman for military affairs, said in a statement. The attack caused injuries, Rasool said, without giving further details.

A U.S. military official, speaking on condition of anonymity, confirmed to AFP that a drone attack was launched "at U.S. and coalition forces" at the airbase, adding "we are still awaiting injury and damage assessments (if any)."

Not long after the drone attack, Islamic Resistance in Iraq claimed to have launched a drone against another base, close to Harir which is northeast of Irbil. That base is also home to U.S. and coalition forces.

A tally by U.S. military officials has counted 103 attacks against its troops in Iraq and Syria since October 17.
(https://www.voanews.com/a/new-drone-attack-against-us-troops-in-iraq/7412169.html).

The above is just one example of an increasing number of drone attacks targeted towards military infrastructure, and with the increased production of especially Iranian and Russian drones, the threats from drone attacks are most likely becoming even bigger in the years to come.

Credit: Shutterstock

THE SOLUTION TO THE DETECTION CHALLENGE: WEIBEL'S XENTA SHORAD RADAR

Credit: Shutterstock

Credit: Weibel

As part of Weibel's business strategy, the company began years ago to develop a radar sensor system specifically designed to counter the growing threat of UAS by refining and adding it to their already proven technology from the air surveillance and tracking market. The Weibel Multi-Frequency Surveillance Radar XENTA-series is based on Continuous Wave (CW), Frequency Modulated CW (FMCW) and Multi-Frequency CW (MFCW) 3D Air Surveillance and Tracking Radar technology.

The dual use surveillance radar comes in a version optimized for air defense in the Close in Defense to Short Range Air Defense (SHORAD) spectrum, as well as a version primarily applied for detecting, tracking and classifying Low, Slow and Small (LSS) targets within the C-UAS & Critical Infrastructure Protection (CIP) spectrum.

Weibel's XENTA SHORAD radars have specifically been developed to address the need of detecting, classifying and tracking all types of aerial threats, from fast moving targets, such as jets and missiles to low, slow, and small targets, such as fixed-wing and multi-copter drones.
In the air defense configuration, XENTA is thus designed to be part of an integrated air defense system supplementing long-range and medium-range air defense sensors as a gap filling radar.

The SHORAD version of XENTA comes with advanced functions such as ECCM, IFF, Stop & Stare mode and ruggedized components for harsh environmental conditions and sense-on-the-move operations. The Stop & Stare mode cannot fully replace a fire control radar, but the data provided is sufficiently accurate to support fire control systems.

The XENTA SHORAD radars feature a 60-degree elevation and 360-degree azimuth 3D coverage, designed for surveillance and tracking in stationary or on-the-move GBAD operations in complex clutter environments.

ABOUT WEIBEL SCIENTIFIC

Danish Weibel Scientific is the global leader in the market for advanced Doppler radar systems. For more than 45 years, the company has sold cutting-edge radars around the world for use in space, aerospace, as well as air and missile defence systems. Weibel has delivered more than 5,000 radars to over 40 countries. To ensure high-quality logistics support, Weibel designs and builds all critical units in-house. In-house design and manufacturing mean that except for standard components, Weibel is independent of sub-suppliers for the manufacturing of both prime equipment and spares. In this way, they can offer fast and guaranteed through-life support.

For more information, please visit
www.weibelradars.com

Credit: Thales

Thales' GM-200 series S-band ground-based air surveillance radar can support SHORAD as well as medium-range air surveillance. Thales recently provided the GM-200MM/C variant of the radar to the Danish military.

An ESM's internal library of radio signal 'fingerprints' may even be able to match the signal with the type of aircraft. For example, determining that a radar signal is from a Thales RDY-3 X-band (8.5 GHz to 10.68 GHz) fire control radar suggests that the aircraft is a Dassault Mirage-2000 series combat aircraft. ESMs are also particularly useful in detecting UAVs. The latter must maintain an RF link between the aircraft and the pilot for C2. C2 RF links use a variety of frequencies spread across a waveband of 27 MHz to 5.8 GHz. These wavebands are reserved by the United Nations' International Telecommunications Union (ITU) for UAV command and control. The ITU is tasked with regulating global use of the radio spectrum.

Credit: Hensoldt

Hensoldt's Spexer-600 X-band ground-based air surveillance radar was launched in 2021 by the company's British subsidiary. The radar employs technology used for the Kelvin Hughes (now part of Hensoldt) SharpEye radar family.

Networking (V)SHORAD brings its own challenges. A general rule of thumb in telecommunications is that 1 bit of data absorbs 1 Hz of bandwidth. The denser the information being moved around a network, the more bandwidth is taken up. Data absorption is a key concern if dense radar pictures or visual imagery and video are being shared. At the tactical edge, this will be further complicated by aggressive adversary electronic attack. Jamming engages the radio links that SHORAD C2 networks rely upon. Digital battle management systems used for air battle C2 will also most likely be under cyberattack.

Design philosophies

The demands of the tactical edge require (V)SHORAD radars to be light enough to mount on vehicles to support the manoeuvre force. Radar performance must be such that the system detects, identifies and tracks the panoply of targets the manoeuvre force expects to encounter. Radar signals must also exhibit low probability of detection/interception (LPI/D) characteristics. Moreover, economy of data sharing is a must. As the above discussion has illustrated, the airspace over the tactical edge is a highly dynamic environment. For (V)SHORAD to be as effective as possible, air defenders need a detailed tactical picture. However, this creates challenges. Red force electronic warfare (EW) will be doing its level best to jam SHORAD communications networks and attack SHORAD C2 systems. Jamming could reduce radio bandwidths available for sharing radar and other tactical data.

(V)SHORAD radar performance demands create challenges for radar engineers which can be illustrated by taking a hypothetical (V)SHORAD radar and demonstrating its effective range against targets of various sizes. For the purposes of this demonstration, the radar transmits on a frequency of 566 MHz (UHF band) with a signal strength of 7 kW (68.5 decibels-per-milliwatt) with the radar's antenna providing 28.5 decibels-relative to isotropic gain. An isotropic antenna is one that theoretically transmits the same power in all directions at once. However, radars are designed to focus a specific amount of power in a specific direction. Gain is a measurement of how much signal strength the antenna can focus in a specific direction.

The challenge for a (V)SHORAD radar is that it must detect and track an array of very different targets at suitable ranges to give short-range air defence units at the tactical edge sufficient time to engage them. A Sukhoi Su-27 (NATO reporting

name: Flanker) may have a radar cross section (RCS) of between 10 and 15 m2 (translating to: 10 to 11.75 dB). Conversely, an incoming 227 mm rocket may have an RCS as small as 0.018 m2 (translating to: -17.45 dB). Taking the Su-27 as a first example, the theoretical SHORAD radar could detect this at a range of 106 km for a 10 m2 RCS target. Detection ranges are slightly greater, 117 km, if the Su-27 has a 15 m2 RCS. Nonetheless, these ranges start to reduce considerably as targets get smaller. A rocket with a 0.018 m2 RCS could be detected at 22 km, while a small UAV with a 0.001 m2 RCS could be detected at a mere 11 km.

The 7 m diameter antenna of our hypothetical radar makes it impractical to move around the battlefield to support (V)SHORAD at the tactical edge. Moreover, the comparatively low frequency of 566 MHz may not depict targets in the rich, precise detail that AAA and SAM units need for weapons-quality tracks. Leaving the other parameters as they are, but reducing the antenna size to have a surface area of 2 m2 reduces detection ranges. A target with a 10 m2 RCS is now detected at 38 km, or 42 km for an aircraft with a 15 m2 RCS. When detecting a rocket, range reduces to 7 km and to 4 km for a small UAV. Reduced detection ranges mean reduced early warning times for the (V)SHORAD effectors, severely hampering their reaction times. Increasing the radar's transmission frequency also helps improve range. Retaining the 2 m2 antenna, but raising the frequency to 2 GHz (S-Band) increases detection ranges. A target with a 10 m2 RCS is now detectable at 20 km. This detection range increases to 22 km for an aircraft with a 15 m2 RCS. Radar performance against other targets, however, reduces. Detection ranges for 0.018 m2 RCS rockets and UAVs with a 0.001 m2 RCS diminish to around 4 km and 2 km respectively.

One solution is to move (V)SHORAD radar frequencies further up the radio spectrum; let us assume the hypothetical antenna size is reduced to 1 m2 but transmission frequency is increased to 33.4 GHz (Ka-Band), and the other radar parameters are maintained, notably the 120 W transmitting power. It should therefore be possible to detect a target with a 0.018 m2 RCS at 15 km. A UAV with a 0.001 m2 RCS will be detectable at 7 km, while larger targets such as aircraft with 10 m2 and 15 m2 RCSs will be detectable at ranges of almost 73 km and 82 km respectively.

Evolutions

Mark Radford, founder and chief technology officer of Blighter Surveillance Systems, says that this embrace of higher frequencies shows the direction of travel for SHORAD radar evolution: "Given the greater diversity of threat types compared to Cold War days, such as nano-drones and guided ordnance, the modern radar systems will benefit from adoption of higher operating frequencies such as X-band (8.5 GHz to 10.68 GHz) and Ku-Band (13.4 GHz to 14 GHz/15.7 GHz to 17.7 GHz)."

Using these, and other comparatively higher frequencies, will have the added effect of helping to reduce the physical size of SHORAD radars: Radford adds that, "This shift to higher frequencies, and hence shorter wavelengths also allows the radars to be more compact, which in turn provides the opportunity for on-the-move operation." Radford emphasises that while (most) SHORAD effectors may not be able to engage targets when mobile, "a radar system designed to operate while being driven at speed can provide some level of protection while moving and is instantly available for full SHORAD capability the moment the vehicle stops". Moreover, there is no need for a SHORAD radar to use a traditional, rotating antenna. Instead, flat panels could be mounted on the side of a vehicle with each providing 90° of air surveillance. Together, these panels would give the radar 360° coverage of the airspace in its locale. Several vehicles

equipped to this end could provide overlapping coverage at the tactical edge. Removing the need to have a rotating antenna on top of a vehicle would also help to reduce its visual signature, improving survivability.

Moving into higher radar frequencies and embracing non-rotating antennas are two important aspects towards improving (V)SHORAD radar surveillance, but other factors are equally important. First and foremost, radars are detectable thanks to their RF emissions. LPI/D techniques can reduce hostile opportunities to detect and attack a radar either electronically or kinetically but cannot eliminate the risk: "Possibly the greatest and growing challenge is that active radars can be readily detected by both remote ground-based and compact airborne electronic-surveillance equipment, resulting in rapid reactive targeting by the enemy," noted Radford, adding that, "This has been observed in Ukraine and is resulting in an evolution of alternative threat detection techniques."

Passive radar – one SHORAD technology garnering interest – watches for disturbances to the prevailing radio spectrum in the locale caused by an airborne object within range. We are continually surrounded by electromagnetic energy, particularly in urban areas, with broadcasting and cell phone signals being two of the most ubiquitous sources of this energy. Other passive radars work to detect radar and radio signals from airborne targets. In both cases, these signals and signal disturbances are used to detect, locate and track a target. Passive radar's key asset is that it does not emit any electromagnetic energy.

Credit: Lockheed Martin

Lockheed Martin's AN/MPQ-64 Sentinel-A4 radar is equipping the US Army. This X-band system typifies a trend in radar design which combines SHORAD and medium-range surveillance.

Credit: DRS Rada Technologies

Rafael's I-Dome is an all-in-one VSHORAD system, comprising radar and launcher on a single vehicle, currently in development. The vehicle makes use of four fixed-face radar panels, notionally set to be the exMHR model from DRS RADA.

Radford believes that passive radar is not "sufficiently mature for tactical use yet" but is showing promise as an alternative to conventional SHORAD radars. Realistically, land forces are unlikely to benefit from uncontested airspace over their manoeuvre areas in future wars. Air threats will arrive in all shapes and sizes, collecting intelligence, surveillance and reconnaissance information and delivering ordnance. The advent of drone warfare, so graphically illustrated in Ukraine, shows that the danger of UAVs will only increase. (V)SHORAD radar design will need to continue evolving to be survivable and to work with a host of traditional and emerging threats. Meanwhile, air defenders will need to think about how technologies such as passive radar could contribute to their efforts to protect the manoeuvre force. ■

I, Robot? Autonomy developments for UAVs

Tim Mahon

The crucible of conflict in Ukraine is teaching many things to those willing to look, listen and learn. Almost at the pinnacle of the hierarchy of lessons learned lie multiple aspects of drone warfare – fast becoming a warfare domain in its own right.

Sensors, propulsion, data processing and dissemination, effectors and payloads – all exhibit persistent tendencies towards innovative solutions for perennial battlespace challenges. Cutting through the marketing hype and misleading propaganda that surrounds the two-year-old conflict, however, is not that simple. Especially when it comes to the question of platform autonomy.

The confusion is not helped, of course, by the fact that the very word 'autonomy' has different meanings for different stakeholders. For those whose first language is not English, the word can indicate the available range of action or endurance for a platform – parsing the question to an unmanned aerial vehicle (UAV) context; for others it indicates a degree of organisational or regional political independence. Others see it as indicative of an ability for independent thought, reasoning or action. From the perspective of UAVs, both the endurance and the independent action interpretations are relevant and, though distinct, are allied to a degree.

One of the principal motivations for development of early UAVs lay in the ability to project effect to a distance. That effect could be to prosecute an intelligence, surveillance and reconnaissance

Author

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Credit: Anduril Industries

The Anduril Roadrunner is predicated on achieving rapid transit from unattended launcher to target area, then on autonomous target detection, location and classification prior to programmed or autonomous attack.

(ISR) mission – to determine "what is on the other side of the hill" and provide tactical level commanders with data and support for improved decision-making – or it could be to deliver kinetic effect on a target. The question of effective range, flight endurance and security of control and communication signals therefore became of paramount importance. Interpreting manufacturer data, reading specifications and requirements couched in *procurementese* and separating the wheat from the chaff in international reportage of ongoing events, the word autonomy when applied to UAVs can often be substituted for range, endurance or loiter time. "An autonomy of x hours" is a frequently seen capability label.

That is not unimportant. Combat operations in Ukraine are showing an imperative need for delivering effects at range – and for reducing the time to bring effects to bear, which in turn is influencing platform development. One of the key concepts underlying the development of the Anduril Industries Roadrunner UAV, for example, is exploitation of a high 'dash speed.' With a high subsonic speed capability, the system's tactical utility is considerably enhanced, enabling an effect to be delivered to a point of need significantly faster than is normal in 'traditional' operations. That enhances the autonomy of operations, from the perspective of the one definition.

However, it is the other definition that is far more prevalent when discussing the unmanned system domain. The capability to prosecute a mission – and, where possible, adjust the mission parameters in line with evolving circumstances – in an independent, or at least semi-inde-

Credit: DefendTex

Short-range drones or loitering munitions, such as the Australian-developed DefendTex D40, are, frequently fully autonomous in the conduct of the attack, including the terminal phase.

pendent manner, with little or no human intervention represents the Holy Grail for the unmanned systems community. This is the goal to which vast resources and intellectual capital are being directed with varying results and a host of longer-term issues arising that will require resolution sooner rather than later. The issues fall into two broad categories – operational and political. The operational issues, while thorny and complex, are more easily dealt with in good military fashion, by breaking a complex issue into its component parts and resolving each sub-issue in sequence. The political issues require a more subtle and cohesive approach.

Autonomous operations

In most cases, the operational issues surrounding autonomous capability revolve around controlling independence of action. That may sound counterintuitive but take, for example, the case of a combat reconnaissance unit commander with a number of UAVs at his disposal and a mission to determine hostile dispositions and intent at a range of, say 30 km. Some of his platforms are equipped for ISR, while others have weapon systems. Some of his concerns will revolve around whether his ISR assets are sufficiently reliable to be able to pass targeting information directly to the weaponised aircraft, effectively cutting him out of the decision loop.

The concept of the Observe, Orient, Decide, Act (OODA) loop was developed with combat operations in mind, though it is increasingly applied to non-military organisational constructs. It was developed, however, with *Homo sapiens* in mind as the thinking machine that would conduct all four of those activities. Libya, Nagorno Karabakh, Syria, Gaza and Ukraine have all, to greater or lesser degrees, begun to change militaries' approach to the concept. Intelligent machines are capable of conducting all four constituent activities in certain contexts, and – subject to carefully developed guidelines and algorithms – doing so in a safe, reliable and repeatable manner.

The implications for autonomous action in aerial platforms for military and security applications are enormous. Effect at range hugely expands the areas of interest that can be monitored and/or protected, whether that area is the immediate environs of an airport or the whole of the Andaman Sea for example. The ability of a high-altitude UAV monitoring an area over weeks or months to determine changes in 'patterns of life' and generate appropriate alerts is valuable. Some would argue that its ability to make decisions as to what to do about the changes observed would be equally valuable – and, in saving time and avoiding the uncertainty of the human decision-making process, potentially saves critical time and saves lives. Others believe that is a bridge too far.

Scrutiny, suspicion and safety

The era in which UAVs have developed and become so prominent has coincided with a time when the general public has been granted unprecedented access to information and communications capabilities, with the inevitable consequence that debates become far more frequent, and encompass far more divergent points of view than was previously possible. One consequence is increased public scrutiny of action (or inaction) by 'the authorities' and nowhere, arguably, is this more prevalent than in politics, with international relations and the use of military power very high on the agenda of scrutineers. Those who subscribe to conspiracy theories see malicious intent at the heart of every action and many have seized on fears that intelligent systems might overrule human intent and cause mayhem on a global scale.

Although science fiction to a degree, there remains a kernel of reality at the heart of such fears. But what most ill-informed commentators miss is the fact that autonomy has not emerged, butterfly-like, from a recently woven cocoon: it has been developed and considered, experimented with and modified, for decades. In all unmanned system domains, shrewd manufacturers and concerned authorities have debated, discussed and collaborated in the development of operational architectures that meet the rigid constraints of operational safety and enduring human control. The fact that we are only now seeing the emergence of routine UAV operations in airspace populated by manned aircraft is a testament to the 20-plus years it has taken to consider and frame the regulatory environment in which such operations must take place.

On the battlefield, such considerations are secondary. The imperatives are different. Yet, keeping a 'human-in-the-loop' capability for ultimate authority over the use of deadly force remains a powerful component of the argument for allowing unmanned systems to operate relatively independently. Rheinmetall's announcements of developments in unmanned systems on the ground and in the air are peppered with assurances of the primacy of human authority in all circumstances. AeroVironment emphasizes the positive control of ISR drones and unmanned combat aerial vehicles (UCAVs). Developers of software and analysis algorithms focus potential customer attention on the multiple safety precautions built in to every new release. Concerns, however, persist.

Credit: HAJIM School of Engineering & Applied Sciences, University of Rochester

Simultaneous Localization and Mapping (SLAM) algorithms that lie at the heart of the capability have been around for nearly three decades. Yet researchers are now driving research in different directions, with an emphasis on reliability and deep machine learning applied to intelligent drones.

Where is autonomy going?

Questions remain as to the direction autonomy is headed – how will we reconcile the multiple requirements and

Credit: US Army

Given the low numbers of counter-UAV systems in most militaries, one of many nightmare scenarios is the vastly difficult nature of countering swarms of intelligent, autonomous hostile drones.

make efficient, effective use of the wide range of capabilities we have unleashed through unmanned systems? How do we ensure the primacy of human initiative and limit the inexorable march of robotic systems?

In the long term, there would seem to be few acceptable answers, since the complexities of the surrounding issues are explained to very few and adequately understood by even fewer. There have been dangers inherent in every development in human history and we should not fool ourselves that the development of machine autonomy is free from all potential for disaster. In reality, however, we already live with the benefits stemming from degrees of autonomous machines conducting everyday activities. Driverless trains have become a familiar sight in London's Docklands and many other cities. Flight crews tend to monitor airliner activities for an astonishingly high percentage of every passenger-carrying flight, intervening for mere minutes at each end of the flight segment. They are, of course, still poised to intervene immediately in the event of systems failure. Telesurgery is already saving lives in circumstances in which medical intervention might otherwise be impossible. Defence and security, though, are different.

Credit: GA-ASI

MQ-20 Avenger, typical of the larger categories of UAV fielded by governments globally.

