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AFV Lessons Learned from Ukraine

- The Role of Wheeled Vehicles in Peer Conflicts
- Main Ground Combat System (MGCS): Status Report
- SITREP: Optionally Manned Fighting Vehicle (OMFV)

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Word from the Editor



A Ray of Hope?

As the new year dawns, the War in Ukraine continues to dominate the headlines, and is now approaching one year in duration. As such, this is a good time to take a look at the situation as it is today, and do some horizon scanning for near-term problems presently waiting in the wings. Over the winter months, Russia's energy gambit seems to have failed amid an unseasonably warm winter, though it may be premature to celebrate just yet, as unpredictably cold weather in Europe may yet rear its head. In any case, at least Europe's dependence on Russian energy has drastically decreased, and many European countries have prepared for a harsh winter by topping up their gas storage reserves, leaving them less vulnerable to energy-related blackmail for the time being. In terms of equipment, a few Western countries have signalled their intent to provide further equipment to Ukraine. The UK has reportedly offered 10 Challenger 2 MBTs, Poland to provide 14 Leopard 2 MBTs (expected to be the 2A4 variant), Germany offering 40 Marder IFVs, the USA to provide 50 M2 Bradley IFVs, and France estimated to have around 30 AMX-10RC Fire Support Vehicles ready to send to Ukraine. While every little helps, and these will no doubt provide a small boost to Ukraine's capabilities, nonetheless, this will not have been quite the package Ukraine was hoping for, having previously requested modern variants of the Leopard 2 and M1 Abrams families.

Unless Poland exceeds expectations by sending the more modern Leopard 2A5 or Leopard 2PL variants, all the vehicles due for Ukraine will be fairly dated by modern standards, often lacking capabilities possessed by current equivalents. Age aside, the addition of these vehicles, in particular Challenger 2 and AMX-10RC, will introduce new or uncommon ammunition types not in use with Ukraine, complicating logistics somewhat. On top of this, it remains unclear whether spares and ammunition are going to be supplied from the donor countries' war stocks or by industry. The UK's war stocks for Challenger 2 are estimated to be relatively modest, and as such, supplying even small batches of tanks with the requisite spares and ammo could impact the British Army's readiness. This may go some way to explaining why Britain is only sending 10 tanks.

The second, more serious problem for Ukraine concerns quantities. Ukraine had previously asked for around 600-700 IFVs and 300 MBTs. The aforementioned promised vehicles comprise just 90 IFVs, 24 MBTs, and around 30 Fire Support Vehicles, about 14% of what Ukraine asked for. When considered in conjunction with the vehicles' relative age, it is difficult to see these contributions making a strategic-level impact on the war. Much the same is likely true of the PATRIOT systems Ukraine is due to receive from the US, with the expectation being that Ukraine will receive an older variant such as PAC-2, and in limited quantities, rather than something like PAC-3 in sufficient quantities to make a real difference.

A potentially concerning development has been heralded by the reports of Russian forces being deployed to Belarus, with some of the trains carrying troops unloading as far West as the town of Baranovichi. From this town, there is a highway linking to Brest, and going South, to the towns of Kovel' and eventually Lutsk in the far-West of Ukraine. While it seems doubtful that Russia has the manpower, equipment, and logistics, to open another full front and cut off Ukraine from Western supplies, this probably isn't the scenario Russia is looking toward. Instead, the objective may be far less ambitious, but potentially still effective — to split Ukraine's defences.

The majority of Ukraine's armed forces are fighting in the South and East of the country, around key areas such as Kharkiv, Bakhmut, Sloviansk, Lyman, or stationed defending vital points near Kramatorsk, Kherson, Zaporizhzhia, and Kyiv. Comparatively fewer personnel are stationed in the far-northwest of the country near Belarus. Without an adequate response, even a poorly-trained force of mobilised personnel ('Mobiks') could cause Ukraine problems if left unchecked. Responding properly would require Ukraine to reroute trained personnel, vehicles, logistics, support equipment, and reconnaissance capabilities to the far-northwest. Once there, they will be unable to contribute to more important fronts, potentially creating tactical opportunities for Russia to capitalise upon.

Compounding this problem are reports that Ukraine may be running low on surface-to-air missiles, due to their expenditure on Russian cruise missiles and loitering munitions targeting Ukraine's civilian energy infrastructure. If this problem is not addressed, Russia could start aerial bombing and reconnaissance from medium altitudes, which would be deeply problematic for Ukraine. While the past year has revealed many deep weaknesses in the Russian war machine, and provided plenty of reasons for Ukraine and the West to be optimistic, the war is not yet over, and it is likely that further challenges for both lie ahead. As such, cautious optimism remains the order of the day.

Mark Cazalet

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Cover Photo: An M115A2 Artillery Ground Burst Simulator explodes to simulate indirect fire from an Opposing Force (OPFOR) at Fort Greely, Alaska, at night on 17 March 2022. Artillery has once again proven a decisive threat during the War in Ukraine, incentivising the training of forces to operate in an artillery-heavy environment.

(Photo: US Army/Spc. Alexander Johnson)

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■ Canada Announces Procurement of the F-35 Lightning II

jh) The Government of Canada has announced its intention to procure the 5th generation F-35 Lightning II fighter aircraft in the scope of the Future Fighter Capability Project, Lockheed Martin writes in a press release. The Royal Canadian Air Force is to receive 88 F-35A multirole stealth fighters, a sustainment solution tailored to Canada's sovereign requirements and a comprehensive training program.



The F-35 is expected to strengthen Canada's operational capability with its allies and interoperability with NORAD and NATO.

To date, the F-35 operates from 27 bases worldwide, with nine nations operating F-35s on their home soil. There are more than 890 F-35s in service today, with more than 1,870 pilots and 13,500 maintainers trained on the aircraft.

■ Elbit to Provide Mission Training Centre for Israeli F-16 Fleet

(jh) Elbit Systems has announced that it was awarded a contract in the amount of approximately USD 180 M from the Israeli Ministry of Defence (IMoD) to provide, operate and maintain the new Mission Training Cen-



tre (MTC) for the Israeli Air Force's (IAF) F-16 fleet. The contract covers a period of three-years with an additional 15 year period that is to include operation and maintenance services. According to current plans, the new Mission Training Centre will complement the existing MTC, that will be upgraded as part of the contract. Both MTCs are expected to improve the quality of aircrew training, doubling the number of training sorties for the IAF's F-16 and F-15 aircrew.