One aspect of the conflict in Ukraine that concerns some observers is the extent to which the desire for instant gratification bypasses the need for caution in capability development. Ukrainian authorities and frontline troops have been hugely innovative in jury-rigging, adapting and cajoling existing systems into doing things they were not originally designed to do. Examples include civilian UAVs being repurposed for dropping grenades. Yet little attention has been paid to the potential for disaster which, despite dire predictions, does not yet appear to have happened. Absolute safety has been sacrificed on the altar of immediate effect – a trait common throughout the history of warfare. Popular concerns centre on the spectre of large-scale 'collateral damage' resulting from decisions taken at a literally inhuman level.

There are, however, powerful minds at work in charting the future course of autonomy. Sensor and computing behemoths such as Hensoldt and Microsoft are working on development and integration of capabilities that will make the routine operation of ever more capable robotic systems possible. Companies large and small – from Lockheed Martin and BAE Systems to Milrem Robotics and Anduril Industries – are developing powerful capabilities that will make swarming attacks, and defence against them, viable considerations for aerial combat in the immediate future.

The way forward, at least for now, may well be a continued evolution of what we have seen in the combat aircraft avionics environment in the last four decades or so. Early iterations of advanced combat cockpits provided sensor output for human interpretation, decision and action; the glass cockpit advanced the method by which machine-derived data could be presented for aircrew intervention; the F-35 cockpit, as an example, takes this a stage further, with the sensor fusion relying on sensors and computing power to collect, analyse and parse data, and then offer the pilot a series of choices. This all saves time and eases the cognitive load of the pilot, thereby shifting the cognitive focus onto decision-making rather than analysis. Whether that speaks adequately to the human need to feel in control remains to be seen.

The bottom line is that this genie is too good (and too independent) to be put back into the bottle. Autonomy in unmanned systems is here to stay and, indeed, is pivotal to the much-hoped-for success expected of them in short and medium terms. ■

When networks become weapons

Thomas Withington

The US Army's Unified Network promises epic levels of consolidation for its disparate communications links at tactical, operational and strategic levels.

Multi-domain operations (MDO) form the doctrinal cornerstone not only of the US Army, but of all services of the US Armed Forces. While definitions vary, put simply, MDO envisages a level of supreme inter- and intra-force connectivity at all levels of war – from tactical through operational to strategic. Connectivity will link every person, platform, base, weapon, sensor and capability, henceforth known as assets. Not only will intra-force connectivity join these assets, disparate services will share similar links. The goal of MDO is to improve the quality and speed of decision-making vis-à-vis those of one's adversaries. The US Department of Defense's (DOD) MDO vision is to be facilitated by the Joint All-Domain Command and Control (JADC2) system; JADC2 is the hardware and software that will provide these levels of connectivity. If MDO is the vision, then JADC2 is the facilitator.

Credit: US DoD

This graphic demonstrates the sheer complexity of the overall JADC2 undertaking. All services will enjoy unprecedented levels of intra- and inter-force connectivity as this diagram illustrates.

Facilitating MDO

In 2021, the US Army published its Unified Network Plan, which stated that it must become an MDO-capable force by 2028. Key to this effort is what the Army calls its Unified Network which will enable the Army, as part of a wider joint or coalition undertaking, "to integrate and operate simultaneously and seamlessly in all domains, all environments, across all geographies and all warfighting functions". The document noted that this approach would enable the Army "to calibrate a force posture and converge capabilities at the point of need". The US Army's Command, Control and Communications Technology Programme Executive Office (PEO C3T) is overseeing the Unified Network's introduction.

The Unified Network directly relates to the Army's information technology resources and the links connecting them. Succinctly, the plan covers "all hardware, software, and infrastructure from the very forward edge of the battlefield back to our posts, camps and stations". The Army says that the Unified Network is a secure, survivable end-to-end system. The network will provide inter- and intra-force, and allied, secure and robust links. One way to visualise the Unified Network, and the motivations for its creation, is to see the Army's communications networks evolving from being just those, to being a weapons system in its own right, as outlined in the Unified Network Plan.

Several components comprise the Unified Network; a Common Operating Environment (COE), Common Services Infrastructure (CSI), a transport layer and Unified Network Operations (UNO). US Army documents state that the network will carry both classified and unclassified data. Taking each of these components in isolation, the COE covers computing standards and associated technologies. Despite seeming mundane, these standards and associated technologies will allow the secure and interoperable software applications underpinning army MDO. Software applications to be delivered via the COE include data-driven, decision-making tools, according to the Unified Network Plan. The CSI, meanwhile, provides the hardware and software to secure, store and process the data these software applications will rely upon. These applications will be globally available thanks to the communications links the Unified Network provides.

Data is but one part of the CSI, since artificial intelligence (AI) and machine learning (ML) tools also form part of the CSI. Both AI and ML will be vital to help users make sense of the data sorted by the hardware and software. As US Army documents note, Cloud Computing is one technology considered integral to the CSI. The transport layer provides the communications links to connect users to the CSI and in effect comprises all the communications networks at the Army's disposal. These links encompass everything from DOD strategic satellite communications to radio networks at the tactical edge.

Author

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Credit: US Army

US Army command and control will increase in complexity over the coming years because of the adoption of the MDO mindset and the Joint All-Domain Command and Control system facilitating MDO.

Alongside these established, conventional conduits, the Army fully expects to exploit emerging communications technologies. These technologies will include fifth- and sixth-generation cellular communications protocols. A key consideration for the Army is to create a militarised 'Internet of Things' (IOT). Formally known as the IOMT (Internet of Military Things), these communication links will network assets so that they are able to continually upload the data they are collecting and download relevant information to support their missions. The IOMT forms a key aspect of facilitating the levels of connectivity that MDO relies on.

Last, but by no means least, is the UNO, which the Army says will provide the protective aspects covering the network. In the Army's own words, this includes "the capabilities, required to secure, configure, operate, extend, maintain and sustain the cyberspace to create and preserve the confidentiality, availability and integrity of the Unified Network". In a nutshell, the UNO ensures the cyber security and protection of all the Unified Network's constituent parts. Cyber security and protection will be realised through "a common suite of hardware and software" all of which employ 'zero trust' principles. Microsoft defines the zero-trust approach as "never trust, always verify". In essence, anything connecting into the Unified Network, or any data moving across it, must be treated as hostile until it can be determined otherwise.

Taken together, the UNO, alongside the transport layer, CSI and COE will, in the Army's own words, enable "cross-domain manoeuvre". Manoeuvre will be achieved via "the application of strategic, operational and tactical effects at the speed and range required for the Army and the joint/coalition force in the rapidly emerging battlefield of tomorrow". Taking all these components together, the Unified Network will allow the Army's MDO mindset to become a reality.

UNO – it makes sense

Software plays a major role in realising the Unified Network. Paul D. Mehney, the PEO C3T's director of public communications cites UNO as an example. UNO is a "software-based capability" that will be hosted on existing hardware already used by Army formations and "is intended to be hardware agnostic, meaning it can reside on any hardware platforms (in) any formation echelon". UNO provides network management applications for corps, division and brigade network managers that they can use to "plan and see their network use across terrestrial and satellite communications connections". On a practical level, UNO will allow a single soldier to plan, manage, monitor and operate their network using a single workstation. Currently, according to Mehney, soldiers must perform these functions using unique system management applications. To put matters into perspective, Bill Seiss, director of US Army tactical communications programmes at L3Harris, says that UNO "will consolidate more than 20 network operation tools currency in the Army's inventory into a simplified user-friendly capability."

Unified Network Operations will yield a single, common interface through which soldiers can access several software applications or services. "The ultimate goal of the UNO is to create a simplified user experience with increased situational awareness and stronger cyber network defence," according to L3Harris' Seiss. Elsewhere, Dominic Perez, Curtiss-Wright's chief technology officer stated that UNO will act as middleware connecting and integrating future components: "The Army is looking for solutions to make this happen."

A new programme of record for UNO and a rapid prototyping effort is expected to commence in the 2023 fiscal year, according to Mehney at PEO C3T. These efforts will focus on a "foundational integration capability to deliver unified applications on a common software framework". In 2025, UNO prototype capability will be assessed and evaluated. Mehney added that UNO components have been prototyped since 2019, with efforts focusing on lower and upper tier network planning and management. He also expects initial UNO capabilities to begin fielding by 2026 and for a single vendor to be selected to deliver an integrated UNO solution.

Building the Unified Network

The Unified Network will be delivered through five so-called Lines of Effort (LOEs). LOE-1 builds the Unified Network to enable MDO. LOE-2 configures force postures of the Army for MDO. LOE-3 works to preserve the security and survivability of the commander's freedom of action in cyberspace. LOE-4 reforms processes and policies to improve performance and affordability. Finally, LOE-5 will sustain enterprise and tactical networks.

LOE-1 places a premium on synchronising network modernisation efforts across the Army. Basically, the Army's tactical, operational and strategic networks will merge into the prevailing Unified Network architecture. Part of LOE-1 will see the development of the Army's cloud computing structure discussed above. Also relevant to LOE-1 is ensuring that all the Army's current networks meet stipulated security standards. This latter point is vital to ensure that tactical units can securely plug into the network and use it when they need to. For example, the Army is rolling out its Integrated Tactical Network (ITN), which, broadly speaking, is a deployed communications network for use at the tactical edge. The ITN creates a secure wireless network for the carriage of non-classified voice and data traffic within the Army and between sister and allied services. The philosophy behind the ITN is to use as much commercially available off-the-shelf hardware and software as possible. To that end, troops are receiving civilian-style tablet computers which can work with the ITN. It is imperative that the ITN can effortlessly and securely plug-and-play into the Unified Network to smooth the flow of information.

LOE-2 stresses the training and preparation of personnel, civilian and military alike, to fight in the MDO environment. Allied to this is the Army's adoption of the Expeditionary Signal Battalion-Enhanced (ESBE) formation, which are being deployed across the US Army's manoeuvre forces to provide uninterrupted mission command while rapidly deploying and manoeuvring. The battalions will have a plethora of communication systems and links at their disposal to improve redundancy against kinetic and electronic attack. The Army says the ESBEs will help reduce its manoeuvre forces' dependency on the Warfighter Information Network-Tactical (WIN-T). WIN-T is a deployed tactical communications backbone, typically providing trunk communications within a brigade. The ESBEs are not intended as a permanent fixture and the Army says that these battalions will deploy and evaluate alternative network equipment and postures to reduce WIN-T reliance. The results of the ESBE's efforts will then be used to inform the future configurations of the Army's ESBEs.

'Bits and bullets' has become a mantra for contemporary and future military operations. The Unified Network places a high premium on the smooth and uninterrupted flow of zeros and ones around the battlefield. This imperative underlines the importance of LOE-3. The Army's Unified Network Plan recognises that the network itself can only "provide the means to apply strategic, operational and tactical effects if it is secured and defended". Implicit in LOE-3 is a comprehensive overhaul of the Army's cybersecurity processes key to which is the adoption of continuous network monitoring and zero-trust approaches. Cybersecurity approaches stress data integrity, user authentication and data availability based on the user's level of authorised access. Continuous monitoring will be facilitated by Cyber Protection Teams (CPTs), which will constantly hunt for adversaries within the network and those seeking to gain access to it.

Inevitably, realising the Unified Network will necessitate the procurement of new hardware and software. LOE-4 provides the management and governance framework for the Army's Unified Network investments and also has a role to play in synchronising decision-making to ensure work is not unnecessarily duplicated. Finally, LOE-5 will ensure that the Unified Network "continuously evolves as technology and, just as importantly, the threat, evolves", the Army states. The watchwords for the network are that it must remain resilient, defensible and manoeuvrable. LOE-5 will also stress the divestment of legacy technologies as much as it will emphasise the acquisition of new ones.

Credit: US Army

Cloud computing forms a key part of the US Army's approach to MDO. The Unified Network Plan incorporates cloud computing into its CSI component.

Credit: US Army

The US Army is currently rolling out the Integrated Tactical Network which provides troops with a means by which non-classified voice and data traffic can be carried at the tactical edge. This traffic will be moved across civilian standard wireless networks and accessible via civilian devices, including tablets.

Implementation

The Army's plans call for the Unified Network to be ready to support an MDO-capable Army by 2028. The Unified Network Plan is rolling out the Army's vision in three phases spanning from 2021 to 2024 (Phase 1) and 2025 to 2027 (Phase 2). Phase 3 covers the period from 2028 and beyond.

The MDO-capable Army is to be the prelude for the MDO-ready Army of 2035. The Unified Network Plan is therefore the sheet music the Army will use to guide the network's introduction. The ambitious Unified Network has a myriad of inputs and components, some of which are already in the Army's possession, while others are still to be developed. Fortunately, the plan has been drafted with the future in mind so that new hardware, software and capabilities can be integrated with a minimum of fuss. This philosophy is essential as the Unified Network represents the connectivity the Army will depend on to fight, and win, tomorrow's wars. ■

Delivering the Royal Navy's future surface fleet

Conrad Waters

The British Royal Navy is in the middle of a significant programme of fleet renewal. Two major projects are currently underway that will ultimately see the commissioning of eight Type 26 anti-submarine warfare and five Type 31 general purpose frigates. Together, they will replace over two thirds of the navy's major surface combatants. Responsible for ensuring the delivery of these new warships to time and budget is the Naval Ships Delivery Group, currently headed by Mark Beverstock. ESD recently spoke with him about the challenges involved in securing the success of an endeavour that has huge importance for both the future Royal Navy and the revitalisation of the British naval construction sector.

Delivering capability

The Naval Ships Delivery Group (NSDG) forms part of the Defence Equipment & Support (DE&S) organisation; a procurement arm of the UK Ministry of Defence headquartered at Abbey Wood near Bristol. The group's responsibility is to work on behalf of the Senior Responsible Owner (SRO) – the officer at Navy Command tasked with delivering the overall Type 26 and Type 31 programmes to full operating capability – to get the ships that form the core part of these projects to vessel acceptance stage. In the words of Mark Beverstock, "The SRO provides me with a budget and a requirement, and I have to deliver that capability to the cost and timescale specified".

While the overall structure of DE&S is being redesigned for more speed, efficiency and "operational excellence", the NSDG currently has two separate teams dedicated to the management and oversight of the Type 26 and Type 31 programmes. Each team works with the assigned prime contractor for the relevant programme; BAE Systems in the case of the Type 26 and Babcock International for the Type 31. According to Beverstock, "We expect industry to be the ones who bring in all the various supply chain partners. NSDG's role is to manage

Author

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Credit: Babcock International

The keel laying party for the second Type 31 'Inspiration' class frigate, Active. Mark Beverstock, Head of the Naval Ships Delivery Group, is seen at the far left of the group.

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Mark Beverstock joined the Royal Navy in 1981, serving on HMS Ambuscade during the Falklands campaign. Specialising as a submarine weapons engineer, his seagoing appointments included taking the strategic submarine HMS *Vanguard* out of build, through first-of-class trials, and onto its first operational deployment. He has also been commanding officer of HM Naval Base Clyde. The majority of his career has been spent within equipment acquisition and, on promotion to rear admiral in 2012, he was appointed as the Chief Strategic Systems Executive in DE&S. His final appointment in the Royal Navy was as Assistant Chief of the Defence Staff, responsible for assessing and reducing global strategic risks. On retirement, he undertook a number of consultancy roles before joining the Civil Service to head the NSDG in 2020. Outside of his DE&S role, he took over as the National President of Poppyscotland and Royal British Legion Scotland in 2022.

the contract and to manage the risks to delivery that are inherent in the construction process". Each team is comprised of a range of experts in areas such as engineering, systems and commercial specialists so as to encompass all the functions needed to manage these risks.

Achieving this objective can be easier said than done. A widely-reported case-in-point related to construction of the Royal Navy's Batch 2 'River' class offshore patrol vessels (OPVs). The lead ship, HMS Forth, was handed over in 2018 with significant defects that were only identified after delivery, leading to the ship being handed back to the shipbuilder for remedial work. Whilst Beverstock was open that mistakes were made in the supervision of the early stages of that programme, he pointed to the value of the lessons learned from the experience, *"There was a belief at the time that you could take a light-touch approach to oversight and that proved to be a mistake. What that told us was that we need to keep a presence on shipbuilding at the waterfront and, by the time the final OPV was delivered, the list of defects was reduced to a single sheet of A4 paper. We have now carried those lessons forwards into the Type 26 programme."*

Type 26 acquisition

Overseeing the programme for the Type 26 'City' class frigates' construction currently forms a major part of the NSDG's activities. A GBP 3.7 billion (EUR 4.3 billion) contract for three of the new warships was placed in July 2017 and was followed by a GBP 4.2 billion (EUR 4.9 billion) order for a further five vessels in November 2022. Both awards were let to BAE Systems on a single-source, non-competitive basis. Collectively, the eight warships will replace the Royal Navy's existing anti-submarine configured Type 23 'Duke' class frigates on a numerical like-for-like basis from the latter half of the current decade onwards. The ships are being built in BAE Systems' Govan and Scotstoun shipyards in Glasgow. Variants of the design will also be built by Australia and Canada to meet their own future surface warship requirements.

Implementation of the Type 26 programme has not been entirely plain sailing. Delivery of the lead ship is expected in 2026 prior to declaration of initial operating capability in 2028; around 12 months later than first planned. An early problem related to a considerable delay to the delivery of the gearbox for the first ship of the class, the future HMS Glasgow. This was a long-lead item ordered from David Brown Santasalo after an international competition run by BAE Systems as far back as 2013 for installation at an early stage in the frigate's construction. Interestingly, Beverstock cites the NSDG's collaboration with industry to mitigate the consequences of this challenge as a good example of a successful partnership: *"There is no question that the gearbox was late but the extent of the delay that this caused has been somewhat misreported. We only lost a small amount of time in the programme's critical path as we were able to work proactively with industry to restructure the ship's build sequence so as to allow its installation at a later date."* This involved cutting an opening in the ship's hull to slide the gearbox into the relevant compartment.

Beverstock is also keen to stress that there is no problem with the quality of the gearbox that was ultimately delivered. Indeed, he points to the overall strategy adopted for the system's procurement as another example of benefits that have been gained from previous experience. It is no secret that a number of international warship procurement programmes have been badly impacted by the emergence of gearbox problems after initial ship deliveries. Keeping in mind this experience, as well as the criticality of the achievement of stringent acoustic requirements to stealthy anti-submarine operation, for the first time ever in a Royal Navy programme a shore-based test rig was built to ensure the gearbox met its design parameters. Ironically, according to Beverstock, *"The vast majority of the challenges of delivering the gearbox were actually with the test rig and not with*

Credit: Conrad Waters

The Batch 2 'River' class OPV HMS Forth pictured on her maiden arrival into Portsmouth naval base. Lessons learned from the emergence of defects after her delivery have resulted in greater oversight of current Royal Navy construction programmes.

Credit: BAE Systems

The lead Type 26 frigate, Glasgow, is rolled onto a barge at BAE Systems shipyard in Govan in November 2022 prior to being floated out. The Naval Ships Delivery Group is responsible for overseeing the delivery of eight ships of the class.

the gearbox. However, through completing this process we now know that that gearbox is fully functioning, de-risking an important programme component that would only previously have been tested when we took the first ship down the river on sea trials". As of December 2023, the gearbox for Cardiff, the second ship of the class, had been installed in line with the original build sequence whilst that for the third ship was in the course of performance testing.

Beverstock added, *"We have done similar things to de-risk other elements of the Type 26 programme. The ships feature an innovative mission bay and we have built a full representative load test and handling facility to ensure it operates as intended. Another example is the use of GE's land-based electrical integrated test facility to put the electrical propulsion and distribution system that is being installed in the class through its paces. In this way the Ministry of Defence is learning lessons from past programmes to de-risk our ability to deliver future warships as quickly and effectively as we can."*

A disruptive approach

A further example of the Ministry of Defence's desire to improve the performance of future warship construction is provided by the Type 31 frigate project, which Beverstock describes as, "a deliberately disruptive programme to bring competition to the British warship procurement market". A more than GBP 1.25 billion (EUR 1.5 billion) contract – exclusive of certain government furnished equipment – for five ships was awarded by DE&S to Babcock International in November 2019 after a competitive procurement process. The agreement anticipates all five frigates being delivered by 2028 to replace those Type 23 frigates used to conduct general-purpose missions. The ships are being built in a new ship hall at Babcock's Rosyth facility near Edinburgh. Beverstock explained, *"Type 31 procurement was based on setting a very competitive price point and asking industry to come back with the best capabilities they could provide within this budget. Equally, we also asked for an extremely competitive build programme. Our ambition, by the end of the programme, is to be able to build a frigate from first cutting steel to delivery in less than three years."* So far, he was happy that the front end of the programme "has pretty much stuck to time, to cost and to quality" despite the fact that most of the infrastructure required at Rosyth to undertake the project had to be assembled in the course of the COVID-19 pandemic.

In spite of the very real progress that has been achieved with the Type 31 programme, the project has not been without its complications. Babcock has entered a dispute resolution process with the Ministry of Defence over the impact of macroeconomic changes – likely the impact of high inflation –since the contract was first agreed, and has taken a GBP 100 million (EUR 115 million) provision to cover the likely loss if these excess costs cannot be recouped. However, relationships between the Ministry of Defence and Babcock remain strong, with Beverstock emphasising that "We are working with Babcock to make the programme the success that it needs to be to ensure that we have a competitive shipbuilding industry".

The design's success in export markets – Indonesia and Poland are already building variants of the 'Arrowhead 140' frigate from which the Type 31 is derived under licence – is evidence of the potential market to be tapped. Nevertheless, Beverstock was realistic that future hurdles lie ahead, *"We set a really ambitious target for Type*

Credit: Conrad Waters

The first and second Type 31 class frigates – respectively Venturer and Active – under construction at Babcock International's new ship hall at Rosyth. To date, the programme has largely met time and quality requirements.

Credit: Babcock International

A computer generated image of a Type 31'Inspiration' class frigate. Five of the class have been ordered from Babcock International following conclusion of a competitive contract process.

31 completion and I am pretty sure we are going to face some challenges as we enter the difficult integration stage. But even if we get close to the ambitions we have set for ourselves in building these ships, it's going to be a really remarkable programme".

Future aspirations

The achievements of the Royal Navy's frigate programmes are in line with the tenets of Britain's National Shipbuilding Strategy (NSbS), which aims to drive a revitalisation of the shipbuilding sector. Beverstock stated, "Our aim is to put our shipyards into the top quartile of performance in warship building internationally."

The resurgence in shipbuilding activity is, however, bringing difficulties of its own making. In Beverstock's words, *"The biggest challenge we face in both shipyards is making sure industry can resource them to the right level. We are recapitalising the navy through the Type 26, Type 31 and Fleet Solid Support Ship programmes and what is almost a resurgence in shipbuilding is leading to significant capital investment to make the yards more competitive. However, fundamentally we are still constrained by the workforce we are able to get hold of."* A short-term answer to this problem is to outsource block construction to other shipyards, including A&P Tyne and Cammell Laird for the Type 26 programme, to maintain the production schedule. In the longer term, a major drive in industrial apprentice programmes is intended to put industry on a firmer footing.

Although the British naval shipbuilding sector has undoubtedly seen considerable success in recent years, the speed of delivery of current construction programmes has not been without its critics. Whilst much of this criticism is seemingly based on limited knowledge of the shipbuilding process and an inability to make effective time and cost comparisons with international programmes, it inevitably detracts from the sector's real achievements. Beverstock asserted, "We are happy to be compared with international shipbuilding norms if done on a like-for-like basis." He added, "If you take a long-term view on where we have come from and what we have done, then we have come a long way in meeting some really ambitious targets".

A good example of the pace of development is set by progress achieved at BAE Systems since the start of the contract for the second batch of Type 26 frigates in November 2022. This gave the green light for the modernisation of the group's shipyard at Govan. Beverstock pointed out that since then, *"BAE Systems have got all the permissions needed for the new shipbuilding hall, awarded the contract for construction of the building, completed much of the initial assembly work and are on track to finish work so as to allow the third ship [editor's note: the hall was intended to facilitate the completion of the fourth and subsequent frigates] to be consolidated within the new structure. That is a fantastic success story on delivering infrastructure in a country which has a poor reputation for completing infrastructure in a timely manner".*

Beverstock also noted the level of political support the naval construction sector has gained, including the focus placed on implementing the NSbS and real push being given to securing export orders. The political importance of the frigate programmes is undeniable given that the six ships already under construction – four Type 26 frigates on the Clyde and two Type 31 frigates at Rosyth – support 6,500 long-term, highly-skilled jobs across the UK-wide supply chain. This will also doubtless ensure the work of the NSDG remains a matter of ongoing scrutiny. Beverstock was under no doubt as to what is expected, "We maintain a laser-like focus on managing both frigate programmes to achieve their delivery on time and to budget". ■

Credit: Crown Copyright 2022

Glasgow is seen transiting the River Clyde prior to being floated out. Significant work undertaken to de-risk key elements of the construction programme for the Type 26 frigates should ease the class's entry into service.

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Doomsday or business as usual? Artificial intelligence, machine learning, and CBRN threats

Dan Kaszeta

Chemical, biological, radiological, and nuclear (CBRN) threats are potential sources of disaster in modern life. Enemies might be able to use them for some sort of advantage, terrorists could use them for havoc, and accidents could cause disruption, property loss, and death. The same could be said of the broad field of artificial intelligence and machine learning. This expanding field has intersected that of CBRN in both practical and theoretical ways. There are areas for concern. But how concerned should we really be? And is often the case, concern can also bring opportunity. As this new aspect of modern life will be with us from now on, it is worth examining some of the more prominent ways in which AI and machine learning may penetrate in CBRN defence and security.

Artificial poisons?

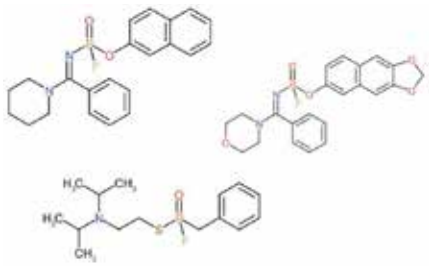
AI could make new threat materials. Numerous accounts in both popular and specialist publications have talked about AI novel toxic compounds. Various experiments have set AI models loose to crease, on paper, new molecules. Within hours, AI models were creating molecules deemed to be poisonous. Some likely had toxicological properties that make them possible 'nerve agents' – a category of chemicals than includes some of the deadliest chemical warfare agents. A fair bit of alarm and hang-wringing accompanies some of these A little bit of context is helpful in determining whether to get alarmed by this talk of synthesising chemicals. First, it is not necessary to use AI to do this. The rules for assembling plausible chemical compounds are relatively straightforward. A fairly simple bit of software code or a modestly trained undergraduate will spit out thousands of plausible structures for new chemical compounds. Moreover, even if you did it at random, of course you would get poisonous compounds. Anything you do to create new compounds will inevitably create poisons. Nearly every plausible chemical compound is likely to have toxicity at some level or concentration. Very few things are biologically inert. Even water is poisonous in high enough doses.

In reality, the AI algorithms that are alleged to be poison-generators are actually 'everything generators' because basically everything they make is a poison. Given the state of computational toxicology, just how poisonous a novel compound is, without test data, is not much better than guesswork. Some are just nonsense compounds, theoretically possible but impossible in real life. Promethium fluoride is plausible on paper, and almost certainly toxic. Yet with only 500-600 grams of promethium on the entire planet, dispersed in the Earth's crust in vanishingly small traces, it is not really plausible. However, an AI tasked to find poisons may churn it out on the list.

Another point is that that many compounds are possible medicines. The difference between something medicinal and something harmful is the dose. Some nerve agents are medicinal in fact, such as the drugs pyridostigmine and physostigmine. AI could discover medicines as well as poisons. Even optimising an AI to select for theoretical toxicity is not actually as relevant as one might think. Toxicity in poisons is basically an already solved problem. Ample poisons exist in nature and science. Yet many poisons are also medically useful, even extremely toxic compounds, if used in dilute form. We must recognise the complexity of modern chemistry and biology.

There are also some limiting factors. The size and complexity of molecules is also an important point. Since there are only so many types of atoms in the universe, (for instance – as defined by the periodic table of elements), and only so many ways in which you can stick them together, there's only so much scope for what AI (or a simpler algorithm) can do. Simply stated, all of the small molecules are already spoken for. New compounds are likely to be large, unwieldy compounds that are solids at room temperature. Solids tend to make poor chemical warfare agents. Additionally, some that might be theoretically poisonous might also be practically insoluble, so would have a hard time being used as a poison. All told, diagram of a plausible molecule is a long way from manufacturing.

Given this author's own experiments with AI, asking the natural follow-on questions of 'So, AI, how do I actually make this molecule?' and 'What tools do I need?' will get you some interesting but not terribly useful results. We should be right to also



Credit: Chem4Word

AI models can knock together plausible molecules, but they may be very difficult to make in real life.

Author

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consider biology, but the nexus between AI and artificial design of biological materials is, hopefully, still some way off in practical term. AI at present will point you in the right direction to make some poisons – but so will a library card.

Industrial Hazards

Another area of concern is encroachment of AI onto industry. AI and various aspects of machine learning are in use in industry, and the extent to which this is already happening and what the level of potential threat may be is difficult to ascertain due to the opaque nature of many industrial processes. This area of concern impinges upon CBRN because of various industries that use CBRN materials. Is it possible that AI could cause a disaster with chemical or radiological materials? The difference between a CBRN terrorist incident and an industrial hazardous materials accident with toxic chemical lay in intent and mechanism, but not in the actual harm produced.

AI in industry, commerce, and transport is therefore a CBRN AI safety issue. Industrial processes could be overseen by various AI-type tools, and these processes could have accidents. Transportation networks could be overseen by AI and cause accidental releases. Nuclear power accidents could occur. For now, these hazards are fairly well circumscribed in industry. Regulators and standardisation bodies are active in this area. We are not a critical point right now, but continued vigilance is needed as AI and machine learning become more ubiquitous.

What is the feedstock of AI?

We are right to ask the question 'how does this all work?' A factor that needs to be strongly considered is that large language models are trying to cobble together answers to questions based on looking at the widest possible sets of data. In the case of CBRN weapons and technologies, where does the information come from? We should never assume that every bit of information that is relevant to an AI query – whether innocent or malevolent – is available for a model to search.

It may be best for to illustrate this with an example. You can ask an AI a query such as 'give me a good recipe for a chocolate cheesecake' and it will give you some results. It will look through thousands of cookbooks, web posts, articles, and possibly even YouTube videos and give you a result. However, not every chocolate cheesecake recipe in human history is available for searching. Some cookbooks may be old and in languages that the AI has trouble understanding. An AI might be clever enough to deal with a recipe that starts out 'start like in the plain cheesecake recipe, but at step 4 add some cocoa powder.' Yet what about other sources of information? How well does AI read odd fonts and typography in other alphabets? Or, say, a Czech recipe in a blurry scan of a newspaper article from 1935? So far, there will be a bias towards material that is written in English, or at least in easily-readable graphic form. But the AI will not have access to your grandmother's hand-written recipe in a desk drawer. There will be many thousands of such recipes out there, unavailable for online search.

Credit: US Army/Sgt 1st Class Samantha M. Stryker

A service member is decontaminated during a Toxic Industrial Chemical Protection and Detection Equipment training exercise on Contingency Operating Base Basra, Iraq, on 15 December 2009. Military or terror threats aside, AI running complex industrial processes presents a risk of potential release of dangerous chemical or radiological materials.

The reason why this allegorical example is relevant is that much, possibly even most, of the really useful information from the large state programmes that made CBRN weapons is not available online for AI tools to parse and digest. The good bits of these programmes are basically the equivalent of your grandmother's chocolate cheesecake recipe. They exist, but they are in hard copy locked up in archives. They are not searchable or discoverable online. Some, such as notes from the original German scientists who invented nerve agents are available to keen researchers in an archive. However, they are not reproduced online and are handwritten, so even if they were available

Credit: US Navy/Specialist 2nd Class Eric Lockwood

Much of the useful information on state CBRN programmes is not available online, often existing in hardcopy format, stored in secure archives.

they might be a challenge to read. Others are deeply buried behind procedural and physical safeguards. AI simply does not have access to the archived or lost secrets of the old national production programmes.

Misinformation, disinformation, and propaganda

One problematic area in CBRN affairs in the current day is alleged or fake incidents. In conflicts in recent years, there have been numerous incidents that were either innocently or maliciously misrepresented as possible CBRN incidents. For people who wish to create mayhem, AI represents a serious threat, though. Misinformation is incorrect information spread unintentionally. Disinformation is false information that is spread maliciously. It can be difficult to tell the two apart, and incorrect information starting innocently out of lack of background knowledge can be deliberately spread farther. Likewise, disinformation started maliciously can be passed along by people who simply do not know any better.

We can look at recent conflicts and see numerous instances of misinformation and disinformation in the subject area. Incidents involving Sarin and Chlorine in Syria were variously denied, misrepresented, and misattributed. Tear gas and smoke grenades in several countries have been wrongly described as 'nerve agents' or 'mustard gas' during various incidents. The 4 August 2020 large fertiliser explosion in Beirut was alleged by some to be a nuclear explosion before the truth came to light. Similarly, in the Ukraine conflict, tear gas grenades have been misrepresented as the chemical chloropicrin, yellow- or orange-coloured explosions due to nitrate explosive material have been alleged to be chemical warfare agents, and very old chemical warfare test kits were passed off as samples of Sarin. A large hazardous materials accident in the US state of Ohio was widely but erroneously described on social media as emitting 'mustard gas'. Hardly a day goes by in the current Israel-Gaza conflict without some kind of similar claim being made.

For those malefactors who wish to conduct malicious information operations, various AI tools are already useful and will continue to improve. Dangerously, still, video, and audio evidence can be mocked up as completely faked evidence of some sort of CBRN incident. We've already had non-AI versions of this scam with images taken from other sources and misrepresented on social media. But reverse-image searches quickly debunk such recycling of images. Yet totally new images of deep-fake quality would be impervious to reverse-image searches.

Further AI techniques are similarly disturbing. We already know that AI tools can concoct fake laboratory data. A brief news item in the 22 November 2023 issue of Nature cites one such problematic incident. What if, during and after the Beirut explosion, AI tools invented radiation sensor readings? AI inventing fake article citations claiming that tear gas really is a nerve agent is certainly plausible. Fake patent citations and fake case law citations have been seen as AI outputs in the last year. We have long needed tools to help debunk disinformation. It now seems clear that we will have to develop tools to deduce the hidden hand of AI.

Opportunities: What can AI do to help?

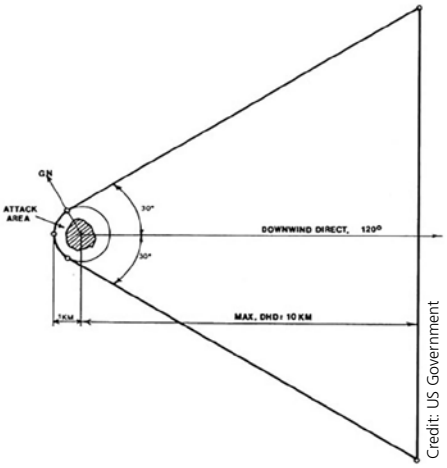
Enough with the downsides. Are there positive uses for AI and machine learning with regards to CBRN threats? There certainly will be some areas in which these new technologies will have some application. One way to look at the issue is that AI and machine learning are merely another step, albeit a large one, in a continued improvement in computing capabilities. Computers and data processing are now integral to many CBRN defence tasks, so it stands to reason that those improvements in information technology, AI or otherwise, will improve aspects of CBRN operations as a matter of course.

The utility of general-purpose AI models such as Chat GPT in CBRN affairs is still a largely untested area. However, there is a reasonable track record wherein AI and machine learning tools are focused on specific narrow tasks. Three particular aspects of CBRN countermeasures seem to be natural areas wherein specialised AI tools may be helpful. The three aspects that come to mind are non-proliferation intelligence, hazard modelling, and networked detection.

Historically, countries have gone to lengths to hide the development, production, testing, and stockpiling of CBRN weapons. The question of whether or not a particular country has offensive CBRN programmes

Credit: US Army/Sgt Benjamin Northcutt

Participants run through a simulated chemical attack during a CBRN exercise 11 July 2018 at Baumholder, Germany. During conflicts, tear gas and smoke grenades have often been misrepresented as chemical agents.



Credit: US Government

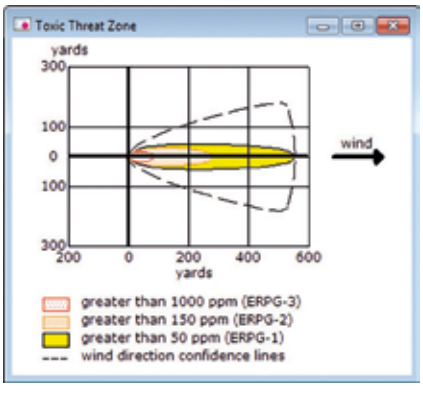
AI could be expected to make hazard modelling and prediction more accurate or user friendly.

is often a hard one for intelligence services to analyse. Rarely is there a single piece of information that proves or disproves the existence of a programme. Analysts examine lots of small pieces of information to try to put together a jigsaw puzzle. The types of information that might be useful for finding a covert CBRN programme are quite varied. Only the largest and best-resourced intelligence services are likely to have the resources to do a thorough effort of collection and analysis.

However, you could train an AI tool to do some of this work. AI tools could sift through lots of raw data looking for clues and do it in ways that are faster than human analysts. Could an AI look at thousands of small clues and come up with useful intelligence in ways that a human analyst might not? How long might it take for human analysts to sift through the CVs and publication record of thousands of scientists to look for trends? Some phenomenon such as ten organophosphate specialists disappearing out of social networks and ceasing publishing might be of interest if Country X is suspected of making nerve agents. Perhaps tasks such as these are already being done, but this correspondent has no direct knowledge of such, of course.

'Hazard prediction' in CBRN is basically a term for 'if such and such a CBRN material is released, where will it travel?' In older times, and in some settings, very simplistic models and templates are used to plot simple triangles on a map. This correspondent remembers doing some in the dark with a red-lens flashlight on a NATO 1:50000 map in his early training. Increasingly sophisticated computer models have supplanted but not completely replaced antiquated analogue methods. Larger models take a lot of input and do a lot of calculations. The largest hazard prediction capabilities, such as NARAC at the USA's Livermore National Laboratory use supercomputers and a large number of PhD-level staff. Identifying all of the relevant inputs, searching for data, and crunching the numbers to produce a relevant and accurate hazard prediction seems a task well suited for AI and machine learning. At a minimum, an AI model could serve as the front-end and feed useful inputs into an existing hazard prediction model. A well-crafted AI tool could very quickly interrogate thousands of useful datapoints, such as meteorological sensors, across an area of interest.

Half a century ago, CBRN detection was usually a handful of expensive sophisticate devices manually operated by highly trained CBRN specialists. In the modern era, vastly improved technologies, miniaturisation of electronics, and digital communications, there is not any technical impediment to proliferating thousands of CBRN sensors all over the modern battlefield or a city. Managing, meaningfully interpreting, and integrating all of this data with other forms of information, however, is a task that still befuddles CBRN specialists. A narrow-scoped AI that tends a sensor network can likely weed out false alarms and provide near real-time situational awareness in both military and civil protection environments. By looking at a lot of different types of sensor outputs, and not all of them necessarily specific CBRN sensors (i.e., temperature sensors, wind direction sensors), there is the prospect of a much more accurate alert. Combined with the hazard prediction capability described above, an alert can be confined strictly to the area where it is needed, thus reducing impact on military missions.



Credit: US Government

Improving our hazard modelling and prediction capabilities would go a long way to improving responses to CBRN threats.

Safeguarding the future

Many people are legitimately concerned about what threats AI and related technologies may bring. Some have even voiced existential fears. Because of the nature of CBRN threats, combining these threats in people's minds has caused some degree of anxiety. What can be done? Are we actually right to worry?

To a certain extent, this author believes that worries are slightly overblown. AI does not fundamentally alter the calculus that CBRN warfare is inherently more expensive, less reliable, more dependent on weather variables, and often less effective than sophisticated conventional means of lethality. Explosives and firearms are still going to be far easier for terrorist groups than nerve agents, despite whatever information a chat with an AI might provide. Also, historically, the defensive arms race in CBRN has been more fruitful than the offensive one. Defensive measures, which have continued for decades long after meaningful technical developments ceased, have more than matched most CBRN threats. This basic fact will not change.