The Air Force's new MTC will be equipped ten simulators with advanced high resolution displays, accurate weapon simulation and Elbit's ARENA generator, that combine to enable simulation of both current and future battlefield environments, the company writes in a press release.

■ German Armed Forces to Procure New Self-Propelled Howitzers

(lah) Due to the transfer of weapons and materiel to Ukraine, the German Army's level of available equipment has declined in recent months. In particular, the transfer of 14 German PzH 2000 self-propelled howitzers (SPHs) to the Ukrainian armed forces is likely to have significantly weakened the Bundeswehr's artillery capabilities.

In order to replace the howitzers handed over to Ukraine, the German MoD now wants to procure up to 14 PzH 2000 SPHs, using funds from Section 60, and it wants to submit a bill in this regard to the respective Parliament committees in 2023 for approval. This was the German MoD's response to a question by Member of Parliament Jens Lehmann (CDU) from Leipzig and member of the Defence Committee of the German Bundestag.

Jens Lehmann, MP, commented on the MoD's answer: "I am very pleased that the Bundeswehr is to receive replacements for the self-propelled howitzers it has given up. These plans are good for the Army for the time being. Unfortunately, so far they are only plans of the MoD but as of yet no concrete measures have been taken." In his opinion, the procurement should have been initiated much earlier. "In light of the war in Ukraine and limited industrial resources, every day counts. That is why I demand that the necessary submissions be made to the relevant committees in the German Bundestag as soon as possible and not sometime later 2023," Lehmann said.

Within the framework of the aforementioned Section 60, a total of EUR 2.2 Bn has been earmarked from the 2023 budget for "supporting partner states in the field of security, defence and stabilisation". The largest part of this aid is likely to be destined for Ukraine. The transfer of the 14 Bundeswehr PzH 2000 was carried out in cooperation with The Netherlands, who also transferred weapon systems of the same type to Ukraine. Both countries also cooperate in training Ukrainian soldiers.

■ Puma Infantry Fighting Vehicle: Further Examinations Required

(lah) Of the 18 Puma infantry fighting vehicles (IFVs) that broke down during VJTF train-

ing at the training ground in December 2022, 17 are operational again. Industry has been able to eliminate the defects on all but one of the IFVs, the Ministry of Defence wrote in a recent statement. Inspection of the vehicles by industry and Bundeswehr personnel at maintenance facilities in Pfreimd, Regen and Unterlüß revealed a nuanced picture of minor and medium problems, but also some more serious problems, the MoD said.

Further investigations are now necessary concerning high-value parts and fire damage. According to the MoD's assessment, the Puma is basically a powerful IFV and has the ability to serve the troops effectively in combat. However, the Puma has to become a more robust and reliable platform to be suited for deployment. "At present, the system can only be operated in a closely interlocked system of troops, army maintenance logistics, project management and industry," the ministry complained. In order to improve its in-service performance, the MoD will invite industry, the troops and the procurement authority BAAINBw to a toplevel meeting in the near future.

As announced immediately after the breakdown of the 18 Puma vehicles last year, the MoD is sticking to its contingency plans to ensure the Bundeswehr contribution to NATO's VJTF spearhead task force continues, with Marder infantry fighting vehicles to be deployed in place of the Pumas. Two armoured infantry companies with a total of 28 IFVs are part of the German task force. According to the MoD, 150 Pumas from the first batch are currently being upgraded to the improved "S1" design. In addition, the technical-logistical concept of the force is being further developed. "The effectiveness of these measures is a prerequisite for the triggering of further upgrade options or the commissioning of the second batch," the MoD statement read.

■ Rheinmetall to Modernise Multi-Sensor Platforms for Norway

(jh) Rheinmetall has signed a contract with the Norwegian Defence Material Agency (NDMA) to modernise the MSP500 multisensor platform, the company writes in a press release.

The total value of the order is in the low double-digit million-euro range. The framework contract covers the replacement of the old MSP500 system supplied in 2002 as well as the associated simulators with the more powerful MSP600digital sensor system. The installation of the new systems is scheduled to start in summer 2025.



The multi-sensor platforms slated for modernisation form part of the Norwegian NASAMS air defence system. They are integrated with NASAMS batteries. According to Rheinmetall, the MSP600digital is the performance-enhanced, HD-capable, digital successor of the

MSP500 and MSP600 sensor platforms used by various armed forces worldwide.

The MSP600 digital system is based on the MSP600 system, which is in service with many navies, coastguards and other military and civilian users. The four-axis stabilised platform controls an electro-optical sensor package, consisting of a state-of-the-art thermal imager (day/night vision), a high-precision laser rangefinder and a high-resolution HD colour daylight camera.

■ Spanish Army Selects E-LynX SDR from Elbit

(jh) Elbit Systems has announced that its E-LynX tactical Software Defined Radio (SDR) solution was selected by the Spanish defence procurement organization Directorate-General for Armament and Material (DGAM) in the scope of the "Urgent Acquisition of V/UHF SDR Radio Equipment" programme.



This follows the Spanish MoD's selection of the E-LynX SDR solution for its combat battalions in November 2020, and for its 8x8 DRAGÓN vehicles in November 2021, Elbit writes in a press release. The E-LynX SDR will be manufactured and maintained in Spain as a national sovereign radio, equipped with Spain's national crypto solution, through the cooperation between Telefonica and Elbit Systems.

Designed in an open architecture approach, the E-LynX family of SDR systems reportedly provides interoperable multi-channel network capacity, capable of dynamic and autonomous optimisation of spectrum resources and concurrent mission execution while maintaining resilient and secure communication.

■ SPYDER Offering Counter TBM Capabilities

(jh) Rafael has announced that its SPYDER air defence system has been enhanced with a counter-TBM (tactical ballistic missiles) capability.

This feature has been developed in the scope of Rafael's counter-TBM SPYDER programme, which involved researching and analysing the lessons learned from recent and ongoing armed conflicts involving extensive use of tactical ballistic missiles, the company writes in a press release. In response to operational requests from several existing in-



ternational customers, the objective of the programme is reported to include the extension of the capabilities of the SPYDER's effectors as well as the implementation of various counter-TBM derivatives across the system. Rafael emphasises that SPYDER is the only Israeli-made air defence system that has been incorporated into the aerial defence array of NATO. SPYDER is a low-level surface-to-air missile system designed to counter attacks by aircraft, helicopters, UAVs, and precision-quided munitions.