For the most part, CBRN hazards lay within a much broader panoply of potential AI hazards. Broader safeguards are likely to have a direct benefit in CBRN affairs. Creators of AI tools must be responsible for helping to make them safe. Governments, standards bodies, and regulators of every type can develop and advocate for codes of conduct and good working practices, as well as laying down a regulatory framework. As with cars, aircraft, medicines, and other technological aspects of modern life, safety needs to be actively promoted and guided. It is what taxpayers want and demand.

We have long agreed that cars need crash safety standards and seatbelts. However the problem with AI is that few of us know what these standards and seatbelts look like. Society and industry need to develop them. Within CBRN defence, some early promise has been shown by red-teaming efforts. These have involved experts deliberately poking holes and exploiting an AI to see the extent of possible impact, and can help in the development of safeguarding policies. AI creators big and small need to develop the 'seatbelts' that make their products safe and limit their ability to cause harm in CBRN or other areas. The problems posed by possible disinformation could be mitigated by 'watermarking' – the idea that creative output by AI systems is cleverly marked so that it can be seen by all as artificial output. ■

Designated marksman rifles – closing the range gap

David Saw

The modern designated marksman rifle (DMR) came about in response to conditions encountered in the post-2000 asymmetric conflicts, in particular in Afghanistan. Put simply, the requirement arose to complement the existing inventory of infantry weapons, specifically for a weapon that could offer increased range and significantly increased stopping power. Along with increasing adoption, new DMR designs are emerging to meet these requirements.

The DMR concept traces its origins to the early 1960s following the US military's adoption of the M16 rifle in the 5.56 × 45 mm M193 cartridge. The US had previously influenced the selection of the 7.62 × 51 mm as the standard NATO rifle round in the early 1950s and by the early 1960s, most NATO nations were using rifles in 7.62 ×51 mm cartridge. At that point, it became clear that the US was opting for an intermediate 5.56 × 45 mm round for an assault rifle. By the end of the 1960s, the conventional wisdom had changed, and the aim was to develop a standard intermediate round for NATO small arms that would replace or supplement existing 7.62 × 51 mm calibre systems.

Eventually a new round, the SS109 in 5.56 × 45 mm, developed by FN Herstal in Belgium, was selected as the NATO standard round in October 1980 and remains so to this day. Performance of the standard round has improved over the years, with impressive results. However, there is only so much that you can achieve with a round of this calibre. Evolutionary developments in assault rifle designs undoubtedly help, as does the installation of an optic. However, the 5.56 × 45 mm round was generally seen as adequate operationally until conditions in Afghanistan revealed the need for a new weapon.

Others had already come to the conclusion that while an assault rifle was exactly what the infantry needed in terms of firepower, the loss of range compared to the round used by an old-fashioned battle rifle was a concern. This was an issue that the former Soviet Army chose to confront in the late 1950s and they eventually opted for a solution that could be classified as a DMR.

The Soviet Army inherited the 7.62 × 54R mm round as its standard battle rifle round from the Imperial Russian Army that had first entered service in 1891 for the Mosin-Nagant rifle. After years of searching for a replacement round, they concluded that the 7.62 × 39 mm intermediate round was the best solution for future small arms use and this was the type classified in 1943. Its first use was with the SKS rifle, but it really came to prominence with the AK-47 assault rifle and its many variants. The AK provided the firepower required, but the concern was a reduction in range. This led to a decision in the 1950s to develop what we would now call a DMR and this weapon would use the old 7.62 × 54R mm round which was also due to remain in service as a machine gun round.

Credit: US DoD

The 7.62 × 54R mm SVD rifle developed by Dragunov, can be regarded as the first DMR and the catalyst for recent Western DMR developments. Here a Spanish paratrooper fires an SVD at the Besmaya Range Complex, Iraq, on 7 August 2015.

The SVD rifle was subsequently developed by Dragunov, with a 10-round magazine and equipped with a 4× PSO-1 optic and backup iron sights. Standard 7.62 × 54R mm rounds can be used, but special 'match grade' ammunition is available, offering increased performance. Over the years, multiple variants of the weapon were developed with unlicenced versions built in China, Iran, Iraq and elsewhere. The weapon can also be equipped with 1PN51 or 1PN58 night sights, if the appropriate rail is fitted. The SVD was widely deployed in the Soviet Army as it increased infantry range coverage out to between 600 m and 800 m. The SVD was produced in massive numbers from the early 1960s onwards and has proliferated all over the world.

It is important to emphasise the significant performance of the SVD when it entered service. Up until the end of the 1980s, the standard British Army sniper rifle was the L42A1, a 7.62 × 51 mm calibre weapon based on the old Lee Enfield bolt action rifle. Official performance capabilities of the L42A1 were an effective range of 600

m and harassing fire out to 800 m. The British Army would subsequently recognise the importance of sniping and substantially improve their capabilities in that area. Yet they, like many other NATO armies, perhaps failed to appreciate the problems that the SVD and similar weapons would cause in the future.

Russia intends to eventually replace the SVD with the Chukavin SVCh from the Kalashnikov Group. This semi-automatic weapon will be available in multiple calibres for DMR applications and in a dedicated sniper configuration in .338 Lapua Magnum (8.6 × 70 mm) with a 10-round box magazine. The weapon is fitted with a MIL-STD-1913 Picatinny rail for sight and accessory integration. The DMR variants are available in 7.62 × 51 mm, with a 10 or 20-round box magazine, or 7.62 × 54R mm where they can use the standard SVD 10-round magazine.

The need arises

As operations in Afghanistan evolved, the British Army found itself having to deal with situations that exposed the limitations of its standard 5.56 × 45 mm squad weapons. Firstly, they were out-ranged by SVD-type weapons, and secondly, standard 5.56 × 45 mm rounds lacked 'stopping power' at extended ranges. Increasingly, the Taliban were also gaining access to body armour, making targets harder to neutralise. This opened the way to an urgent operational requirement (UOR) for an infantry weapon that could successfully engage and neutralise targets at extended ranges.

The objective was to have a highly accurate semi-automatic 7.62 × 51 mm calibre weapon that would be particularly effective in the 600–800 m range zone. A number of different weapons were evaluated including the FN Herstal SCAR-H, the Heckler & Koch (H&K) HK417, an AR-10 derivative from Sabre and the LMT Defense LW308 Modular Weapon System (MWS). The latter weapon was selected for the UOR in 2009 and features a 406 mm (16 in) barrel and a 20-round detachable box magazine. It is fitted with a 6×48 Trijicon ACOG TA648 optic and a Trijicon Rugged Miniature Reflex (RMR) red dot sight. Also available is the MilSight S135 MUNS (Magnum Universal Night Sight). The weapon was type classified as the L129A1 Sharpshooter by the British Army and an initial batch of 440 weapons was ordered.

The L129A1 entered service in Afghanistan in 2010 and was so successful that a total of 3,000 weapons had been acquired by 2014. Perhaps the best endorsement of the L129A1 is that, unlike other infantry weapons acquired under UOR terms by the British Army, for example the L110 5.56 × 45 mm machine gun and the 60 mm mortar, it was not withdrawn from service after the end of operations in Afghanistan. Indeed, it was to find an additional role as it was selected to meet the Sniper Support Weapon (SSW) requirement. In the British Army, snipers operate as a two-person team – the sniper with the L115A3 sniper rifle in .338 Lapua Magnum (8.6 × 70 mm) with a Schmidt & Bender 5-25×56 scope and the spotter equipped with the SSW. The L129A1 was selected to meet the SSW requirement and in this form it would be equipped with a Surefire suppressor and a Schmidt & Bender L17A2 3-12×50 scope. If there was a problem with the scope on the L115A3, the SSW would 'donate' its L17A2 scope to the L115A3 and revert to iron sights.

The LMT Defense L129 story does not end with the SSW, as there is now a new system variant in the L129A2 configuration. Royal Marine Commandos are in the midst of a major capability upgrade as a part of their Commando Force Programme. As part of this upgrade, they will receive the new L403A1 5.56 × 45 mm assault rifle, and will also upgrade their DMR capabilities through the acquisition of the new L129A2 rifle. The L129A2 features significant changes over the original L129A1: the lower receiver is upgraded to the Modular Ambidextrous Rifle System (MARS-H) configuration; there is a new two-stage trigger and adjustable stock; the rail is longer than on the L129A1; and it has the M-LOK configuration offering a more flexible platform for optics, night and thermal sights and other devices.

The L129A2 has a 457 mm (18 in) barrel in 6.5 × 48 mm Creedmoor (6.5 CM) cartridge, although there is a quick-change barrel feature allowing the weapon to utilise the 406 mm (16 in) barrel in 7.62 × 51 mm of the L129A1. Using the 6.5 CM round, the L129A2 can achieve an engagement range of over 1,000 m. The weapon is fitted with a HuxWrx suppressor, Leupold Mark 5HD scope, Pixels-on-Target thermal sight and accessories include an Envision Technology ballistic calculator. According to the Royal Marines, each of its Commando Strike Teams will have two designated "expert shooters", each equipped with the L129A2.

British soldier with an L129A1 Sharpshooter DMR during Exercise Northern Forest in Finland in May–June 2023. The L129A1 is also used as the Sniper Support Weapon (SSW) and the L129A2 in 6.5 × 48 mm Creedmoor has recently been fielded.

Elsewhere

In Austria, Steyr Arms is introducing its own DMR under the Steyr DMR designator. The company is already known for its assault, sniper and hunting rifles and they have developed a DMR that offers sub-MOA accuracy in a lightweight package. This is a semi-automatic 7.62 × 51 mm weapon that can use standard AR-10 type magazines in 10 or 20-round formats. The weapon will also be available in 6.5 CM and even in the 6.8 × 51 mm round selected by the US Army for its future XM7 rifle. There is no quick-change barrel option, but a barrel replacement to accommodate a different calibre should be easily accomplished by a competent armourer.

Credit: Steyr Arms

Austria's Steyr have a complete military small arms range of pistols, assault and sniper rifles and have recently introduced their own DMR solution in the form of the Steyr DMR in 7.62 × 51 mm. It is designed to offer sub-MOA accuracy in a lightweight package.

In neighbouring Czechia, the CZ Group has seen its Bren 2 PPS DMR replace the SVD in Czech Army service with an initial order of 350 weapons. This is a semi-automatic DMR chambered in 7.62 × 51 mm with a 457 mm (18 in) barrel and a 10-round box magazine. The weapon is fitted with a Nightforce 1-8× optic, though no suppressor requirement has emerged for this DMR to date.

The French Army resolved its DMR requirement via the Fusil de précision semi-automatique (FPSA), or semi-automatic sniper rifle, programme to replace the FR-F2 rifle in 7.62 × 51 mm acquired in the 1980s. After evaluating a number of European solutions, the FN SCAR-H PR in 7.62 × 51 mm was selected and 2,620 weapons ordered; they are equipped with a Schmidt & Bender PMII ShortDot Dual CC 1-8×24 scope and precision ammunition was acquired from MEN in Germany. OIP Sensor Systems Tigris clip-on sights were selected for the DMR, in an image intensifier and infrared variant.

Cooperative weapon development and acquisition is becoming increasingly important between Finland and Sweden, reflected by a number of sniper rifle and DMR acquisition programmes to replace existing systems. Finland has always placed a strong emphasis on sniping and precision shooting and developed a new DMR requirement to replace the SVD and the TKIV 85, a bolt-action rifle based on the Mosin-Nagant design, with both weapons using the Russian 7.62 × 54R mm round. These weapons will be replaced by the Sako M23 in 7.62 × 51 mm equipped with a Trijicon VCOG 1-6×24 optic. Finland uses another variant of the Sako M23, the TKIV 23, equipped with a Steiner scope as a dedicated sniper weapon.

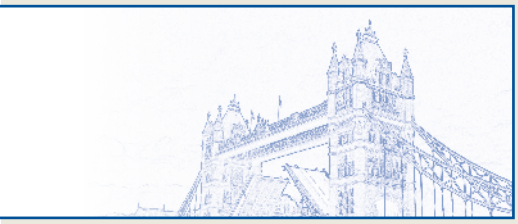
The US Army began fielding a DMR solution in 2020 in the form of the M110A1 squad designated marksman rifle (SDMR), which emerged out of the related M110 A1 compact semi-automatic sniper system (CSASS), essentially both based on the HK417 design via the German Army G28 variant in 7.62 × 51 mm calibre. The US Army SDMR is described as having a range of up to 600 m using M118LR precision ammunition, and is equipped with a SIG Sauer TANGO6T 1-6×24 mm optic.

The key issue in the US remains the next generation squad weapon (NGSW) programme awarded to SIG Sauer in April 2022 for the XM7 rifle that is to replace the M4/M4A1 carbine, the XM250 automatic rifle due to replace the M249 squad automatic weapon (SAW), and the new 6.8 × 51 mm round they will use, as well as the Vortex Optics XM157 fire control optic. Testing on all of the NGSW elements continues and there is still a long way to go until these weapons are accepted for service. Should the US Army adopt these new weapons and a new small arms calibre, that will have implications for US allies and there will certainly be pressure to standardise the 6.8 × 51 mm round in NATO. In turn, that will force NATO and other US allies to rethink their commitment to the NATO standard small arms calibres of 5.56 × 45 mm and 7.62 × 51 mm.

In the meantime, while serious consideration is being given to future calibres, the evolution of the DMR sector will continue. For some a DMR that offers accurate engagement ranges out to 500 or 600 m is perfectly acceptable, while for others, the optimum DMR engagement range extends out to 800 m. This is where the British decision to acquire the L129A2 in 6.5 CM makes things very interesting in the DMR context. If you can field a weapon that can accurately engage at 1,000 m and neutralise the desired target array, then infantry firepower has gained a new dimension! ■

Credit: Armée de terre

The French Army fusil de précision semi-automatique (FPSA), or semi-automatic sniper rifle, programme for a DMR was won by the FN Herstal SCAR-H PR. This 7.62 × 51 mm weapon has a Schmidt & Bender PMII scope and OIP Sensor Systems Tigris clip-on sights.



Viewpoint from London

Photo: via author

Pondering the future of UK space surveillance capabilities

Tim Mahon

As the new year unfolds and defence strategies (and outcomes) are increasingly called into question, it is tempting to believe that the occasional eye in Whitehall is being cast skyward. Not, it must be admitted, for fear that drones delivering consumer goods may fall on the observer, but rather that some thinking is being focused, increasingly, on the not-so-final frontier – space.

At governmental level, the United Kingdom has a reasonably well-thought-out approach to the space domain in all its aspects. It is, after all, one of the primary nations espousing the cause of responsible behaviour in space at the United Nations. Closer to the hearts of readers of this magazine, however, is the Defence Space Strategy, published in early 2022, which paints a picture of quiet competence and middling ambition in a post-Brexit world. As the then Secretary of State for Defence, Ben Wallace, said at the time, "Capability development will be guided by the 'own-collaborate-access' framework first laid out in the Integrated Review. There will be areas where we need dedicated sovereign capability, but also cases where we will access technology from elsewhere or utilise collaborations and partnerships to broaden capabilities and deepen resilience."

Speculation might thus be prompted into what Britain intends to do about the threats intrinsic in the continuing development of hypersonic weapons. Although Ukraine and Gaza illustrate the efficacy of well-provisioned multi-layered air defence capabilities when dealing with more conventional threats, the challenges posed by airborne threats travelling at anywhere between five and ten times the speed of sound represent a challenge of greater magnitude. Detection, tracking and interception require a much faster response and more discriminatory sensors, data processing and decision support assets – all factors recognised on the opposite side of the Atlantic.

It is to be hoped, therefore, that British planners and strategy developers will take a close look at the report published on 18 December 2022 by the Missile Defense Project at the Center for Strategic and International Studies (CSIS) in Washington, DC – 'Getting On Track: Space and Airborne Sensors for Hypersonic Missile Defense'.

Readily apparent from even a cursory reading of the report is the authors' conviction that an effective defence network to counter hypersonic missiles must, at a minimum, comprise three fundamental characteristics: a diversified architecture that spreads capability and risk among satellites (in multiple orbits) and the emerging generation of advanced airborne sensors; rapid cueing of fire-control data to interception effectors; and persistent surveillance. This last capability, the report suggests, needs to be rapidly accelerated in order to keep abreast of the evolving hypersonic capabilities in America's 'pacing threat,' China. Britain's interest, given Vladimir Putin's regular posturing, may be focused a little closer to home.

The question for London is how to develop current-generation and sovereign capability at a cost that would be accepted by the Treasury. European developments are marred, for London, by the glacial pace of development and the somewhat contentious effects of the aftermath of Brexit on collaboration. Better by far, must be the conclusion (or at least one of them) to focus attention on working with a community fast becoming even more important than it was at its origin – the Five Eyes alliance. Not only does that force Britain to stretch its mind around two critically important but robustly dissimilar operational theatres (outside its concerns for the resumption of continental warfare in Europe) – North America and the Arctic, as well as the Indian Ocean and Pacific regions – it also has the added advantage of placing Britain in ever closer contact with one of the principal assets Australia brings to this alliance – the Joint Defence Facility at Pine Gap.

Located near Alice Springs in Australia's Northern Territory, Pine Gap is a critical satellite surveillance facility, and arguably America's most important overseas base.

The information developed as a result of Pine Gap's surveillance and analysis activities will be crucial to understanding the continuing development of hypersonic capabilities, in China, in Russia, and in time, elsewhere. Such information may be the basis for the concept of an effective means of defence. All five members of the alliance face a similar conundrum – so perhaps a joint approach to resolving it may not be out of the question.

In reflecting on the necessity for consideration of hypersonic threats, it is worth sparing a thought for the myriad considerations planners now face: environmental change, water and food security and their effect on migration, economic warfare and cyberattacks – to say nothing of population dynamics, religious conflict and criminal activities. None of these are new as individual threats, though some are taking on fresh dimensions. Their confluence, however, is making broad spectrum security more challenging to achieve.

Ukraine's complex body armour story

Tim Guest

Body armour and related carry systems must be capable of withstanding any ballistic danger, constructed of the appropriate materials, and tested to the highest standards.

When it comes to facing real-world, operational threats such as the Russian-made Dragunov semi-automatic sniper rifle on the battlefields of Ukraine, wearing effective body armour is essential for survival. While the war in Ukraine has taken a dreadful toll, allied states have supplied a vast amount of body armour and the country's industry and Ministry of Defence have also been hard at work creating their own, domestic body armour options. This article examines how body armour is supplied, developed and used to make a difference in Ukraine's fight against Russian forces, along with some latest expert thoughts and views, and presents a brief update on US National Institute of Justice (NIJ) standards influencing the sector.

Credit: Ukrainian MoD

Pictured: female combatants trialling new, Ukrainian-developed, personal protective equipment under realistic conditions in Ukraine. The war in Ukraine has seen body armour supplied from all over the world, as well as home-grown systems designed and manufactured.

Establishing body armour supplies

While Ukraine largely relied on COTS body armour and protective systems, (even after the 2014 annexation of Crimea), back in mid-January 2021, the then Defence Minister, Andrii Taran, announced the development of the country's own advanced body armour, designed with a modular system, that met NATO and accepted military standards. Until then, the country's commercial systems offered disparate protection levels. However, the new system adhered to US NIJ Standard-0101.06, which represented, a degree of progress. The minister said at the time that the new "general military body armour designed for daily combat missions" was to be used mainly by the land forces, with a lightweight model to be developed for the likes of paratroopers. It is worth noting that just one year later, the new capability would be facing the reality of front-line action against the invading Russian forces, and thus some very serious ballistic threats.

Since the start of the war, hundreds of thousands of body armour sets have been supplied to Ukraine by Western Allies including Austria, Belgium, Canada, Croatia, Denmark, Estonia, Finland, France, Germany, Ireland, Israel, Italy, Latvia, Montenegro, The Netherlands, Norway, Portugal, Romania, Sweden, the UK, and the USA (with over 100,000 sets sent), with other supplies also from the EU. Private entities, too, have supplied body armour, such as the Ukrainian American Coordinating Council, which obtained a special licence to ship regulated, military-grade helmets and body armour to the country in bulk quantities in 2022.

Closer to home, as of October 2022, Ukrainian-owned international steel and mining group, Metinvest, had supplied 150,000 sets of body armour – according to the company – using the company's own steel, accounting for one tenth of the body armour/vest sets in use by Ukrainian Forces at that time. The initiative has been referred to as 'Steel Front'.

Rinat Akhmetov, shareholder of Metinvest Group, stated that the urgent need for large quantities of body armour by the Armed Forces of Ukraine at the start of the invasion led the company to become "one of the largest suppliers of special steel and protective gear", although it had to "find an alternative to Azovstal's armoured steel and bring in rolled steel from abroad" if it was to set up domestic production of body armour. By the spring

Credit: Metinvest

Metinvest supplied 150,000 sets of body armour by October 2022 to Ukrainian forces using the company's own steel.

Credit: Crown Copyright

Pictured: NP Aerospace of body armour with Ukrainian troops in training in the UK. Ukraine has received vast supplies of body armour from overseas and has had it troops train in various European countries.

of 2022, some 600 tonnes of steel had already been imported from Europe and Turkey, which was then transferred to armour producers, including its own group specialists, which then made armoured steel on existing production lines, with 20 tonnes of special steel being produced weekly by October 2022. The group said it had also been procuring "ready-made body armour".

The company added that, "the greatest burden on manufacturers and suppliers of body armour vests" were in the early months of the war, from March to May 2022, and that "collaborations such as the partnership between Metinvest-SMC and the Lviv Defence Cluster (LDC) helped to steer them out of a difficult situation, with the LDC having received more than 500 tonnes of steel plates from Metinvest-SMC during that period, free of charge, for the production of body armour vests"; these sets went to equip the National Guard, the Territorial Defence and numerous units of the Armed Forces of Ukraine.

In terms of UK support, in October 2022, British company NP Aerospace announced that it had "manufactured and delivered more than 20,000 sets" of body armour plates and carrier vests to Ukrainian military personnel during the previous three months "on behalf of NATO governments". It added that the initial 20,000 units were just part of "contracts totalling 62,000 sets of armour, (124,000 plates), due to be delivered weekly" over the following nine months until mid-summer 2023. NP Aerospace said that the first 6,350 sets of body armour plates and carrier vests had been made and delivered within 10 weeks from the start of the conflict, which had only been possible by ramping up production with the recruitment of 90 additional factory operators, working 24/7 shifts. James Kempston, CEO and owner of NP Aerospace, said at the time that the company was "working around the clock" to deliver protection to Ukraine's front-line soldiers.

Looking after Ukrainian women on the front line

Back in Ukraine, reports in the Ukrainian media mid-September 2023, detailed the demo of new body armour for women, which had been designed and produced by company 'Ukrainian Armor', following a request from the country's MoD, after 'feedback' from female combatants who had been coping with ill-fitting male armour systems. Rather than flat plates typical of male armour, which had been chafing the women soldiers, the new tailored, curved plates were reported in the press to distribute weight more evenly and comfortably over the body, and were also lighter than a standard male vest making the systems easier to put on and take off. The new kit also includes detachable torso, neck, groin and leg protection elements. In addition, whereas the male body armour relies of heavy metal plates, the lighter weight of the women's plates is due to the use of composite ceramic-polyethylene.

The reports added that the manufacturer said the vest and carry system itself were also armoured, to an extent, providing soft ballistic defence and Category 2 protection against shrapnel, even without a plate inserted. According to a report, it is also some 20% lighter than other Cat 2 protection systems. With the appropriate plates, however, the report noted that ballistic protection to Category 4 or 6 provides the wearer with protection against small arms fire. A company spokesperson told the media that the system had passed internal tests at the time of the mid-September demo and would be handed over to the MoD for its evaluation, after which reports said "negotiations will take place".

Not even a full month later, the MoD announced that it was testing two models of modular body armour and vests, including "structurally-curved plates" with women combatants from a unit of the armed forces. As with earlier media reports, the MoD said, "The new design takes into account the specifics of female body structure and shape." It said personal protective equipment was being tested during combat training drills to make the test conditions for the new armour "as realistic and as close to real combat environment as possible".

The MoD statement said that the Central Department of Development and Material Support of the Armed Forces of Ukraine was conducting this second round of "usage tests" having already received

Credit: Ukrainian MoD

The lighter-weight female plates are made from composite ceramic-polyethylene.

feedback from first-round tests, adding that, "The manufacturers perceived the comments and took into account the anthropometric data of women, so that it is convenient for military servicewomen to operate with weapons." The statement said that after the completion of field tests, laboratory tests will be conducted by the maker, as well as the body armour being tested under different climatic conditions; based on the results, "the Ministry of Defence will approve the reference samples and then the body armours will be considered accepted for provision in the Armed Forces of Ukraine". After that, the MoD said that the next step would be procurement.

Old threat, new threat, qualified comment

Mention was previously made of the Russian-made Dragunov semi-automatic sniper rifle being a key threat to Ukrainian forces and their body armour. This is to provide an idea of what the armour systems being discussed face in terms of sniper weapons of choice, and to what standards they must be tested if plates are to cope with the impact from such weapons. However, while the Dragunov still poses a major threat, the Ukrainian-made Z-10, (also designated UAR-10), which entered service with the Ukrainian military in 2018 when it actually replaced Ukraine's Dragunov inventory, has emerged as a sniper weapon of choice in that theatre, with captured rifles even reported to be preferred by Russian forces, who are still equipped with the older Dragunov as their standard sniper rifle. The Z-10 is made by Zbroyar and fires standard NATO 7.62 × 51 mm rounds, weighs some 5 kg and is also said, by Ukrainian snipers using it effectively, to have an effective range of 1,200 m, compared to the Dragunov's 800 m.

Credit: Crib Gogh

SF unit wearing VAULT (vertical assault user light tactical) system, conducting a special patrol insertion and extraction (SPIE) rig operation beneath a helicopter.

Commenting on this development, Steve Heaword, a body armour expert, and member of the UK MoD's Jungle Warfare Programme, as well as Technical Director at specialist equipment maker Crib Gogh, told ESD that the Dragunov semi-automatic sniper rifle and its various 7.62 × 54 mmR rounds has posed a major threat for militaries in the past. It has been included as a threat under various MIL-STDs and test specs for the testing of body armour, including the NIJ standards to which many Western and NATO manufacturers adhere.

Heaword said, *"Whereas the earlier NIJ 0101.06 standard certification was used by many, including some European forces, to qualify their body armour, this certification will be inadequate for plates and armour systems being used today in Ukraine and facing such serious threats of not only the older Dragunov, but also the lethal Z-10. Sure, it's better to have body armour than no body armour, but when it comes to a level 4 plated body armour system certified by the previous NIJ 0101.06 standard, this will be unable to stop three rounds at point blank range, which a plate must be able to do in such scenarios facing such weapons. So, the latest NIJ revisions to NIJ 0101.07 standard are welcome for industry and militaries alike, as we'll start seeing systems to those specs in the not-too-distant future."*

As for Crib Gogh, Heaword said the company will be following these standards, although it is aware that *"the NIJ standard is used mostly for law enforcement and a lot of militaries will set their own threat level and threshold of what they deem fit for combat"*. He added that, *"As more threats emerge globally and the dynamic of those threats seem to evolve almost monthly, a fixed standard may not be the way forward. Many countries are looking at small, highly mobile and efficient units that are fast in and out, doing as much shock and awe as possible, and they will want, or need, tailored solutions and not necessarily a fixed standard."*

Crib Gogh's VAULT (vertical assault user light tactical) system, for example, is one such system and, according to Heaword, *"meets all of the vertical assault and safety-at-height needs of the military, and would be used in CQC [close-quarters combat] and at height breaching, so the plate dynamics would be for AK-47 amour piercing (AP) rounds and not Dragunov"*.

The company is also leading the way in the provision of new buoyant plates suited for the maritime interdiction role, changing the dynamic of fighting in water, or when encountering vessels at sea. *"The ability to have confidence in the plate in the water is key"*, said Heaword, *"because if you're unlucky enough to be in the water with someone on a container ship shooting at you, doffing your armour to stay afloat is not an option"*. He added that the company had worked with Point Blank International in the US to make sure it had achieved protection against AK-47 AP rounds, physically floats and allows articulation and fighting in the water. *"We are not alone in this domain, as others are looking at it and playing catch-up, but as the threat evolves, so must the operational capability evolve along with the protection. Sadly, it's an insidious circle."*

Final word – NIJ standard latest

Regarding the revision of the NIJ 0101.06 to the revised NIJ 0101.07 standard, the latest news on NIJ 0101.07 timelines is that having progressed through a period with the NIJ 0101.06 standard still in play, but with NIJ 0101.07 published, from early 2024, NIJ 0101.07 will be the standard by which all new armour will be tested by the NIJ's Compliance Test Programme, as well as newly accredited third-party ballistic test labs. That means the first NIJ 0101.07-certified body armour is expected to appear on the market later in 2024, and certainly by spring 2025, although the NIJ 0101.06-compliant product list will remain effective through 2027 and, possibly, beyond.

Finally, it is worth noting that the NIJ is also releasing a companion document, the new 'Specification for NIJ Ballistic Protection Levels and Associated Test Threats, NIJ Standard 0123.00', which provides a more detailed list than previously of ballistic threats common in the US.

The NIJ standard is important, because while many countries have their own standards and benchmarks for the production capabilities of body armour, NIJ standards are the yardstick most widely used and adhered to by leading manufacturers in ballistic protection systems, as well as being expected by leading security and military forces, including NATO. ■

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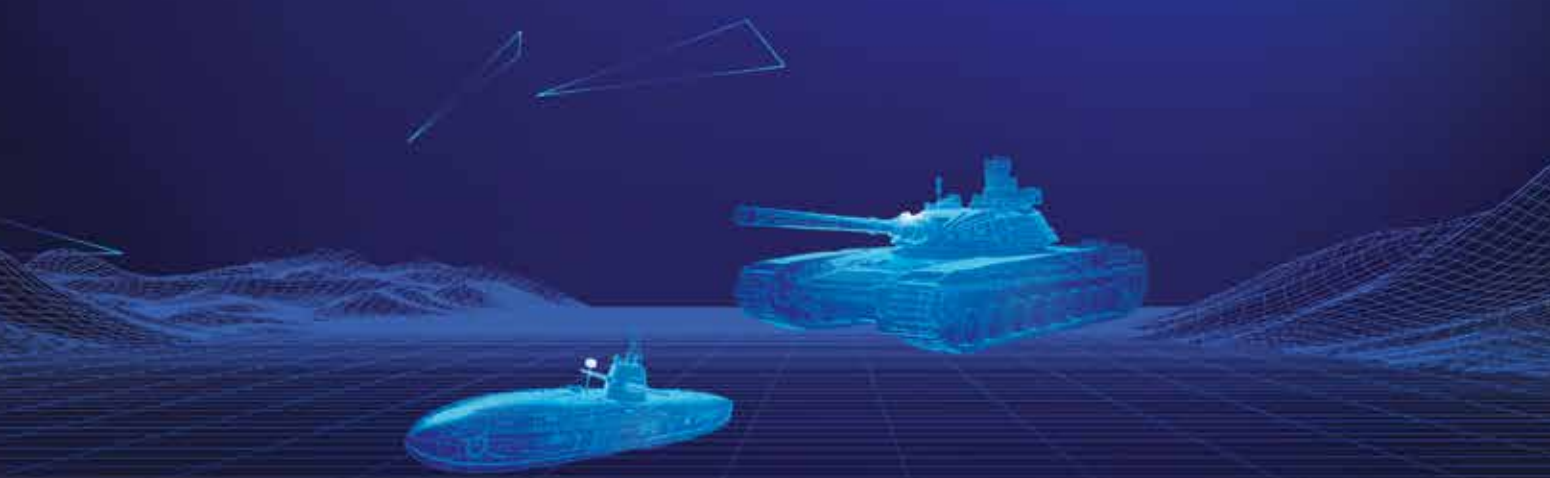

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Calibre conundrums – developments in small arms ammunition

David Saw

Small arms represent one of the most fundamental elements of military equipment. As such, one might expect that these weapons and their accompanying ammunition have benefitted from years of significant technological advances, though such an expectation would only partially ring true. Significant technological progress has indeed taken place, but many widely used types of small arms ammunition have remained basically unchanged for many years. However, it looks less certain whether this trend will continue.

There are very few military systems that remain in service, materially unchanged, for more than 130 years, but that is the case in terms of one widely-used ammunition calibre. The story starts in the 1880s as the then Imperial Russian Army was looking to acquire a new rifle. The 1880s were a time of revolutionary change in small arms, with the primary catalyst being French chemist Paul Vieille who had developed smokeless powder in 1884. This was designated as 'Poudre B' by the French military and led Lt Col Nicolas Lebel to rework the existing 11 × 59 mm Gras cartridge to create the 8 × 50R mm Lebel cartridge known as the Balle M, to be used in his Model 1886 Lebel rifle adopted by the French Army.

Prior to the invention of smokeless powder, black powder was used as the propellant for cartridges, causing a large amount of smoke to be released on firing. Smokeless powder was far more efficient, delivering more velocity and more range, with the lack of smoke also helping to improve shooter accuracy. As the new propellant was more powerful, it also allowed the use of smaller calibre cartridges. Moreover, it rendered most in-service rifles obsolete and led to a wave of new rifle acquisitions across Europe.

The Russian response to this was a competition for a new rifle and a new round to fire from it. Two designs reached the final phase of the competition, one from a Russian Captain Sergei Ivanovich Mosin and the other from a Belgian, Léon Nagant. The Russians decided to combine the best features of both designs into as single new weapon known as the Mosin-Nagant, a bolt action rifle, with a five-round magazine, using the 7.62 × 54R mm cartridge. The rifle entered production in the mid-1890s, with the first examples actually produced in France, before production in Russia commenced. Production of the rifle eventually came to an end in the Soviet bloc and China in the early 1960s.

Credit: US Army

Friendly forces being trained on the PKM machine gun in Erbil, Iraqi Kurdistan, in 2018. The PKM fires the 7.62 × 54R mm round first introduced in the early 1890s, and still in production and service globally.

As to the 7.62 × 54R mm round, its adoption as the standard rifle round of the Imperial Russian Army also made it the de facto machine gun round. This situation continued into the Soviet era, with efforts in the 1930s to develop a semi-automatic rifle using the 7.62 × 54R mm round, part of a desire to generate more infantry firepower. In the end, the firepower demand was met by a new generation of weapons using a new 7.62 × 39 mm intermediate round. The semi-automatic SKS carbine was supposed to replace the Mosin-Nagant and originally the AK-47 was seen as a sub-machine gun replacement. Ultimately, it was decided that the AK select-fire assault rifle would become the standard infantry weapon rather than the carbine.

The 7.62 × 54R mm round remained in service as a machine gun round, as it does to this day. It even found a new application for what we would now call a designated marksman rifle (DMR), which saw the development of the SVD rifle by Dragunov designed to offer range coverage from 600 to 800 m, and which could not be adequately covered by the AK. The SVD came into service in the early 1960s and remains a first-line service weapon with Russia and many other militaries around the world. Supposedly, the SVD is due to be replaced by the Chukavin SVCh, which will also use the 7.62 × 54R mm round. It is truly extraordinary that this round has outlasted two empires, the Tzarist Russian and the Soviet; there is no doubt at this point that it will achieve a service life well in excess of 150 years!

Pistol longevity

Georg Luger (1849–1923), the Austrian designer of the famous Luger pistol, left an ammunition legacy that continues into the modern era with a standard NATO round. Initially, the Luger pistol was chambered in 7.65 × 21 mm (7.65 mm Luger), but the Imperial German Navy, while liking the pistol, were not convinced by the 7.65 mm round. This led Luger to develop a new round in 1902, the 9 × 19 mm Luger, now more commonly referred to as 9 mm Parabellum, and in 1904 the Imperial German Navy adopted the pistol in that calibre, with the Imperial German Army following suit in 1908.

Numerous pistol rounds were available in Europe and the US when Luger designed the 9 × 19 mm and many rounds have been developed since. It is a tribute to the excellence of Luger's 9 × 19 mm design that this round still dominates the pistol scene some 122 years after it was originally developed. From pistols, the 9 × 19 mm would go on to become the standard for Western sub-machine guns, a position that it still retains.

Efforts were made to find a replacement for the 9 × 19 mm round with NATO generating a requirement for such a round to be used by a new category of weapon known as the personal defence weapon (PDW) during the 1980s. The objective was to have a new weapon in two formats, one handheld – that would replace the pistol – and a shoulder-fired system to replace the sub-machine and standard carbines and rifles used by support troops. The new round for these weapons would offer higher accuracy, greater range and superior penetrating power than the 9 × 19 mm round. Part of the specification called for the new round to have the capability to defeat body armour.

Winning the NATO PDW requirement had immense potential, since at this point the Cold War was still active and the task to replace pistols, sub-machine guns and other weapons in second-line roles across NATO presented an extraordinary possibility. One of the first to respond to the NATO requirement was FN Herstal, a company that had developed a new 5.7 × 28 mm round and two new weapons – the P90 as the sub-machine gun replacement, and the Five-Seven pistol, both chambered in the new cartridge. The other competitor for the NATO requirement was Heckler & Koch (HK) with their MP7 PDW and the new 4.6 × 30 mm round.

The next stage in the process saw NATO evaluate the new weapons and rounds in 2002–2003, though without result, as it proved to be impossible to reach a decision. As a result, the two companies looked to find a niche in the small arms marketplace. Since then, both the FN and HK solutions have been adopted by special forces, paramilitary units and law enforcement agencies around the world.

Consequently, the 'official' effort to replace the dominance of the 9 × 19 mm round essentially failed. The dominance of the 9 × 19 mm round was confirmed more recently, when in 2017, the SIG Sauer P320 won the US Army M17/M18 modular handgun system (MHS) programme. In 2022, both Australia and Canada announced the selection of new pistols, with the former selecting the SIG Sauer P320 XCarry Pro and the latter the SIG Sauer P320 – both weapons were selected in 9 × 19 mm. Clearly this round has stood the test of time and will remain in service for the foreseeable future.

Credit: Heckler & Koch

The 4.6 × 30 mm cartridge was developed by Heckler & Koch for their MP7 PDW, shown above. Although the round and weapon are fairly new by small arms standards, they have gained fairly wide adoption by police, military, and special forces worldwide over the last two decades.

Selecting the standard

As we have seen, the service life of small arms ammunition can be extremely long. We now turn to another small arms calibre that has stood the test of time and has also been a NATO standard since the 1950s, namely the 7.62 × 51 mm round. Post-1945, armies in Western Europe were equipped with a profusion of small arms in multiple calibres. For example, the US battle rifle round was 7.62 × 63 mm (.30-06), while the British used the 7.7 × 56R mm (.303), with all sorts of other battle rifle rounds lurking in the shadows. Amidst this confusion, there was also a growing realisation, based on combat experience, that new infantry weapons would be required to meet future requirements and that these would also need new ammunition types.

At the end of the 1930s, Belgian arms maker Dieudonné Saive at FN was working on the design of a new semi-automatic rifle for the Belgian Army when war intervened, forcing him into exile in England, where he continued working on the rifle design. In 1949 this resulted in the SAFN battle rifle in 7.92 × 57 mm Mauser, which was adopted by Belgium and exported to a number of different clients. One useful feature was that the design could accommodate different ammunition types depending on which weapon the client was operating.

The SAFN was a good weapon, but small arms requirements had moved on from a battle rifle of this nature and were headed to what we now would recognise as an assault rifle. Saive was aware of this and had prepared a design for a new weapon that eventually became the Fusil Automatique Léger (FAL). This would be a select-fire weapon and would use an intermediate round, which was initially the German 7.92 × 33 mm Kurz. Trials in the UK in 1947 led to further evolution in the weapon's design when they switched to the British 7 × 43 mm (.280 British) intermediate cartridge, which was used in the British EM-2 future rifle design, selected as the British Army rifle in 1951. However, neither the round nor rifle entered service, in large part due to the US Army's desire for a common cartridge used across NATO.

A 7.62 × 51 mm GPMG of the 1st Battalion, Royal Gurkha Rifles, during the joint British-Japanese 'Exercise Vigilant Isles' held in Japan in November 2023. The 7.62 × 51 mm round was first standardised by NATO back in 1954.

While Europe had been looking at intermediate rounds as a future solution, the US vision was a full-power round that was essentially better suited to a machine gun. While the new round offered extended ranges, it was too powerful to be utilised by the British EM-2, though the FAL could handle the new 7.62 × 51 mm round. So, while Britain, Belgium and others had been looking for an assault rifle using an intermediate round, they ended up adopting a battle rifle with a full-power round in line with US wishes.