SPYDER systems incorporate Rafael's PY-THON-5 dual waveband IIR missile, I-DERBY active radar BVR, and the I-DERBY ER longrange missile, each of which can be used for air-to-air missions. Reportedly, the SPYDER-SR and SPYDER-ER variants provide 360° slant launching missile systems that provide lock-on-before-launch (LOBL), and lock-onafter launch (LOAL) capabilities while extending the range of defence to up to a 40 km radius. The SPYDER-MR and SPYDER-LR are said to offer medium and long-range target interception through vertical launch while pushing the defence envelope up to an 80 km radius. According to the company, the most recent variant, SPYDER All-in-One, incorporates an integrated radar, TOPLITE EO/IR sensor, and launcher onto a single platform.

■ Elbit to Supply Armour Training Centres for USD 107 M

(jh) Elbit Systems has announced that it was awarded a contract valued at approximately \$107M to provide, operate and maintain the



new Main Battle Tank (MBT) simulation and training centres of the Israeli Defence Forces' (IDF) Armoured Corps. The training centres will train commanders and soldiers of the Armoured Corps and are to maintain readiness of both regular and reserve units. The centres are to be delivered over a three-year period and the contract includes operation and maintenance services for an additional period of fifteen years, the company writes in a press release.

The future simulation and training centres will operate on the IDF's cloud using the Elbit Systems' OneSimTM simulation software infrastructure. The MBT training systems will include platform trainer turrets and platform trainer drivers with physical models. The training systems integrate the tank's operational sub-systems and simulate main and secondary armament weapon capabilities, all connected to a common synthetic simulation environment. The systems is to support individual and collective training up to company level.

■ NATO Agency Signs Cyber Security Agreements

(jh) The NATO Communications and Information Agency (NCI Agency) has signed two multiple award, Indefinite Delivery Indefinite Quantity (IDIQ) contracts with King ICT Croatia and IBM Belgium, for the provision of cyber security deployment and configuration services.



Following an open competition, the Cyber Security Services Framework (CSSF) contracts were signed on 12 December 2022

and will be effective as of 1 February this year. The contracts awarded have a ceiling price of €30M for all IDIQ holders during the contract period. The agreements include two base years and two one-year options. These contracts cover the provision of installations and configuration of cyber security assets across the NATO enterprise, supporting the services currently provided by the NATO Cyber Security Centre (NCSC).



■ Leonardo Awarded Contract for AW101/CH-149 Cormorant SAR Helicopter MLU

(jh) The contract has a value of CAD 1 Bn (EUR 690 M) and includes upgrades of 13 existing Cormorant SAR helicopters and the augmentation of a further three aircraft, delivering greater capabilities and extending fleet life expectancy to 2042+. Leonardo writes in a press release. The programme will be executed by Team Cormorant led by Leonardo and comprising IMP



Aerospace and Defence, GE Canada and Collins Aerospace Canada. The majority of the Cormorant Mid-Life Upgrade (CMLU) work will be performed in Canada, primarily at IMP's Halifax, N.S. facilities. According to the company, the CMLU Project will transition Canada's AW101/CH-149 Cormorant SAR helicopter fleet to the latest standard currently being delivered for SAR in Norway. The CMLU project is to cover state-of-the-art avionics, a new glass cockpit, more powerful digitally-controlled engines, wireless in-cabin communications, the latest SAR sensors including electro-optical infrared device and a mobile phone detection location system.

■ Finland Orders Saab RBS 70 Missiles

(ck) On 22 December 2023, Saab announced that they had received an order from Finland regarding missiles for the RBS 70 ground-based air defence system. The order is valued at approximately SEK 800 M (EUR 72 M), and deliveries will take place from 2023 to 2026.



The order includes Saab's latest version of the RBS 70 missile, Bolide, which offers improved performance, and is suited for engaging ground and aerial targets. The missile will be used with Finland's current RBS 70 systems, which have been in use in the country for more than 15 years, and are referred to as ITO05 and ITO05M (Ilmatorjuntaohjus 05) in Finnish service.

■ Defeating Viruses with Microwaves

(mc) During ESD's visit to the Elettronica Rome (ELT Roma) facility in November 2022, the company demonstrated their E4Shield microwave biodefence system, designed to inactivate ambient viruses in the air. Similar in appearance to a flat, square tile the E4Shield works by using a specific frequency of microwave to induce structure-resonant energy transfer onto the virus' structure, in turn fracturing the virus' outer shell and thereby rendering them inactive in aerosol form "within a few minutes" of being switched on. The frequency used by the device can penetrate some building walls, depending on their composition and thickness, but will be attenuated by water or metals. Depending on the setup, this could potentially allow the device to inactivate viruses in rooms adjacent to the one where the emitter is active.



At present, Elettronica has two variants of E4Shield on offer. The first is the E4Shield Personal, which is the smaller of the two, measuring $85 \times 85 \times 22$ mm. It is intended for personal wear, with a peak power of 7 W and an effective protection diameter of 3 m. The larger variant is the E4Shield 50, measuring $150 \times 150 \times 45$ mm. It is intended for use in offices or larger public spaces, with a peak power of 9 W and an effective coverage of 50 m2, which was understood to correspond to a protection diameter of 7.97 m. Both variants are provided with batteries to allow up to 4 hours of continual operation when disconnected from their power supply. They can be recharged fully in 2 hours (for E4Shield Personal) or 3 hours (for E4Shield 50) using a typical USB-A to USB-C charger. The device can be interfaced with either via the aforementioned USB-C cable or via Bluetooth. A company representative stated that the device is completely harmless to humans and is safe around pacemakers. Both variants of E4Shield have already received CE (Conformité Européenne) certification and SAR (Specific

Absorption Rate) safety compliance certification for uncontrolled environment/general exposure limits specified in EN62311:2008 and EN62479:2010.

It should be noted that the technology works only against viruses in the air, and cannot destroy viruses once they have already entered the human body. This is because the body's water content attenuates the microwave signal. At present E4Shield is capable of inactivating different variants of SARS-CoV-2, the virus responsible for the COVID-19 pandemic. According to Elettronica, during testing the device was demonstrated to be capable of inactivating 90% of the viral load in an aerosol containing the virus, and this effectiveness extends to variants of SARS-CoV-2, including the Delta and Omicron variants.

Beyond SARS-CoV-2, the technology could also be applied to inactivate other viruses in future, such as seasonal flu. The company representative stated that making it work against other viruses this would require matching the emission frequency and waveform to a specific viral threat, requiring the building of a threat library of different viruses and their corresponding microwave inactivation signals. When ESD asked how the device would know which frequencies and waveforms it would be required to generate, Elettronica stated that under their future roadmap they were working with partners to develop and integrate a means of determining which viruses are present in the local environment, so that the E4Shield emitter can tune itself to combat those specific threats.

The product is already available on the business-to-business (B2B) market, and Elettronica stated that they are aiming to acquire contracts for the product in the transport, automotive, and real estate/property management sectors. From a public health perspective, Elettronica emphasised that their E4Shield range is intended to complement rather than completely replace masks, since no single measure is guaranteed to prevent infection. However, for a world emerging from COVID-19 lockdowns, this device holds the potential to reduce infection risks in commonly crowded areas such as public transport, airports, indoor venues, hospitals, military sites, vehicle platforms, and various others.

■ Saab Contracted for Life Extension of Swedish MCMV

(jh) Saab has signed an agreement with the Swedish Defence Materiel Administration (FMV) for the life extension of two KOSTER-class mine countermeasures vessels, the company writes in a press release. The order value is SEK 350 M (EUR 32 M). The contract includes options for FMV to order



measures regarding the remaining three Koster-class vessels. The options amount to SEK 270 M (EUR 24.5 M).

Under the terms of the contract, the modernisation measures cover an exchange of systems for life extension and enhanced capabilities to ensure continued operability including a new navigation radar and improved capabilities for the combat system and the surface sensors.

Originally, the KOSTER class MCMVs were designated Landsort class, but as five of the ships went through mid-life upgrades in 2009 and onwards, the class was renamed to Koster. At the same time, the ships were equipped with increased capabilities such as remotely controlled underwater vehicles.

■ Rheinmetall Supplying Logistics Trucks to Ukraine

(jh) By order of the German Government, Rheinmetall is supplying Ukraine with new HX 8×8 trucks. In total, 26 of these hookloading vehicles will be transferred to Ukraine. The order is worth EUR 12.5 M According to a press release by the company, deliveries of the vehicles have already commenced.

Built by Rheinmetall MAN Military Vehicles, the HX family is among the most widely used range of military trucks anywhere, Rheinmetall emphasises. Over 15,000 vehicles are in global service. A military-off-the-shelf family of vehicles, HX trucks are designed for high durability, mobility, ease of use and modularity.



Rheinmetall has already been involved in several activities in support of Ukraine. In 2023, with the backing of the German Government, the Rheinmetall subsidiary Zeppelin Mobile Systeme GmbH is to supply Ukraine with a turnkey field hospital.

In addition, Rheinmetall is taking part in several 'Ringtausch' operations. The 'Ring-

tausch' is a procedure developed by the German Government to support the Ukrainian war effort in cooperation with neighbouring European countries and NATO partner nations. Here, NATO countries transfer Sovietera heavy equipment to Ukraine, receiving surplus Western-made systems in exchange. Rheinmetall is currently supplying various fighting vehicles from company reserves, including Leopard 2 A4 tanks and Marder infantry fighting vehicles, to the Czech Republic, Slovakia and Greece. Furthermore, HX 8×8 trucks are also supplied to Slovenia. In turn, these NATO countries are to transfer tanks and IFVs to Ukraine.

■ JFD Awarded NATO Submarine Rescue System Contract

(jh) JFD, part of James Fisher and Sons plc, has announced that it has won the 'Third In-Service Support' (3ISS) contract, worth GBP 63 M, continuing seven years of safety critical operational assurance services to the NATO Submarine Rescue System (NSRS). The 3ISS contract awarded by the NSRS Author-



ity on behalf of UK, France and Norway as the participant nations, covers a complete in-service support solution. The NSRS is a submarine rescue capability which is to give submariners the best chance of survival should a submarine incident occur. The five-year 3ISS contract will start in summer 2023 and has the potential to be extended to a total of nine years.

■ Sweden, Germany, and the UK to Jointly Procure BvS10 Vehicles

(ck) On 16 December 2022, BAE Systems announced that Sweden, Germany, and the UK would jointly Procure BvS10 vehicles

under the Collaborative All-Terrain Vehicle (CATV) programme. The joint procurement is valued at approximately USD 760 M, and comprises 436 vehicles, with deliveries beginning in 2024. Of this total 236 BvS10s will be going to the Swedish Defense Materiel Administration (FMV), 140 to the German Federal Ministry of Defence (BAAINBW), and 60 to the UK Ministry of Defence (MoD). The



vehicles are based on the latest version of the BvS10 currently operated by Sweden, and the order will include variants for troop transport, logistics, medical evacuation, recovery, and command and control.

The CATV programme includes a framework agreement that could lead to the purchase of more vehicles by the three countries, keeping the BvS10 in production for years to come. Sweden is the lead nation and has established a joint procurement office to lead the effort with representatives from all three nations. This acquisition follows Sweden's 2021 order of an additional 127 BvS10 all-terrain vehicles. In parallel to this agreement, Sweden is also procuring an additional 40 BvS10s in a separate contract valued at approximately USD 50 M.

BAE Systems' BvS 10 vehicles are manufactured in Örnsköldsvik, Sweden. The all-terrain vehicles are designed for operation in harsh environments. The BvS10 can traverse snow, ice, rock, sand, mud or swamps, as well as steep mountain environments, and is also fully amphibious. The vehicle's modular design allows it to be reconfigured in multiple variants that include personnel carrier, command and control (C2), ambulance, repair and recovery, logistics support, situational awareness, and weapon carrier/mortar carrier variants.

BvS10 is operated by Austria, France, the Netherlands, Sweden, and the United Kingdom. BAE Systems' Beowulf, the unarmoured variant of the BvS10, won the US Army's competition for its Cold Weather All-Terrain Vehicle (CATV) programme in August. Under CATV, the US Army will receive 110 vehicles over a five-year period.



■ Germany's Second Lot of Puma IFVs Under Questions Following Breakdowns

(lah) In the week beginning 12 December 2022, 18 Puma infantry fighting vehicles (IFVs) suffered total failure during training at the Bundeswehr's range in Bergen. In response, the German Ministry of Defence (MoD) commissioned a comprehensive inventory and failure analysis effort, which has been underway since 16 December. The vehicles in question belonged to a Bundeswehr armoured company scheduled for deployment to the NATO Very High Readiness Joint Task Force (VJTF) 2023.