The 7.62 × 51 mm round was officially adopted as NATO standard in 1954 and throughout the 1950s, various NATO nations took steps to introduce new weapons for the new round. The FN FAL would go on to become one of the most successful infantry weapons from the 1950s onwards, with production ending in the late 1980s. The vast majority of weapons were sold in 7.62 × 51 mm, with the single exception being Venezuela who ordered 5,000 rifles in 7 × 49 mm Liviano in 1954. This was an intermediate round developed specifically for Venezuela, but eventually the Venezuelan military decided that it made more sense to have all of their FALs in 7.62 × 51 mm and so the Liviano weapons were converted to the NATO round.

After imposing the 7.62 × 51 mm round on the rest of NATO, by the end of the 1950s, the US was having second thoughts, and this eventually led to the selection of the M16 assault rifle and the 5.56 × 45 mm M193 round. This then resulted in a NATO competition for a standardised round in that calibre, with the FN designed SS109 round selected as NATO standard in October 1980. The US opting for 5.56 × 45 mm was also a factor in influencing the Soviet decision to opt for a new small arms round in the 5.45 × 39 mm calibre and the AK-74 as the standard assault rifle, although the old 7.62 × 39 mm round still remains widely used.

New kids on the block

The longevity of standard military rounds is quite extraordinary, however, new rounds are being developed. For example, in 2007, US ammunition manufacturer Hornaday and Creedmoor Sports developed a new round for shooters looking for an improved round for long-range target shooting in the form of the 6.5 mm Creedmoor (6.5 CM). This round was developed for the commercial marketplace, but US Special Forces have adopted the 6.5 CM for their DMR and sniping applications preferring it to the 7.62 × 51 mm round. In Britain, the Royal Marines have selected the 6.5 CM for their new L129A2 DMR.

As to where the future of small arms ammunition is headed, this really depends on whether the US Army Next Generation Squad Weapon (NGSW) programme becomes a reality and starts to replace the US Army's M4 carbine and M249 Squad Automatic Weapon (SAW). The programme was awarded to SIG Sauer in 2022 and a key component is the new round that SIG Sauer has developed for the programme – the 6.8 × 51 mm Common Cartridge (.277 SIG Fury). This new round is due to replace the current 5.56 × 45 mm round and the 7.62 × 51 mm round in certain roles, although the US military will also continue to use the older rounds.

Once the 6.8 × 51 mm round and its associated weapons become US Army standard, then the pressure to adopt the new round within NATO and by US allies will inevitably increase. This new US round is not the result of some technological revolution, but it can be considered an evolutionary development. Even so, it might yet change the path of small arms in both the US and internationally. ■

The XM7 rifle is part of the Next Generation Squad Weapon (NGSW) programme to replace existing M4 and M249 weapons in 5.56 × 45 mm. The NGSW weapons will use a new round in the form of the 6.8 × 51 mm Common Cartridge developed by SIG Sauer.

Portable power storage for the dismounted soldier

Tim Guest

The dismounted soldier today relies on an increasingly diverse array of personal equipment, electronic devices and sensors, most of which require a constant power supply for effective operation. That means already over-burdened warfighters must carry enough stored power to perform their mission.

Electric power and dismounted power budgets are crucial for the future of warfare and electrification of the battlefield across all domains. For the dismounted soldier, equipped as never before with electronics, optical and communications equipment, powered sights, night vision goggles and more, most of which requires a constant, steady and managed power supply. This typically means batteries, which have to be carried in quantities appropriate for any mission.

According to Steve Heaword, Technical Director at Crib Gogh and part of the UK MoD's Jungle Warfare Programme, *"Battery burden depends on the operation type and the power budget you need for that operation, and is something that is mission critical to get right, considering that burden can account for as much as 25% of a soldier's equipment carry. Reducing it is, therefore, a major goal for military and industry vendors, alike, with new technologies, battery chemistries, fuel cells, centralised power units and power management all playing a part in that process. The individual soldier is depending on that burden being lowered. The technologies need to have more AI in them, so they are activated when needed. This would then reduce the cognitive burden that is already impaired by the weight and thermal burdens that the dismount already suffers."*

Companies across the defence industry, including Bren-Tronics, Denchi, Enersys, Epsilor, Lincad, Saft, and many others, are pioneering developments to meet the increasing demands of the military user and to lower the battery burden. ESD spoke with a couple of these companies for some qualified, up-to-data views on man-portable power storage solutions and developments.

Modern soldier, modern demands

Weighing into the man-portable power storage discussion, Peter Slade, joint MD at Lincad, a UK designer and manufacturer of battery and charger technology, told ESD, *"Whilst some man-worn equipment can be powered by either primary or secondary batteries, much of the equipment requires significantly-sized battery packs, which are not available as commercial off-the-shelf items."*

Credit: L3 Harris

Image shows a British soldier equipped with a Falcon III RF 7850S radio. The myriad electronic equipment carried by today's dismounted soldier typically means that batteries have to be carried in quantities appropriate for any mission. This adds to the soldier's already considerable weight burden.

Slade said that to avoid battery waste and the logistical burden of supplying large volumes of primary batteries, secondary batteries are used. He added, *"The ability to recharge is a fundamental consideration and increasing the charging options available improves the flexibility of military operations. Whilst most batteries tend to be swapped out and recharged back at base in a barracks environment using an AC/DC charger, batteries may also be charged by DC sources directly, such as from a DC vehicle source, or from renewable sources, such as solar PV, or a micro wind turbine."*

In this regard, Slade said that the company's Harvester system provides exactly this capability to harvest energy from any DC input, and allows the charging of lithium-ion power systems (LIPS), and other battery types. This offering is a flexible solution to mobile power management where reliability, portability and ease of use are critical.

Credit: Lincad

The Harvester offers a flexible solution to mobile power management.

On battery chemistry, Slade said that, *"Lithium-ion (Li-ion) tends to be the chemistry of choice for most applications using secondary batteries, as it offers several advantages, including: high energy density, long lifecycle, low self-discharge rate, quick charging, versatility, no memory effect and low maintenance."* He added that several Li-ion battery types are available, each with its own specific characteristics and advantages, with Lincad most commonly using lithium nickel cobalt manganese oxide (NMC), which, he said, offered a good compromise between energy density and power capability. According to Slade, *"Most NMC cells that we employ are in a cylindrical format, either 18650s or 21700s, [Note: the numbering system referring to cell dimensions]. More recently, we've been using lithium iron phosphate (LFP) batteries, which are known for their long lifecycle, high thermal stability and enhanced safety."*

As for the immediate future for man-portable energy storage, Slade added that this would continue to rely on secondary battery technology. *"New developments continue to move at pace, and we are already seeing new chemistries being employed, such as sodium-ion, solid-state lithium-ion and lithium-sulphur; longer term, the energy outlook may be very different compared to today."*

He suggested that whilst society moves away from fossil fuels towards renewable energy resources and energy storage technologies such as batteries, liquid fuels will still have a significant role to play in the energy mix.

"Further into the future," Slade continued, *"There will likely be revolutionary energy technologies that seem hard to comprehend now. Much research is taking place on the development of small-scale nuclear technologies, for example, and, whilst this may currently feel like the stuff of science fiction, who knows where technology may be in 50-, or 100-years' time."*

Amongst the range of battery products Lincad designs and makes for wearable soldier equipment, are large volumes of non-rechargeable (primary) battery products for military use (such as AAs and AAAs), though it is the rechargeable (secondary) battery types that the company says it specialises in. According to Slade, Lincad's batteries range in size from relatively simple, single-battery solutions, such as that used on Thales' SquadNet radio, to their more modestly-sized LIPS range of ruggedised, intelligent batteries.

At the larger end of the man-portable scale, Slade told ESD that the company also produces various battery systems that fall within the uninterruptible power supply system category, providing battery back-up power during power outages and protecting against voltage fluctuations and power spikes.

Credit: Lincad

Lincad's LIPS range of ruggedised, intelligent batteries are used in various applications around the globe.

Man-portable, wearable, hybrid

Reinforcing such views and offering others, a senior spokesperson from Bren-Tronics, which produces primary and secondary rechargeable batteries, chargers and complete energy storage systems, told ESD, *"recent years have witnessed significant breakthroughs in energy storage technologies, enhancing the capacity and efficiency of man-portable power systems, with lithium-ion batteries in particular becoming the go-to choice for their high-energy density, longer lifecycle, and reduced weight, all of which offers a lightweight, yet potent, energy source for individuals on the move."*

Credit: Bren-Tronics.

The Bren-Tronics CWB can be configured and adapted to specific user needs, whether powering communication devices, sensors, or other equipment.

Credit: Bren-Tronics

The TRUAS will be capable of carrying a payload of roughly 70 kg of supplies such as batteries, medical supplies, food, and ammunition over a 14 km range.

While this view echoes the lithium-ion sentiments of their industry peers at Lincad, the Bren-Tronics spokesperson noted that beyond lithium-ion, emerging technologies such as solid-state batteries and advanced fuel cells are gaining attention for their potential to further improve energy density, safety, and environmental impact, adding, "As these technologies mature, man-portable power systems will likely see even more compact and powerful energy solutions."

In the meantime, Bren-Tronics stated that the integration of intelligent power management systems, which leverage algorithms and sensors to optimise energy consumption, monitor battery health, and predict usage patterns, is "transforming the way portable power is used", adding, "By intelligently managing power resources, users can extend the operational life of their devices, reduce the need for frequent recharging, and enhance overall mission effectiveness."

Furthermore, the company spokesperson added that the continuing need for versatile charging solutions in the field remains, and has led to the development of multi-modal charging systems, which can harvest energy from various sources, including solar, wind, and kinetic energy. Such solutions ensure that individuals, including special operations forces in remote or dynamic environments, do not have to rely on grid-based charging methods or resupply, and can recharge their secondary batteries using these multi-modal solutions.

On the subject of conformal and wearable battery technologies, Bren-Tronics spoke briefly of recent advances revolutionising how soldiers carry and use power in the field: *"Conformal batteries are designed to seamlessly integrate into equipment, reducing the need for bulky external power sources, which not only improves mobility, but also enhances the overall ergonomic design of military gear. Wearable batteries take this concept a step further, providing power solutions that can be integrated into clothing, or worn as accessories"*.

Before speaking about the company's own products, mention was given to the emergence of hybrid solutions that combine both storage and power-generation abilities in the same system, something which meets the needs of highly mobile and 'independent' operatives in scenarios way off grid: *"Hybrid man-portable power systems combine efficient energy storage with versatile power generation, enabling users to replenish their energy reserves in remote or dynamic environments."*

As for the company's portfolio, the spokesperson highlighted its BB-2590 rechargeable lithium-ion battery, as "versatile and durable" in the man-portable power storage domain, with a "high energy density that allows it to store a substantial amount of energy in a compact and lightweight form factor". The unit also has sophisticated safety features, which include protection against overcharging, over-discharging, and short circuits. The former relates to its high number of charge-discharge cycles, which, amongst other things, reduce the need for frequent replacements while its rugged design sees the battery built to withstand extremes of temperature, vibration and mechanical shock, suiting it to the most demanding military operations.

Another Bren-Tronics' solution highlighted was the conformal wearable battery (CWB), which, according to the company spokesperson, "has a conformal design, enabling it to be seamlessly integrated into a user's gear, which reduces the burden of carrying external power sources.". The spokesperson added, *"The CWB is customisable, so it can be configured and adapted to specific user needs, whether powering communication devices, sensors, or other equipment. The battery also features hot-swappable modules, enabling users to replace depleted modules without interrupting power to connected devices, thereby ensuring continuous power availability in the field."*

The company stressed that the CWB uses smart battery management technology, to optimise energy usage, monitor performance, and provide information feedback about the system to the user.

Final thoughts

Future warfare is an increasingly tech-dependent, power-hungry affair, with the individual warfighter in danger of becoming overloaded, both physically and mentally, by high-tech devices, sensors, communications and electronics, together with the stored energy systems and batteries required to power them all. While major advances already certainly improve the curse of the battery burden, continued progress in man-portable stored power will help ensure that the valuable asset – namely the individual soldier – will not become an overwhelmed beast of burden. ■

Smooth sailing? The strategic relevance of (un)contested control of the Black Sea

Dr Giangiuseppe Pili, Jack Crawford, Nick Loxton and Roman Kolodii

As the war in Ukraine enters its third year, access to the Black Sea for both sides has remained deeply strategically relevant. As the battle for control continues, neither side can afford to surrender control of this vital area.

Credit: Giangiuseppe Pili, Roman Kolodii, and Jack Crawford

This chart shows some of the major factors influencing Ukraine's current sense of urgency in its war against Russia.

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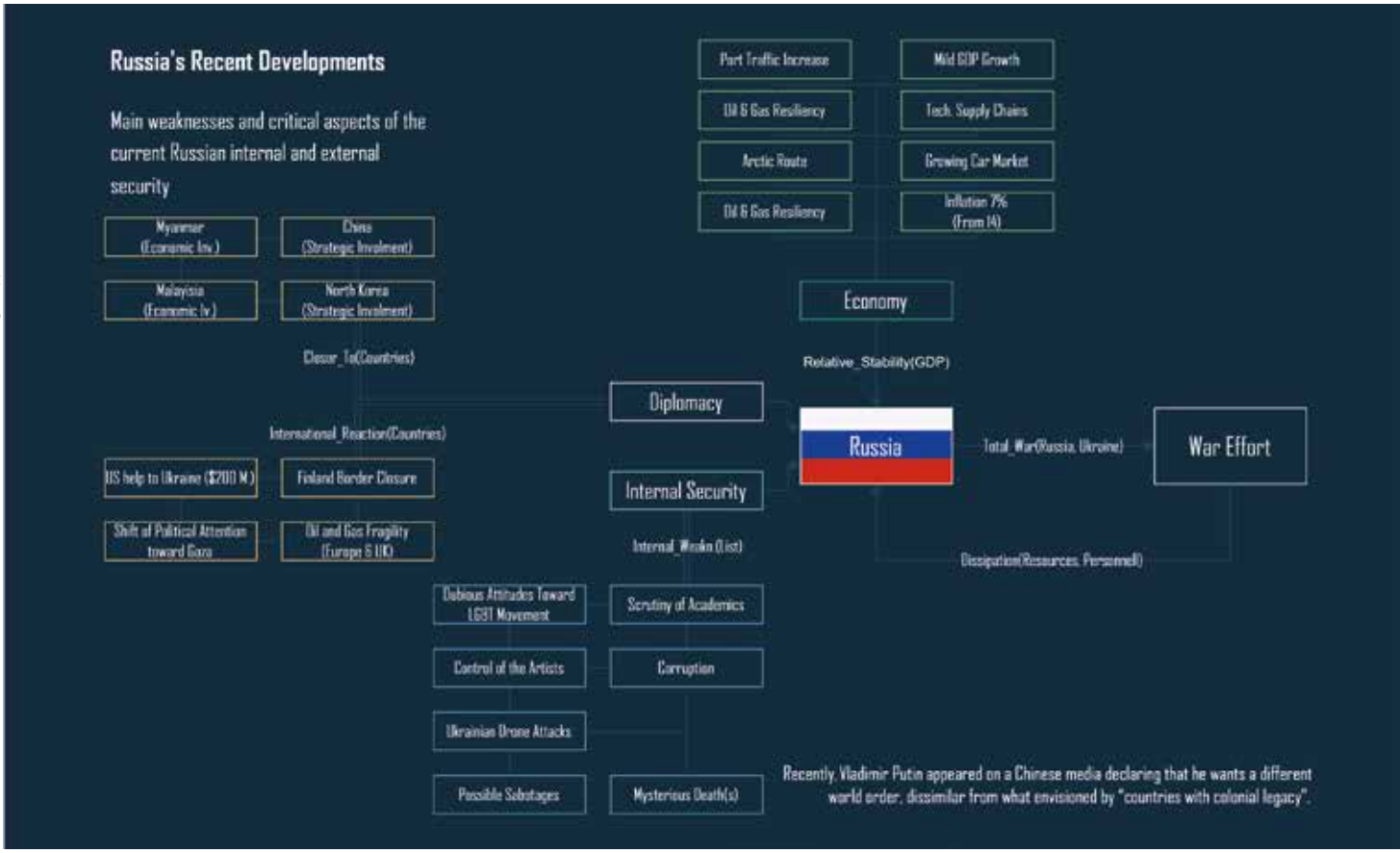
A stalemate and renewed sense of urgency

As Russia's ongoing invasion of Ukraine seems to become a more entrenched facet of the European security landscape, forces on both sides are increasingly faced with the potential of a stalemate. The Ukrainian counteroffensive could slow down even further in the near future, according to Michael Kofman, military analyst at the Center for Naval Analyses (CNA). The difficulty of conducting modern warfare at this scale was proved already by the Russians during the first stages of the war, in absence of any comparable defensive line. Even enthusiastic Western commentators have recently labelled Russian defence systems in Ukraine as "formidable".

Whether these efforts have, in fact, been formidable remains up for discussion. The invasion of Ukraine has shown that loitering munitions, drones, and hybrid warfare are able to create a stalemate through a preventive formation of sufficient fighting mass. This has also been echoed by Commander-in-Chief of Ukraine's Armed Forces, Valerii Zaluzhnyi, who recently conceded that, as in World War I, the level of technology on either side precludes prospects for a 'deep and beautiful breakthrough.'

redit: Giangiuseppe Pili, Roman Kolodii, and Jack Crawford



This chart shows some of the more noteworthy developments influencing Russian internal and external security.

The alleged slowing down of the Ukrainian counteroffensive, in conjunction with limited active Armed Forces of the Russian Federation (AFRF) defence along the Kupyansk-Svatove-Kreminna line near Avdiivka, have the potential to postpone a Ukrainian victory. From an alliance politics perspective, the counteroffensive was instrumental for showing Western partners that their economic and military commitments were worthwhile.

The limited successes of the counteroffensive, when coupled with the uncertainty around Ukrainian casualty rates and President Zelensky's internal struggles against corruption, however, have all aligned with (and potentially contributed to) wavering support from the West compared to the first months of the invasion. US support was already on rockier ground before, as claimed by Zelensky, Western attention returned to the Middle East. The EU is grappling with its own internal struggles, such as Poland's response to the diversion of Ukrainian grain through mainland Europe instead of maritime export routes. Other European countries have also threatened to suspend aid in response to the diversion as well. This setback is due to Russia's weaponisation of Ukraine's grain exports, echoing Stalin's utilisation of grain and hunger as political instruments.

However, the stability required for any renewed Russian efforts may be in question. Recently, Vladimir Putin appeared on Chinese media declaring that he wants a different world order, dissimilar from the one envisioned by "countries with colonial legacies". Internally, this translated into a series of repressive actions, such as sentencing artists, monitoring academics connected to foreign institutions, banning the "international LGBT movement", and sacking a Natural Resources Ministry Official on grounds of corruption. The dubious death of Yevgeny Prigozhin and other Wagner Group associates also sent ripples through domestic channels otherwise supportive of the war. More recently, a former Russian Air Force Commander, Vladimir Sviridov, and his wife were found dead without explanation. Reassuringly, the Federal Security Service (FSB) officers are investigating. These repressive tactics are familiar staples of Russian autocratic measures dating back to at least the 1930s.

It is difficult to say whether these are symptoms of a greater problem, although it is worth recalling how frequently despotic emperors have been deposed by their Praetorian Guards. All of these measures, however, do coincide with the Russian population's digestion of the current situation on the ground in Ukraine; as of late May 2023, roughly 47,000 Russian men under the age of 50 died in the war, and this is according to conservative estimates. As the military analyst Anders Puck Nielsen pointed out, this is already more than three times the number of the total casualties the Soviet Union (with 260 million inhabitants as of 1979) experienced during the ten years war in Afghanistan (which means roughly 1,500 dead per year in Afghanistan, as opposed to at least approximately 30,000 per year in this war) – a war which has often been claimed to be one of the major reasons for the Soviet Union's economic and political collapse.

As the Ukrainian dream of a quick ousting of Russia's invasion further fades into preparations for a longer conflict, time is of the essence for both sides, before factors beyond the battlefield begin to erode momentum. Therefore, it makes sense that Kyiv and Moscow will expand their scopes beyond the arena of land warfare to see where other gains might be made. One such arena—the Black Sea—has already seen its fair share of action, but may very well become a revisited point of priority in the next phases of the conflict.