The incident in Bergen was first reported by Der Spiegel, citing an email sent from the commander of the Bundeswehr's 10th Armoured Division, Major General Ruprecht von Butler, to the Army's Chief of Staff, Lieutenant General Alfons Mais. The email stated that the operational readiness of the 18 Puma IFVs dropped to 0 after just several days on deployment. The failures were primarily attributed to problems with the electronics, but also included a cable fire. German MoD stated that the goal of the failure analysis is to restore the IFVs' operational readiness as quickly as possible. Defense Minister Christine Lambrecht described the renewed failures of the Puma infantry fighting vehicle as a bitter setback, stating "I have commissioned



an analysis by the end of next week by participating agencies of the Ministry of Defence (BMVg) and the Bundeswehr, the Army Logistic Service (HIL), and industry". She added, "The Puma project is at a decisive milestone, and I have made that unmistakably clear to all those involved. Until the vehicle proves to be stable, there will be no second batch." The criticism from parliament was entirely justified, the minister stressed. "Our troops must be able to rely on weapon systems being robust and stable, even in combat."

According to the German MoD, however, Germany's contribution to the NATO spearhead in VJTF 2023 will remain unaf-

fected by these "technical challenges." In the course of preparing for deployment, the MoD said said, Panzergrenadier (mechanised infantry) combat units have already been trained on the legacy Marder IFV, which will replace the Puma units in the VJTF. The Pumas were supposed to form a core component of the VJTF starting on 1 January 2023, however the vehicles affected by the failure are currently being transported back to Bavaria.

Perhaps more concerningly, the Pumas in question were the improved 'Puma VJTF 2023' configuration, which had previously been certified as combat ready. This standard featured various improvements, including software updates, upgrades to the commander, gunner, and driver optics, provision of colour displays for the infantry dismounts, and the addition of Elbit PNR-1000 UHF radio, and two additional Rohde & Schwarz UHF/VHF SOV-**ERON VR5000 Software Defined Radios** (SDRs). Company and battalion command vehicles were additionally equipped with an L3Harris AN/PRC-117G(V)1(C) satellite radio and a Thales SEM 93 VHF radio.

Furthermore, on 14 December 2022, just days before the Der Spiegel broke the story of the readiness failures, the German government released funding to upgrade the Army's baseline Pumas to the VJTF 2023 standard. Additionally, a second batch of 50 Pumas, of a similar configuration to the VJTF 2023 standard, was slated to be ordered in 2023. However, both the upgrade plans and the procurement of the second batch have now been paused, pending the outcome of the investigation.

■ First Two Gripen E Fighters Enter Service with Brazil

(mc) On 19 December 2022, the Brazilian Air Force (FAB) held a ceremony inducting the first two JAS 39 Gripen E aircraft (known as Gripen F-39 in Brazilian service) into service, as part of the 1st Air Defence Group (1st GDA) – Jaguar Squadron. The squadron is based at Anápolis Air Base, located approximately 160 km southeast of the capital Brasília.

Earlier in November 2022, the Gripen E achieved certification for military use from the Swedish Military Aviation Safety Inspectorate (FLYGI) and the Industrial Fostering and Coordination Institute (IFI) in Brazil. The event follows a flight testing phase which commenced in September 2020, conducted at the Gripen Flight Test Center (GFTC), located at the Embraer plant in Gavião Peixoto. The pilots had



previously carried out their training on the Gripen aircraft in Sweden, and are also provided with mission trainer simulators at their Anápolis. The first two production aircraft then arrived in Brazil on 1 April 2022, followed by a further two just months later on 25 September.

The Gripen E's entry into service with Brazil marks a major step forward for the country's air force, which has previously had to rely on a combination of turboprop designs such as the EMB 314 Super Tucano, and ageing jet aircraft such as the F-5EM/F-5FM, and A-1/A-1M (AMX International). Brazil has so far ordered an initial batch of 36 Gripens followed by a supplementary batch of four, and plans to acquire a total of 66. The purchases have an estimated combined value of USD 2.2 Bn, and the new aircraft will be used to replace Brazil's ageing F-5 fleet.

Sweden Orders Additional NLAWs

On 15 December 2022, Saab announced that they had received an order for NLAWs (Next Generation Light Anti-Tank Weapon)



from the Swedish Defence Materiel Administration (FMV). The order was valued at approximately SEK 900 M (EUR 82.6 M), and deliveries are slated to take place from 2024-2026. The order was made within a framework agreement between FMV and Saab.

■ Rheinmetall to **Buy Stake in Blackned**

(ck) On 5 January 2023, Rheinmetall announced that they would increase their partnership with blackned GmbH, a software company based in Germany, by taking a 40% stake in the company. The purpose of this partnership is to support the digitisation of armed forces and to strengthen Rheinmetall's position in the development of tactical information and communication networks and system networks. Blackned GmbH will retain its independence despite the partnership with Rheinmetall.



Blackned specializes in communications systems and has developed a product called TacticalCore. This product will be integrated into Rheinmetall's existing systems as part of their efforts to digitise landbased operations for the Bundeswehr. The goal of this project is to modernise and equip the Bundeswehr for action by 2025 as part of the "Division 2025" project.

Rheinmetall is involved in projects related to the digitisation of armed forces in countries such as Australia, Great Britain, and Hungary.

Dan Slasky Appointed CEO of Aeronautics



(jh) The Aeronautics Group's board of directors, headed by Chairman and Rafael CEO Maj. Gen. (ret.) Yoav Har-Even, has appointed Dan Slasky as the CEO of the company, Aeronautics wriotes in a press release.

Aeronautics specialises in unmanned systems, payloads and communication for defence and homeland security applications.

Slasky replaces Moshe Elazar, who completed a three-year term as Aeronautics Group CEO. According to the company, Aeronautics doubled its sales, tripled its order backlog, developed innovative and ground-breaking products and won major international tenders durin Mr Elazar's office term.

For the past five years, Slasky served as CEO of the SCD Group (jointly owned by Rafael and Elbit), which develops and manufactures infrared sensors for the defence and civilian markets.

He will enter into his role as CEO of the Aeronautics Group within the next few months.

Rheinmetall Awarded **Contract for Explosives Factory in Hungary**

(jh) The Hungarian state is building a new explosives plant to produce RDX (Research Department eXplosive) at its site in Várpalota, Hungary, for which Rheinmetall Denel Munition Pty (Ltd) from South Africa is supplying the necessary plant technology, Rheinmetall writes in a press release. Under the contract signed on 15 December 2022, a new plant will be built and operated by a joint venture consisting of Rheinmetall and N7 Holding, a state-owned Hungarian enterprise. The contract is worth a figure in the low three-digit million-euro range.



The project is to start in 2023, so that production can begin by 2027. The explosives produced in the new plant can be used for artillery, tank, and mortar ammunition, among other things. The contract covers the supply of plant engineering, technology, and process know-how as well as the associated documentation, training, and all activities necessary to achieve full-scale production.

■ NFM Group to Buy Hexonia

(ck) On 3 January 2023, NFM Group announced that they had acquired all shares of Hexonia GmbH in Germany. Hexonia is a supplier of personal protective equipment and combat clothing to the German armed forces and has its head office and production in Nettetal outside Düsseldorf. The acquisition is the biggest in NFM Group's history to date, increasing its total production capacity, access to new technologies, and new markets, making NFM Group now a leading



European company in protective equipment and combat clothing. The acquisition comes at a time when Germany is carrying out a significant modernisation of its armed forces with an investment fund of EUR 100 Bn, and while Hexonia faced strong growth.

■ GA-ASI Announces Partnership with Bharat Forge of India

(jh) In a move to boost manufacturing in India, General Atomics Aeronautical Systems (GA-ASI) and Bharat Forge Limited, India have announced a partnership to manufacture main landing gear components, subassemblies, and assemblies of remotely piloted aircraft, GA-ASI writes in a press release. Part



of the Kalyani Group, Bharat Forge specialises in metallurgical design, engineering and manufacturing. Reportedly, the company has a digitally integrated manufacturing, assembly, and testing facility for aerospace components and systems. It manufactures structural and engine parts and subsystems for aircraft and engines for both civil and military applications. Its portfolio includes aircraft turbine and compressor manufacturing, aero engine components like blades, discs, and shafts, and airframe components, including aircraft landing gear.

■ ARQUIMEA to Buy IberEspacio

(ck) On 22 December 2022, technology company ARQUIMEA announced that they had bought IberEspacio, a company which supplies thermal control hardware and engineering solutions for satellites, from Técnicas Reunidas for EUR 19 M. The company has participated in 53 space missions, having launched more than 991 units, with another 1,357 in progress.

ARQUIMEA is the main shareholder and industrial partner responsible for the manufacture of satellites for BeetleSat, a new telecommunications constellation, for which it plans to manufacture more than 200 satellites in the coming years. The satellites will be manufactured at IberEspacio's facilities.



The Role of 4×4 & 6×6 Armoured Vehicles in Multiple Operational Environments

David Saw

If you were looking to acquire a vehicle at the top of the wheeled armoured vehicle spectrum your attention would immediately be drawn to the 8×8 category of vehicles. These have the performance, load carrying capability, a respectable level of protection and in many cases the ability to provide the basis for a complete family of vehicle variants. Inevitably, the possibilities offered by 8×8 vehicles come at a price premium, yet it is not always necessary to pay that premium. Many wheeled applications do not need the performance of an 8×8 vehicle, and other solutions exist in the form of 6×6 or 4×4 vehicles. Not only can vehicles in these categories fulfil mission requirements, but they can do so more cost-effectively than their larger 8×8 siblings.

he British Army has not seen wheeled armour in 4×4 or 6×6 configurations as central to its vehicle plans for many years. Between the 1950s and the 1970s it had the Saladin armoured car and the Saracen APC in service, both being 6×6 vehicles. Then in the early 1970s the Fox 4×4 vehicle arrived as the Combat Vehicle Reconnaissance Wheeled or CVR(W), with this vehicle remaining in service until the early 1990s. After that it was protected vehicles based on the Land Rover chassis and after the asymmetric conflicts of Iraq and Afghanistan exposed their lack of protected mobility, there was the purchase of a number of different versions of Mine Resistant Ambush Protected (MRAP) vehicles from different manufacturers as Urgent Operational Requirements (UORs).

These days, the British Army is trying to get its armoured vehicle house in order with a number of different armoured vehicle programmes, mixing upgrade efforts with new equipment purchases. Initially there were four major armoured vehicle programmes in the procurement system, these consisted of: Warrior Capability Sustainment Programme (WCSP), Challenger 2 Upgrade, Ajax, and the Mechanised Infantry Vehicle (MIV) won by the 8×8 Boxer vehicle. Of these programmes Warrior was cancelled, the Challenger 2 to Challenger 3 upgrade is going ahead, the future of Ajax is not yet fully resolved, and Boxer is the only programme without any negatives at present.

British 4×4 and 6×6 Efforts

There are also a number of other armour/armour-related programmes cur-



While initially the JLTV acquisition by the UK for MRV-P Package 1 looked extremely likely, the programme has been shelved.

rently in the concept stage with funding from 2025 onwards. The first of these is the Armoured Support Vehicle (ASV), a tracked vehicle that will be acquired in a number of different variants to replace the already aged FV432 Bulldog series of vehicles. Of more interest in the context of wheeled armour is another effort currently in the concept stage that will also receive funding from 2025 onwards, this is the rather challengingly named the Protected Mobility Pipeline (PMP). This programme aims to provide protected mobility solutions across the 'land environment.' What that translates into is a number of different vehicle types to meet a number of different operational requirements.

PMP vehicles are protected mobility platforms, covering multi-role or general applications, in such areas as ambulances, C2 vehicles and beyond. With PMP being a British Army armoured vehicle programme of sorts, it is inevitable that there is uncertainty involved. Back in 2016 much of the PMP effort was operating under a different name as the Multi Role Vehicle - Protected (MRV-P). MRV-P had two components, these were the Troop Carrying Vehicle (TCV), with a crew of two and carrying six dismounts. This vehicle would also provide the basis for a number of specialist variants. The other main part of MRV-P was the Future Protected Battlefield Ambulance (FPBFA).

Being cynical, that all sounded rather sensible and uncomplicated for a British vehicle programme and, inevitably, it all became rather complex. The programme was split into three, MRV-P Package 1 was predicated on acquiring the Oshkosh Joint Light Tactical Vehicle (JLTV), MRV-P Package 2 was the acquisition of systems to meet the TCV and FPBFA requirements, while Package 3 was a recovery vehicle presumably based on the vehicle chosen for TCV and/or FPBFA.