Russia's initial maritime attacks on Ukraine's coastline, including the infamous encounter at Snake Island and its most recent retreat from the Black Sea Grain Initiative, show how maritime logistics have remained a crucial strategic facet of the war. The land warfare aspects of the invasion have created the conditions for a war of attrition, which requires a whole-of-society commitment to sustain supply lines, infrastructure and production capacity. World War I ended on the eastern front, in part, because of a lack of resources that ultimately led to revolution and capitulation. In Russia's approach to its invasion, maritime logistics have proved equally pivotal, as evidenced by recent events in the Black Sea.

The strategic importance of the Black Sea

The strategic importance of the Black Sea lies primarily in its logistical value for Russia. The AFRF rely heavily on railroads and specialised brigades, such as the Material Technical Support brigades, for maintaining supply chains. However, these landbound brigades face challenges in meeting the demands required for sustained invasion efforts, such as capacity for physically transporting military goods.

Enter the role of maritime logistics. Large cargo vessels are an easy remedy the difficulty of moving large quantities of supplies over land. With Russia's closest ports to Ukraine being in the Black Sea, uninhibited access to these ports is essential for Russia's military operations and heavily incentivises Russia to maintain a strategic advantage at sea.

This value has not been lost on the Kremlin. Russia has already used its Black Sea power to impose a blockade against Odessa, Ukraine's major port and primary hub for its grain exports. Russia's Navy continuously targets grain depots in Odesa to eliminate Ukraine's economic prowess, having allegedly destroyed at least 300,000 tons of grain. Additionally, Russia's presence in the Black Sea provides the AFRF with a strategic vantage point for launching missile attacks. The Black Sea is also a major Russian hub for exporting oil and other critical goods.

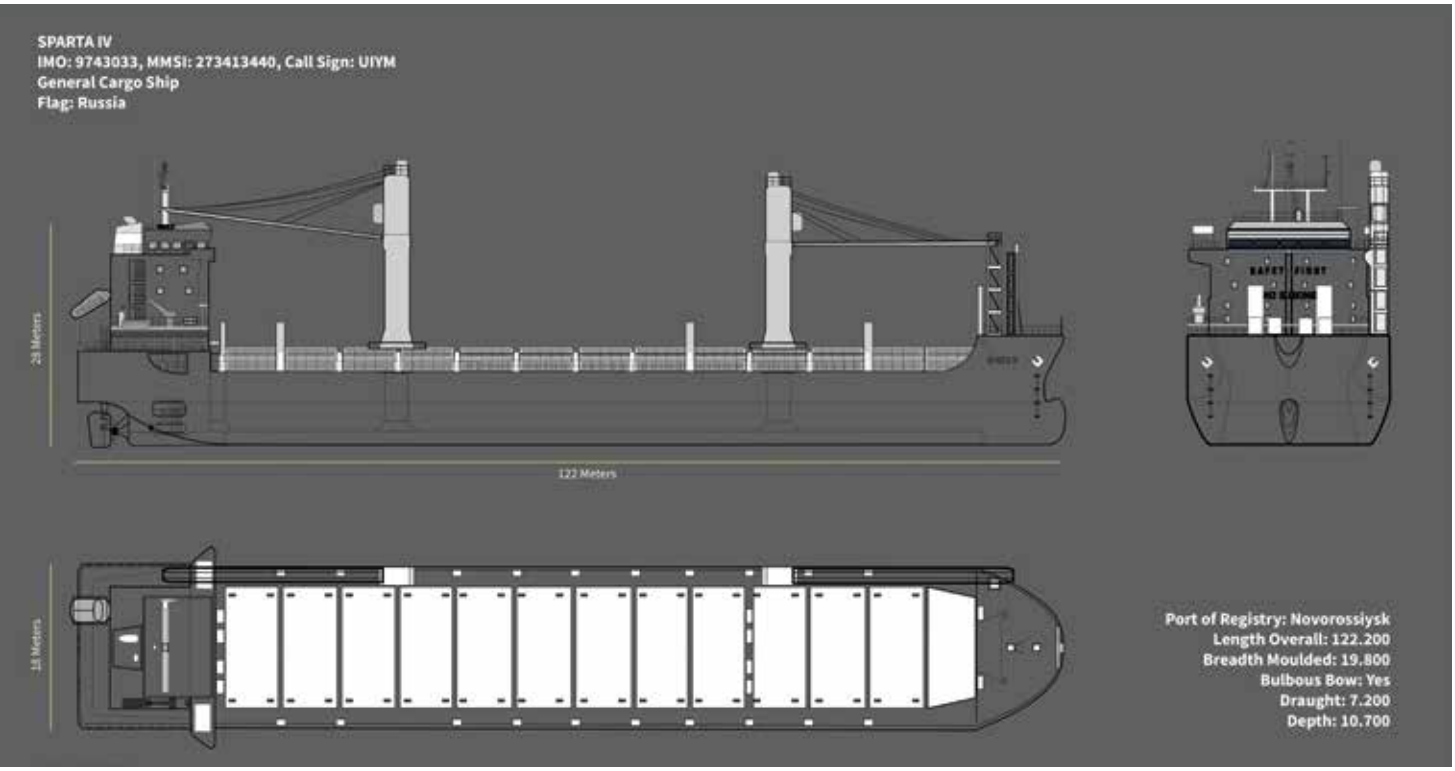
As a result, it is no surprise that Russia would go to great lengths to maintain its operations through the Black Sea, even by using a fleet of 'special ships' that violate international maritime law to procure military goods from abroad.

The SPARTA IV: A case study in Russia's prioritisation of Black Sea logistics

This fleet is owned by the sanctioned Oboronlogistics LLC, a company owned by the Russian MoD and connected to the Chief Directorate for Troop Accommodations JSC, which shares close ties to Russian oligarch Timur Vadimovich Ivanov, deputy Ministry of Defense and close ally of Putin.

This fleet includes ships including the SPARTA II, PIZMA and SPARTA IV that appear to transport Russian military equipment from Syria to Novorossiysk, one of Russia's main Black Sea ports. According to the Center of Strategic and International Studies (CSIS), the SPARTA IV specifically even moved howitzers and other artillery pieces. Throughout 2023, these ships appeared to frequently ferry military goods to and from the Middle East, while Putin made his interests clear through renewed arms purchases with Iran, and senior-level meetings with Iranian and Hamas leaders.

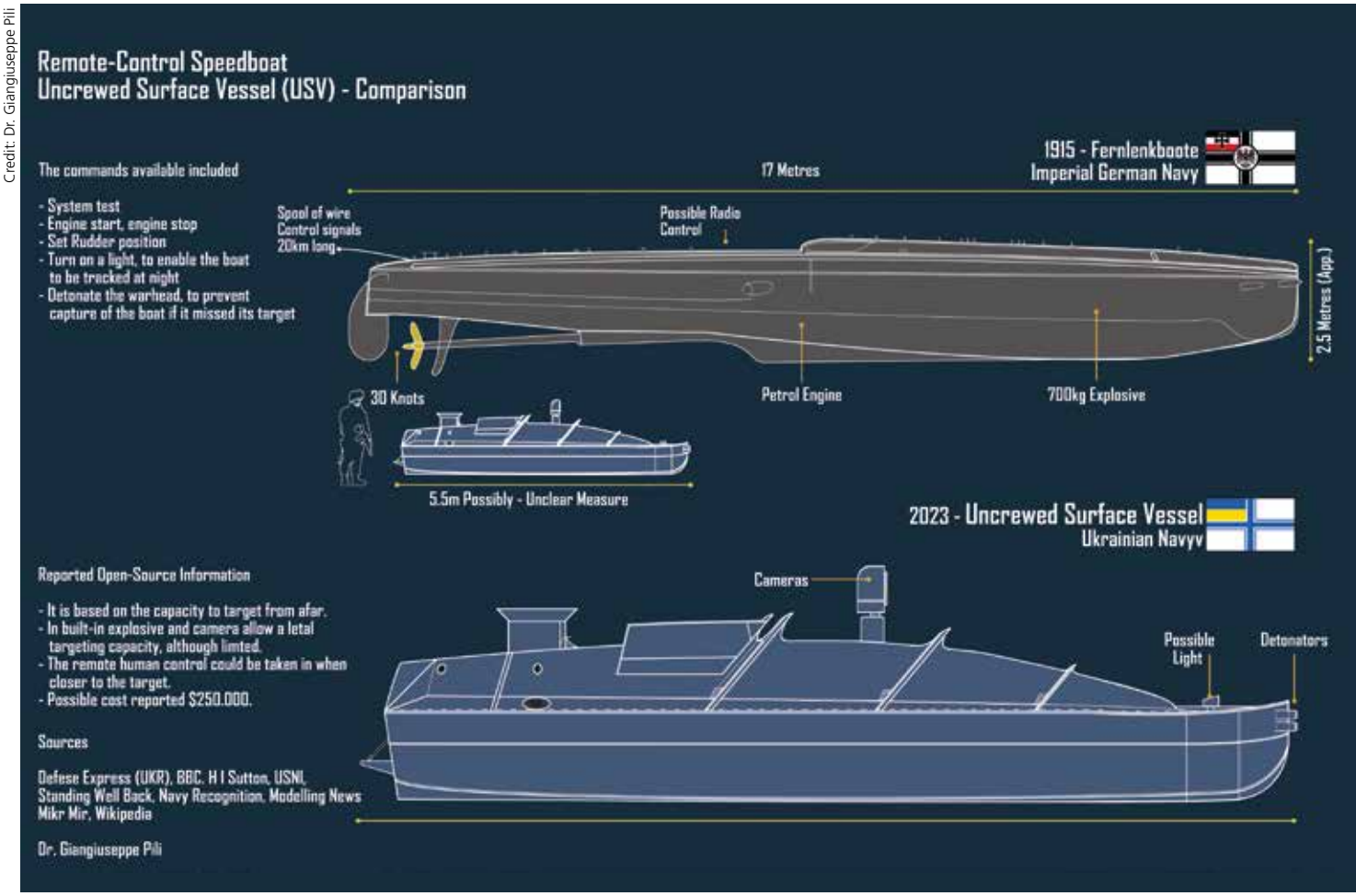
Oboronlogistics' fleet is not stopped in the Bosporus because of the grey legal area in which they play, and they prove Ukrainian efforts insufficient. On 28 February 2022, just four days after the beginning of the invasion, Turkey closed the Bosporus to all military vessels. However, Turkey's decision to do this was no small action, as the Montreux Convention holds Turkey accountable if the country appears to misuse this ability. The Montreux Convention defines the preconditions necessary for Turkey to restrict movement through the Bosporus, the restrictions Turkey may impose on vessels if these preconditions are met,



Credit: Giangiuseppe Pili

SPARTA IV – Layout.

Credit: Dr. Giangiuseppe Pili



USVs then and now. The chart shows the size difference between a 1915 Imperial German Fenlenkboote and a 2023 Ukrainian USV.

and the limits of Turkey's ability to impose restrictions.

Turkey may only restrict freedom of navigation through the Bosporus if it is a belligerent, it perceives to be threatened, or has legal obligation to aid a belligerent. It can only restrict warships and auxiliary vessels, and it must still permit daytime passage to these vessels when they are formally stationed in the Black Sea, so long as the passage is announced in advance by the vessels. Turkey cannot restrict commercial vessels, and it is not guaranteed the right to check the cargo of ships transiting the Bosporus.

This is the loophole Russia uses. By operating assets such as the SPARTA IV as commercial vessels, the ships are not beholden to the same ones applied by Turkey to military ships. However, an investigation conducted by the team (with other analysts converging in the assessment) revealed that these ships are actually possibly equivalent to auxiliary vessels transporting military materiel through the Bosporus.

Despite the ability of these ships to enter and exit the Black Sea freely, Ukraine appears to have paid close attention to these vessels. Since the Ukrainian Navy lost all its limited capability in the very early days of the war, Ukraine seems to have pivoted to guerrilla war, employing asymmetric tactics and capabilities wherever possible.

In the summer of 2023, Ukraine even used unmanned surface vessels (USVs) to target the SPARTA IV's alleged military escort on one voyage, and changes in behaviour of the Russian vessels (such as diversions in sailing routes and the obfuscation of AIS tracking signals) indicates that the fleet was cautious to avoid detection or confrontation. Reliance on unmanned platforms at sea, however, is a different business than doing so on land. While the use of USVs is as old as World War I, a persistent difficulty in their use is the inability employ them at a distance, making destroyers and military escorts reliable assets in the meantime.

As a result, Russian military capability currently provides sufficient protection to allow Oboronlogistics' fleet to avoid both international law and USVs at the same time. Moreover, the Russian navy, though suffering maritime losses unmatched in the West since World War II (including the loss of the Moskva Project 1164 Atlant guided-missile cruiser and the *Rostov-on-Don* Project 636.3 Improved Kilo-class submarine – an historical achievement in itself) was nonetheless able to hamper the Black Sea corridor, where Ukrainian civilian cargo vessels were trying to resist the Russian pressure over the movement of grain, to the point of halting it.

However, as the Vietnamese and guerrilla fighters in Algeria knew very well, the reality is that nobody likes guerrilla warfare. In the 1975 film 'The Battle of Algiers', when being questioned by a French journalist on the practice of planting explosives in baskets, the fictional Algerian guerrilla leader Ben M'Hidi replies: "Obviously, planes would make things easier for us. Give us your bombers, monsieur, and you can have our baskets." As declared by sources in Russia, the war in 2024 could renew the Russian attempt to take over the coast and Odessa. Ukraine and its allies must be prepared – losing the battle for the Black Sea is simply not an option. ■

Search and destroy:

Middle East theatre stages showdown between conducting and countering UAV operations

Dr Lee Willett

Uncrewed capabilities have often been touted as 'game changers', at strategic and operational levels. The current crises and conflict across the Middle East are demonstrating how one type of uncrewed system – uncrewed air vehicles (UAVs) – can have such impact.

Western militaries have for some time been working on delivering new capability and operational outputs through using uncrewed systems, and are slowly introducing them into operations on land, at sea, and in the air. However rogue states, and now non-state actors, are introducing the capability far more quickly, including in high-intensity operations. Here, the Middle East maritime environment takes centre stage.

In July 2021, off the coast of Oman, the tanker M/V *Mercer Street* was attacked with an uncrewed aerial vehicle (UAV). Two crew were killed. According to materials published by US Central Command (CENTCOM) following the incident, the attack "required calculated and deliberate re-targeting" of the vessel, following a failed attack using two UAVs the previous day. After analysing the attack, damage to the ship, and component debris recovered, CENTCOM stated that the attacks were conducted by Iran.

In a conclusion that pointed to emerging capability and operational trends using UAVs – a conclusion that would prove to be correct – CENTCOM said "The use of Iranian-designed and -produced one-way attack 'kamikaze' UAVs is a growing trend in the region. They are actively used by Iran and their proxies against coalition forces in the region, to include targets in Saudi Arabia and Iraq."

Credit: US Navy

The US Navy (USN) Arleigh Burke-class destroyer USS Carney is pictured conducting defensive operations against incoming weapons launched by Yemen-based Houthi rebels. Carney has engaged inbound Houthi threats on a number of occasions.

In fact, Iranian-made UAVs are now being used by Iran's Yemen-based Ansar Allah (Houthi) rebel proxies further afield than Saudi Arabia (with whom the Houthis are engaged in a civil war). Following the outbreak of the Israel-Hamas conflict in Gaza in October 2023, and seemingly in an effort to stretch the crisis and US commitments, in November 2023, the Houthis began using UAVs – amongst other systems – to target commercial ships sailing in the Gulf of Aden/Bab-al-Mandeb/southern Red Sea corridor.

CENTCOM reported that, on 15 November 2023, the US Navy (USN) Arleigh Burke-class destroyer USS Thomas Hudner had engaged and shot down a UAV that originated from Yemen and was heading in the ship's direction. Since then, the Houthis have continued to launch UAVs, alongside uncrewed surface vessels (USVs), anti-ship ballistic missiles (ASBMs) and anti-ship cruise missiles (ASCMs), against commercial and naval ships sailing in the region.

Trends

The use of such capabilities in lower-end 'grey zone' attacks (in the Iranian case) and higher-end combat attacks (in the Houthi case) demonstrate how rogue and non-state actors are currently able to harness new technology faster than Western armed forces. Western armed forces must go through regulation when introducing technology innovation, to reduce risk when bringing in new capability; rogue actors may see value in taking on more risk to get ahead of the game.

Author

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Credit: US Navy

Commercial ships are pictured being escorted in the Gulf of Aden by the USN Arleigh Burke-class destroyer USS Mason. The destroyer presence is designed to deter and defeat incoming Houthi threats, including uncrewed aerial vehicles (UAVs).

Nonetheless, rogue actors' use of UAVs – especially in one-way attack operations – is a step beyond current concepts of operation (CONOPS) Western military forces have been broadly considering for using such capability. Indeed, although some Western forces have actively been developing capability to arm uncrewed systems including UAVs with offensive weapons, continuing ethical concerns over deploying kinetic capability onboard uncrewed systems have, to date at least, served to focus development on non-kinetic roles like intelligence, surveillance, and reconnaissance (ISR).

It is also worth pointing out that, while Western forces have been assessing what weapon system options may offer strike capability for uncrewed systems such as UAVs, rogue actors have been keeping things more simple by just using the vehicle itself, fitted with explosives, to provide the strike capability. While Western industry is no stranger to this concept, with purpose-built loitering munitions (LMs) becoming increasingly common, their adoption has nonetheless been a step behind that of rogue actors.

CENTCOM's use of the word 'kamikaze' draws the link between this capability approach and operational methods used by Japan's armed forces in the Second World War. Beginning at Leyte Gulf in October 1944, Japan used crewed aircraft in kamikaze attacks to devastating effect against USN ships in battles across the Pacific.

Prior to Japan's use of kamikaze tactics, Germany had, since June 1944, been launching V1 'Doodlebug' flying bombs – the forerunners of contemporary cruise missiles – against targets in the UK. In the 1980s, cruise missile evolution included the use of Exocet missiles in the Falklands War and Styx missiles in the Iran-Iraq War, before Tomahawk cruised into view as the uncrewed, stand-off strike 'game changer'. Tomahawk's own evolution has included, at two points, development of an anti-ship capability. However, Tomahawk and other weapons like it are state-of-the-art, high-end, stand-off systems, and are priced accordingly.

What UAVs are clearly offering to rogue actors is an affordable and readily-available means of generating effect. Such affordability and availability means they can also be acquired in large numbers. Moreover, the international responses to both the Iranian attacks in the Gulf and the Houthi attacks in the Red Sea underline the strategic-level impact that such affordable capability can have when

Credit: US Navy

A USN sailor onboard the Arleigh Burke destroyer USS Laboon keeps watch for aircraft activity in the Bab-al-Mandeb Strait region. USS Laboon has been involved in at least four defensive operations to tackle Houthi attacks.

used in the right context. The fact that the Houthi threat to international shipping has prompted the United States and the United Kingdom to conduct kinetic strikes into Yemen against Houthi targets, despite the risk of this escalating tensions across the Middle East region, underscores the point.