The JLTV acquisition under MRV-P Package 1 was considered to be a 'done deal,' this 4x4 vehicle offered the protected mobility that the user desired and it was only a question of time before the British purchased the vehicle. Indeed, in July 2017 the US Defense Security Cooperation Agency (DSCA) announced an offer to Britain as many as 2,747 JLTV systems, plus appropriate support valued at USD 1.035 Bn. At that time, the initial British JLTV requirement was only for some 750 JLTV vehicles. As time went on, the British JLTV requirement grew in size as the Royal Marines added their needs to those of the British Army, boosting the programme to a buy of 821 JLTV.

While Britain was testing the JLTV, in the US, production of the latest 'A2' version of the JLTV was going to be re-competed under a 'competitive rebuy,' and the winner of that competition, who will build the JLTV in future, should be announced in early 2023. Despite this, in July 2022 Oshkosh received a USD 216 M contract for 513 JLTV and 1,152 trailers (JLTV-T) for the US military and exports to Brazil, Lithuania and Montenegro. Then in December 2022, Oshkosh received a USD 543 M contract for 1,681 JLTV and 618 JLTV-T for the US military. At that time, Oshkosh stated that they had built 18,500 JLTVs since 2015.

As for the JLTV and Britain, the Ministry of Defence (MoD) decided to wait for the JLTV re-compete to be settled before advancing towards an order, therefore in mid-2022, MRV-P Package 1 was shelved. However, the JLTV acquisition then resurfaced a part of the PMP programme under which the British Army hopes to reduce its protected vehicle fleet down to as few as five different types. Under the PMP programme comes a programme to replace the Land Rover Defender, the current Army fleet is 6,609 vehicles, they will look to acquire a protected variant of the vehicle selected as the Defender replacement. Then comes the acquisition of a 'medium-protected' vehicle under PMP and that should eventually result in an order for the JLTV, although as stated above, much depends on the fate of the US

JLTV competitive rebuy process. Then comes arguably the most interesting part of the PMP effort in the form of the 'heavy-protected' category, essentially TCV/FPBFA reborn from the MRV-P programme in either a 4×4 or 6×6 format. The acquisition of a recovery variant remains unclear, especially since there never appeared to be much enthusiasm for MRV-P Package 3.

For the heavy PMP requirement, we can expect at least some of the original contenders for TCV/FPBFA to compete in the programme, with some new entrants possibly considering participation. Originally some 12 companies expressed interest in TCV/FPBFA, it is likely that the Thales Bushmaster, a 4×4 solution, will return to the fray, as will the Penman Metras MRV 6×6 and the General Dynamics European Land Systems (GDELS) Eagle V 6×6. Perhaps a new contender might emerge, with the Patria 6×6 as a possible option, especially since it has recently been selected by several European countries.

What is distressing about the British MRV-P and the successor PMP programme is that it has taken so long to acquire systems that are already in service with other European armies. If you look at the JLTV, this is in service with or on order for Belgium, Lithuania, Montenegro, North Macedonia, Poland, Romania and Slovenia, as well as with the US military. This is starkly contrasted by the lack of progress in TCV/FPBFA, and looks even worse when one considers that under current planning, PMP funding only becomes a reality from 2025 onwards!

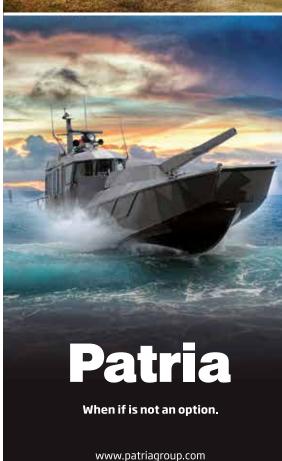
Meanwhile in Finland

Patria in Finland has had great success with wheeled armour, such as their 8×8 AMV and the 6×6 XA vehicle family in the XA-180/XA-185/XA-186/XA-188 and XA-200 variants. The XA was initially acquired by Finland and later by seven other countries, with the Netherlands later selling on its 90 XA-188 vehicles to Estonia. Then Patria embarked on a programme to develop a new modular 6x6 vehicle, based on their experience with the AMV and the XA. Eventually this led to the imaginatively named 'Patria 6×6', sometimes also referred to under the name of its acquisition programme – 'Common Armoured Vehicle System' (CAVS).

The starting point for the CAVS system was in January 2020 when Finland and Latvia agreed to work together to jointly define a 6×6 armoured vehicle, with Patria subsequently being selected as the









The Thales Bushmaster Protected Mobility Vehicle (PMV) being used to train Republic of Fiji Military Forces (RFMF) crews on Bushmaster vehicles acquired by Fiji. More recently Bushmaster has been supplied to Ukraine and is of interest to the British Army for the high end of its Protected Mobility Pipeline vehicle requirement.

prime contractor. This was followed by an October 2020 agreement covering CAVS R&D, this led on to the next phase of the programme in August 2021 when Latvia actioned the acquisition of more than 200 CAVS vehicles, with first deliveries taking place in October 2021. Finland then expressed its intention to order 160 CAVS with deliveries from 2023 onwards, in addition they acquired three pre-series CAVS vehicles in mid-2022 for test and evaluation purposes.

The next stage in the evolution of the CAVS programme came in late 2021 with the Swedish announcement that they intended to participate in the CAVS programme, signing a participation agreement in June 2022. Estonia then joined the CAVS programme, followed by Germany signing a Statement of Intent to join CAVS in June 2022. It is actually quite remarkable that a programme that got underway in January 2020 has made so much progress so quickly, making first

By combining features from their existing AMV and XA vehicles, Patria developed the 'Patria 6×6', being procured under the Common Armoured Vehicle System (CAVS) programme. CAVS has already been ordered by Finland and Latvia, with Sweden and Estonia moving to acquire CAVS and more recently in June 2022, Germany announced its intent to join the CAVS programme.

deliveries in October 2021 and gaining three export customers countries, on top of the original two partner countries, within 30 months from programme start.

France on Wheels

France has always had an affinity with wheeled armoured vehicles, such as the 8×8 Panhard EBR (Panhard is a legacy company of Arguus), the 4×4 Panhard AML and, of course, the Véhicule de l'avant blindé (VAB), with some 4,000 acquired by the French Army in a 4x4 configuration, and with the 6×6 variant proving very successful in export markets. Then there is the French Army 8×8 Véhicule blindé de combat d'infanterie (VBCI) from Nexter to consider, plus the 6×6 AMX-10RC/RCR reconnaissance vehicle also built by Nexter. Believing that the AMX-10RC was too heavy for rapid deployment missions, the French Army also acquired a lighter combat system in the form of the 6×6 ERC-90 Sagaie.