Timelines

In the wake of the M/V *Mercer Street* attack, US experts concluded that debris retrieved from the ship demonstrated that the UAV was Iranian-designed and produced, with CENTCOM concluding that "Iran was actively involved in this attack."
It is worth noting that the United States deployed a UAV to the ship's position to support the international community's incident response. This response included forensic assessment confirming, according to CENTCOM, that the UAV was carrying explosives.
Iran had presaged development of this capability. Back in October 2018, the US Naval Institute reported that USN warships in the Gulf were being regularly overflown by Iranian UAVs. In September 2020, a UAV overflew the USN aircraft carrier USS *Nimitz* as the ship transited the Straits of Hormuz. In these earlier instances, surveillance appeared to be the name of Iran's game. However, Iran's capability and intent has clearly evolved.
Following the M/V *Mercer Street* attack, in November 2022 the oil tanker M/V Pacific Zircon was struck and damaged by an Iranian Shahed-136 one-way UAV. According to a March 2023 report by the Middle East Institute, Shahed-136 has a range of up to 2,500 km.
In June 2023, a US official said Iran had tested a UAV in a kamikaze-type role in the Gulf, against a barge located several miles offshore, and had launched another missile or UAV without issuing notice to mariners in the area, media reported. The official was quoted as saying the UAV test was "essentially practicing hitting merchant vessels".
These incidents foreshadowed the spike in attacks observed during late 2023 and continuing into 2024:

- In late November 2023, aircraft from the USN's *Nimitz* class aircraft carrier USS *Dwight D Eisenhower* intercepted an Iranian UAV that was, according to CENTCOM, "operating in an unsafe and unprofessional manner" close to the carrier while the ship was conducting flight operations in the Gulf. The UAV got within 1.37 km (1,500 yards) of the carrier, with repeated warnings ignored, US Naval Forces Central Command (NAVCENT) said in a statement.
- On 23 November, across the region in the Red Sea, the USS *Thomas Hudner* was back in action. A CENTCOM statement said the ship "shot down multiple one-way attack drones launched from Houthi controlled areas in Yemen".
- On 29 November, Arleigh Burke sister ship USS *Carney* – also sailing in the Red Sea – shot down a UAV that was launched from Yemen and was heading towards the ship. CENTCOM identified the UAV as an Iran-produced KAS-04 system.
- On 3 December the USS *Carney* was back in action, shooting down three single UAVs in three separate incidents. The UAV attacks were interspersed with ASBM launches.
- On 10 December, the French Navy FREMM frigate FS *Languedoc* shot down two UAVs.
- On 14 December, another Arleigh Burke destroyer became involved. USS *Mason* shot down a UAV, launched from Houthi-controlled territory, which was heading directly for the destroyer, which had gone to help a tanker that was being harassed by Houthi forces in skiffs. In the incident, the Houthis also launched ASBMs at the destroyer.
- On 15 December, a UAV conducted a successful attack in the Red Sea, striking the container ship M/V *Al Jasrah.* The ship's crew put out a resultant fire, and the ship was able to continue its transit.
- On 16 December, USS *Carney* was back in action again, this time successfully engaging 14 UAVs in what CENTCOM referred to as a "drone wave". "The UAVs were assessed to be one-way attack drones," CENTCOM added.
- On 18 December, the tanker M/V *Swan Atlantic* was attacked by a one-way UAV and an ASBM, and was hit.
- On 23 December, the Arleigh Burke-class destroyer USS *Laboon* got involved, shooting down four incoming UAVs. On the same day, two tankers were attacked by a UAV each, with one hit and one miss.
- On 26 December, USS Laboon teamed up with F/A-18E/F Super Hornet strike aircraft from USS *Eisenhower* to shoot down 12 one-way UAVs, three ASBMs, and two ASCMs. These attacks took place over a 10-hour period, CENTCOM said.
- On 29 December, USS *Mason* shot down a UAV and an ASBM.
- On 6 January, USS *Laboon* was the first USN shooter back in action in 2024, bringing down an inbound UAV on 6 Jan.
- On 9 January, perhaps the biggest attack to date took place, with 18 UAVs, two ASCMs, and one ASBM shot down in what CENTCOM referred to as a "combined effort" involving USS *Laboon*, USS *Mason*, sister ship USS *Gravely*, the UK Royal Navy Type 45

The UK Type 45 destroyer HMS Diamond was one of several ships that conducted combined defensive operations to shoot down 21 Houthi UAVs and missiles, during an attack on 9 January 2024.

destroyer HMS *Diamond*, and F/A-18s from the USS *Eisenhower*.
- On 17 January, a UAV struck the bulk carrier M/V *Genco Picardy* in the Gulf of Aden. CENTCOM noted that some damage was reported, but that the ship remained seaworthy and underway.

In a press briefing on 4 January 2024, Vice Admiral Brad Cooper – the USN's Bahrain-based, triple-hatted commander of US NAVCENT, US Fifth Fleet, and the USN-led Combined Maritime Forces (CMF) maritime security partnership – said that the regularity of the attacks and numbers of missiles involved presented a complex threat for the naval ships gathered, under the multinational Operation 'Prosperity Guardian' (established on 18 December 2023), to defend against the Houthi strikes, but that the response had been effective. "It's a very active defensive role," he said.

However, some of the operational evidence may indicate that Iran (or perhaps the Houthis) have not yet fully optimised the 'game-changing' capability that uncrewed systems such as UAVs are perceived to offer. Few of the UAVs launched across Red Sea waters appear to have reached their apparent targets; those that have done so appear to have inflicted only limited damage, at least in that the ships do not appear to have been stopped from continuing on. While perhaps Iran may have decided to take more risk with the capability to create a threat through fear of potential attack – and to some extent this has been successful, given that some shipping companies have opted to re-route their ships southward around the African continent – the military effectiveness of the Iranian/Houthi UAV capability does not yet appear to be as potent as it could be.

This is demonstrated too in the tactical employment of the systems, when launched in numbers. Iranian fast-attack surface craft operating in the Gulf routinely harass naval and commercial shipping by swarming around them in an apparently co-ordinated manner. Swarm tactics are a central element of Western discussion regarding harnessing the potential benefits of the mass that uncrewed systems can bring. Yet, despite launching weapons in large numbers towards the Red Sea shipping lanes, there is no public evidence to date that such weapons have been operating in an integrated, co-ordinated manner. US officials have been clear in using the word 'waves', as opposed to 'swarms', when characterising the nature of the larger-scale strikes.

A lack of integrated ISR and command, control, and communications (C3) capabilities could be a primary explanation for why swarm tactics have not yet been used, and could also explain the apparently limited targeting effectiveness. Despite these limitations, the Houthi attacks have endured, and still constitute a threat in being. In his press briefing, Vice Adm Cooper said "We are certainly mindful of the continued threat, and expect the Houthi attacks may continue."

The threat has also expanded. The Red Sea crisis has seen the use of USVs. While the Houthis have modified rigid-hull inflatable boats – either crewed or uncrewed – with explosives to attack naval ships in port and commercial and naval ships at sea before, the current crisis saw the first use of a bespoke USV in the region. "I'd characterize the USV incident as the use of a new capability," said Vice Adm Cooper, noting, "The introduction of a one-way attack USV is of concern."

Credit: US Navy

Iranian fast-attack craft are pictured swarming around an oil tanker in the Straits of Hormuz in May 2023. It is not evident that Iranian UAVs as yet are sufficiently integrated to conduct swarming operations.

Wider demonstration

Iran has also found other routes by which to test, develop, and demonstrate its UAV capability. Writing for the Gulf International Forum in November 2023, Giorgio Cafiero – a US-based analyst and expert covering Gulf security matters – noted that, through its supply of UAVs to Russia that Moscow has used to some effect in its war with Ukraine, Iran's capacity to develop and deliver such capability has been tested and demonstrated. Indeed, the Russo-Ukraine war is acting as a testing ground for Iran's UAV capability, Cafiero continued. Citing a Carnegie Endowment for International Peace report on Iran's UAV developments, Cafiero wrote "As Iran's role as an exporter of unmanned technology becomes more robust, it may well acquire 'future clients'."

Moreover, provision of such capability has made Iran "increasingly useful" to Russia, Cafiero explained, giving Iran greater leverage in its relationship with Russia while also providing revenue for Tehran at a time when the country is under US-led international sanctions.

Iran's technology development also has wider implications for Gulf regional security: Cafiero said that Bahrain, Israel, Saudi Arabia, and the United Arab Emirates (UAE) "have long perceived Iran's drone and missile programmes as an enormous danger to their security": moreover, he added, the transfer of such capabilities to non-state actors across the region confers plausible deniability for Tehran. Iranian-produced UAVs have been used in various attacks across the region, including in Saudi Arabia in September 2019 and the UAE in September 2022.

Reports also note Iran's development of two naval 'drone carriers', designed as host platforms for its UAV capability. According to the Middle East Institute report, a sea-launched UAV capability would give Iran "strategic depth, greater strike options, and the means to threaten adversaries from the Gulf of Aden to the Gulf of Oman [and] may influence shipping patterns across the Arabian Sea and into the Indian Ocean".

Iran's UAV capability, alongside a selection of other weapons, enables Tehran – for example, when distributing these capabilities to the Houthis in Yemen – to cast a shadow over shipping and shape events in both the Gulf and the Gulf of Aden/Bab-al-Mandeb/Red Sea corridor, two of the world's most important maritime choke points. ■

US security aid to Ukraine falls hostage to the cult of Trump

Peter Felstead

Any potential Ukrainian progress in pushing back the country's Russian invaders is already being threatened by political machinations in Washington, but if Donald Trump were to be re-elected president in November 2024, Kyiv's position could be fatally compromised.

As 2023 drew to a close, the administration of Ukrainian President Volodymyr Zelensky must have looked with some degree of consternation at political developments in the United States, where continued funding to assist Kyiv fight off the Russian invasion, which began almost two years ago, is already stymied.

In the second week of December 2023, no doubt hoping to move the dial on this issue, Zelensky travelled to Washington, DC, and gave a speech at the National Defense University on 11 December. However, while both the US House of Representatives and US Senate passed the 2024 National Defense Authorization Act in December 2023, providing USD 841.4 billion (EUR 768.6 billion) in funding for the US Department of Defense (UD DoD), the department's supplemental budget request – which includes more than USD 60 billion military aid for Ukraine – remains hostage to a cabal of Republican lawmakers, aligned with the Make America Great Again (MAGA) movement of former president Donald Trump, who are demanding stronger border security and are generally not conducive to delivering military aid to Ukraine.

Thus, when the US DoD announced a security assistance package for Ukraine valued at up to USD 250 million on 27 December 2023, it was the last such package that could be authorised under current legislation.

Credit: Office of the President of Russia, via Wikimedia Commons

In his summit with Russian President Vladimir Putin in Helsinki on 16 July 2018, Trump infamously sided with Putin over the word of his own intelligence services in denying there had been any Russian interference in the US presidential election that put him into power. A second Trump term would be unlikely to help Ukraine in its struggle to regain territory occupied by Russia.

How did it come to this?

The current stance of the US Republican Party – and in particular its ambivalence to a belligerent Russia – is one that would have the Old Guard of the Grand Old Party (GOP) turning in their graves. Typically known as more hawkish and interventionist than the Democratics across the four decades from the 1970s – this is, after all, the party of Ronald Reagan, who was widely perceived, in the US at least, to have been the US president who 'won' the Cold War. Yet the answer to how the Republican Party has ultimately come to this position is relatively simple: Trump.

At the most basic level, it can be argued that Trump is not really even a Republican to begin with. After all, within the last 40 years he has registered as a Republican, with the Independence Party, as a Democrat and as being of no party affiliation, before returning to the Republican Party in April 2012. Before winning the 2016 presidential election, Trump, unlike every other US president before him, had never held any political office whatsoever. Thus, when Trump assumed office in January 2017, having essentially run a campaign as the antidote to the 'Washington Swamp', Republican politics effectively disappeared down a rabbit hole where the party's traditional values, along with those lawmakers who still adhered to them, were drowned out by Trump's MAGA acolytes.

When it came to US foreign policy in relation to Russia, Trump displayed what ultimately emerged as common yet disturbing trait in praising the world's authoritarian leaders. In a summit with Russian President Vladimir Putin in Helsinki on 16 July 2018, Trump infamously sided with Putin over the word of his own intelligence services in denying there had been any Russian interference in the US presidential election that put him into power. The late Republican Senator John McCain said at the time that "No prior president has ever abased himself more abjectly before a tyrant."

Trump also, of course, has previous form with President Zelensky in the years prior to the Russian invasion of Ukraine. Following a whistleblower case made in August 2019 it emerged that, during a phone call between Trump and Zelensky on 25 July 2019, the US president had tried to coerce his Ukrainian counterpart into assisting in

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Credit: US DoD

Ukrainian President Volodymyr Zelensky speaking at the National Defense University in Washington, DC, on 11 December 2023. Zelensky's US visit failed to persuade US Republican lawmakers to support ongoing US security assistance for Ukraine, despite strong support from the Biden Amdninistration and US DoD.

the manufacture of a damaging narrative about his 2020 Democratic presidential rival, Joe Biden, by making the release of US military aid dependent on Kyiv's cooperation. Zelensky commendably declined to become embroiled in Trump's machinations – which ultimately led to Trump's first impeachment – while US military aid to Ukraine at the time was only released once Trump became aware of the whistleblower complaint.

Trump: the Teflon president-to-be?

As the United States enters the 2024 presidential election year, the prospect of a second Trump term poses a profound threat to Ukraine's ability to continue its resistance to the Russian invasion on anything like an even playing field. Trump's inclination to emulate the behaviour of the world's autocratic rulers he appears to so admire – he even stated on 5 December 2023 that he would only be a dictator on "Day One" – reveals a presidential candidate likely to only double down on his defiance of democratic norms.

With regard to policy on the Ukraine war, Trump blithely stated on 16 July 2023 that he could end the conflict in a day by persuading Putin and Zelensky to "make a deal". He offered no further details, but any such deal would almost certainly require a ceding of Ukrainian territory that Kyiv would find completely unacceptable.

Meanwhile, Trump's tendency to ride roughshod over political convention, and indeed US law (the Trump Organisation has already been found to have committed fraud in New York), has – so far – not dented his frontrunner status as the Republican presidential nominee. This is despite Trump running as the only indicted presidential candidate: he faces four felony counts in a Federal case for his efforts to overturn the 2020 election; 13 felony counts for his election interference in the state of Georgia; 34 felony counts in New York in connection with hush money payments to a porn star; and 40 felony counts in Florida for hoarding classified documents after he left office and impeding the government's efforts to retrieve them.

Despite all of this, the US-based website '538', which tracks US political polling, has Trump way ahead in Republican Primary polling as of 14 January 2024, on an average of 60.4%. His closest rivals, Florida Governor Ron DeSantis and former US ambassador to the United Nations Nikki Haley, were on just 12.1% and 11.7% respectively. DeSantis then dropped out of the race on 21 January 2024.

Trump's most vociferous critic among the Republican Primary candidates, former New Jersey governor Chris Christie, bowed out of the race on 10 January 2024, having supported increasing military aid to Ukraine. The remaining two candidates for the Republican presidential nomination, US entrepreneur Vivek Ramaswamy and former governor of Arkansas Asa Hutchinson, were on 4.3% and 0.9% respectively in the 538 poll averages as of 14 January, giving them very slim chances of securing the Republican nomination. Ramaswamy, who said he favoured ending US military aid to Ukraine, suspended his campaign on 15 January after coming fourth in the Iowa Caucuses and endorsed Trump, while Hutchinson, who has supported US military assistance for Kyiv, polled last in Iowa, consequently ending his presidential campaign on 16 January.

In an increasingly bizarre election year, two US states – Colorado and Maine – have legislated to ban Trump from their primary ballots under the US Constitution's 14th Amendment, determining that Trump did, in fact, engage in insurrection for his role in inciting the 6 January 2021 attack on the US Capitol Building. A final adjudication on this, however, is likely to go all the way to a US Supreme Court on which Trump appointed three of the nine justices.

If, despite his many legal hurdles, Trump does prevail as the Republican presidential nominee, Ukraine will have to take a long, hard look at its strategy regarding the Russian invasion while hoping that current Democratic President Joe Biden, who has steadfastly sided with Kyiv, can again beat Trump in a national presidential election.

Among the Republican presidential alternatives should Trump's candidacy be barred, Haley is the most pro-Ukrainian prospect, having broken from Trump in calling Putin a tyrant and stating that defending Ukraine is in the US national interest, while DeSantis has often presented a muddled view of his prospective Ukraine policy, while only appearing as a lukewarm ally at best.

Ukraine's largest benefactor

Meanwhile, Kyiv must hope that the current impasse in the US Congress is broken and the supplemental tap dispensing US military aid is turned back on sooner rather than later.

While Ukraine does, of course, receive military aid from its European allies, the fact remains that Washington provides more funding than all of Kyiv's other allies put together. According to a speech by US Defense Secretary Lloyd J Austin III during Zelensky's Washington visit, the United States has so far committed more than USD 44 billion in security assistance to Ukraine compared to USD 37 billion by Kyiv's other supporters. This means that the United States has been responsible for more than 54% of the total military aid extended to Ukraine.

Kyiv can at least take some solace from allies such as the UK holding firm and even increasing their commitments. On 29 December 2023, UK Defence Secretary Grant Shapps announced that delivery of a new package of British air defence missiles for Ukraine had commenced, while on 12 January 2024, during a visit to Kyiv, UK Prime Minister Rishi Sunak announced that the United Kingdom will provide GBP 2.5 billion (EUR 2.91 billion) worth of military funding to Ukraine in 2024/25: an increase of GBP 200 million over the previous two years.

However, while such commitments will have been graciously welcomed in Kyiv, without the lion's share of military aid that the US has provided up until now, the Ukrainian armed forces will struggle to maintain their positions and defend Ukraine's people and infrastructure, let alone proactively take the fight back to the invading Russians. ■

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Exhibitions & Conferences 2024

January		
22.-25.01.	**IAV (International Armoured Vehicles)**	London / UK
23.-24.01.	**DWT – Prospects for the Defence Industry 2024**	Bonn / Germany
24.-25.01.	**Mobile Deployable Comms**	London / UK
February		
04.-08.02.	**WDS**	Riyadh / Saudi Arabia
26.-29.02.	**Enforce Tac / IWA / U.T.SEC**	Nuremberg / Germany
27.-29.02.	**Int'l Mil Helicopter**	London / UK
March		
tbc	**ISDEF**	Tel Aviv / Israel
04.-05.03.	**Defence Logistics CEE**	London / UK
04.-06.03.	**DIMDEX**	Doha / Qatar
05.-06.03.	**Future Indirect Fires / JMTS**	Bristol / UK
11.-13.03.	**DGI**	London / UK
11.-13.03.	**Future Soldier**	London / UK
12.03.	**Parliamentary Evening**	Berlin / Germany
12.-14.03.	**Combat Engr/Log**	Warsaw / Poland
19.-21.03.	**DWT – Applied Research for Defence and Security in Germany**	Bonn / Germany
April		
09.-11.04.	**IT²EC / UDT / MILSIM CEE**	London / UK
May		
tbc	**IDEB**	Bratislava / Slovakia
06.-08.05.	**GPEC**	Leipzig / Germany
06.-09.05.	**DSA**	Kuala Lumpur / Malaysia
06.-09.05.	**SOF Week**	Tampa / US
07.-08.05.	**DWT – Multi-Domain Ops**	Bonn / Germany
07.-09.05.	**SEDEC**	Ankara / Turkey
13.-15.05.	**AOC Europe**	Oslo / Norway
14.-16.05.	**Aerospace Seville**	Seville / Spain
21.-23.05.	**CNE**	Farnborough / UK
22.-24.05.	**BSDA**	Bucharest / Romania
29.-30.05.	**CADSI**	Ottawa / Canada

June		
05.-08.06.	**Hemus**	Plovdiv / Bulgaria
05.-09.06.	**ILA**	Berlin / Germany
17.-21.06.	**Eurosatory**	Paris / France
26.-27.06.	**AFCEA**	Bonn / Germany
July		
02.-04.07.	**DCC Shrivenham**	Shrivenham / UK
22.-26.07.	**Farnborough**	Farnborough / UK
26.-27.07.	**Helicopter Forum**	Bückeburg / Germany
September		
02.-06.09.	**SOFEX**	Aqaba / Jordan
08.-11.09.	**MSPO**	Kielce / Poland
23.-25.09.	**DWT – MarineWorkshop**	Linstow / Germany
tbc	**SPIE**	Berlin / Germany
tbc	**DVD UK**	Millbrook / UK
October		
08.-09.10.	**DWT – Energy Transition in the Military Context**	Bonn / Germany
14.-16.10.	**AUSA**	Washington D. C. / US
16.-18.10.	**Future Forces Forum**	Prague / Czech Republic
22.-26.10.	**SAHA**	Istanbul / Turkey
November		
04.-07.11.	**Euronaval**	Paris / France
08.-11.11.	**Indodefence**	Jakarta / Indonesia
19.-22.11.	**IDEAS**	Karachi / Pakistan
26.11.	**Parliamentary Evening**	Berlin / Germany
tbc	**NIDV**	Rotterdam / Netherlands
December		
10.-11.12.	**DWT – IT Conference**	Bonn / Germany
tbc	**I/ITSEC**	Orlando / US
tbd	**International Fighter**	tbd

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