Under the SCORPION programme, the French Army is acquiring a new generation of vehicles to replace the AMX-10RC/RCR, the ERC-90 Sagaie and the French Army version of the VAB mounting HOT anti-tank guided missiles (ATGMs). It should be noted that in early January 2023, French President Emmanuel Macron announced that ex-French Army AMX-10RC vehicles would be supplied to Ukraine. The vehicle is equipped with a medium-pressure 105 mm F2 gun firing 105 mm × 527R rounds, not to be confused with the 105 mm x 617R rounds fired by standard NATO L7 tank guns. One does not envy those tasked with ammunition resupply in the Ukrainian Land Forces, as the logistics of coping with so many different calibres must be immense.

Returning to the SCORPION programme, two 6×6 vehicles are being acquired in the form of the Engin Blindé de Reconnaissance et de Combat (EBRC) Jaguar and the Véhicule Blindé Multi-Rôles (VBMR) Griffon, with the last Scorpion programme vehicle being the Véhicule Blindé Multi-Rôles Léger (VBMR-L) Serval. Apart from the French Army, Belgium has ordered both the Jaguar and the Griffon for the Capacités Motorisée (CaMo) programme of the Belgian Land Component. Belgium will receive 60 Jaguar and 382 Griffon, as well as two batteries of the Mortier Embarqué Pour l'Appui au Contact (MEPAC) mortar carrier variant of the Griffon, mounting a 120 mm Thales 2R2M mortar.

By the end of 2022, a total of 452 Griffon, 38 Jaguar and 70 Serval had been delivered to the Direction Générale de l'Armement (DGA). As previously noted, the Jaguar will replace the AMX-10RC/

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The serious end of the 6x6 armoured vehicle spectrum, the French Army AMX-10RC reconnaissance system on exercise in Norway in March 2022. In January French President Emmanuel Macron announced that the AMX-10RC would be supplied to Ukraine, there is speculation that as many as 30 could be delivered.

RCR, the ERC-90 Sagaie and the anti-tank version of the VAB mounting HOT anti-tank missiles. The Griffon and the Serval will replace the multiple variants of VAB that are in French Army service.

Another 6×6 armoured vehicle solution is being offered by Arquus in the form of the

VAB Mk3, the company believes that there are excellent market possibilities for this vehicle in Eastern Europe to meet protected mobility requirements and in Africa to replace elderly Soviet-era 8×8 vehicles such as the BTR-60/BTR-70/BTR-80. The VAB Mk3 is available in a number of different

variants – alongside an APC variant, it can be equipped with turrets from John Cockerill or Nexter mounting 20/25 or 30 mm automatic cannon, there is a Fire Support Variant with a 90 mm low pressure gun, a mortar carrier with 81 mm or 120 mm mortars, as well as command post, ambulance, and riot control vehicle variants.

VAB Mk3 technologies can also be offered to existing VAB operators for upgrade programmes, for example Qatar upgraded its VAB fleet using a complete

VAB Mk3 technologies can also be offered to existing VAB operators for upgrade programmes, for example Qatar upgraded its VAB fleet using a complete VAB Mk3 driveline supplied by Arquus. The VAB Mk3 driveline has also been supplied to PT Pindad in Indonesia for the indigenous 6×6 Anoa wheeled armed vehicle as used by the Indonesian Army (Tentara Nasional Indonesia Angkatan Darat – TNI-AD).

Wheeled armour in 4×4 and 6×6 configurations has an important role to play in delivering protected mobility. Protected mobility solutions are moving beyond the MRAP vehicles procured in such large numbers as a response to the asymmetric threats encountered in both Iraq and Afghanistan. All of which begs a question, are we in such a hurry to escape from the mine and IED threats of asymmetric conflicts that made MRAPS such an essential capability, that we are forgetting that mines and IEDs will be encountered in all sorts of conflicts and remain a serious threat that needs to be countered?



The Engin Blindé de Reconnaissance et de Combat (EBRC) Jaguar will replace the AMX-10RC, the ERC-90 Sagaie and the version of the VAB with HOT anti-tank missiles in the French Army. The Jaguar will be the primary wheeled combat system for low intensity conflicts that the French Army might become involved in.

The Role of Wheeled Vehicles in Peer Conflict and the Tracks vs Wheels Debate

Sherman Karpenko

Barely a year goes by without some debate on the utility of tracks vs wheels, and alongside questions about the validity of tanks it appears to be one of the most recurrent themes discussed by armoured fighting vehicle enthusiasts. It is difficult to arrive at any conclusive answers about the role of wheeled vehicles, but doing so through the lens of peer warfare provides an angle that may settle the debate.

Limited Mobility – Tracks vs Wheels

A brief Google search of the term "Tracks vs Wheels" will return multiple articles wading into a topic that is ultimately fruitless if it is not provided country- and conflict-specific context. The arguments are broadly divided between those who advocate for wheeled vehicles based upon their supposed reduced logistics burden and cost when compared with their tracked counterparts, those who argue that the better mobility of tracked vehicles makes them a more optimal choice, and those who support the use of both but recognise the maintenance burden this imposes. Others yet argue that the mobility of wheeled vehicles – especially 8×8s – approached that of tracked vehicles. It is fair to argue that every thesis on tracks vs wheels, with the exception of their parity in off-road mobility, is valid depending on the context in which they are employed. Yet at the same time, every thesis can also be wrong for the same reasons. However, there are physical truths that apply to armoured vehicles operating off-road, which necessitates delineation and impacts their utility to an armed force. These truths relate mostly to the mobility and trafficability of large wheeled vehicles when compared with tracked vehicles, which in turn impacts their ability to bear weight, in turn limiting their capacity to carry additional armour and weapons.

Trafficability is the ability of a vehicle to travel over certain types of terrain or ground. This should be differentiated from mobility, which typically describes the movement characteristics of a vehicle, such as speed, operational range, height of obstacles that can be overcome, and so on. Mobility characteristics dictate the trafficability of a vehicle. One key characteristic that defines offroad driving is known as traction, or tractive



Stryker Soldiers with B Company, 5th Battalion, 20th Infantry Regiment, roll through a village heading towards Baqubah, March 2007.

performance. The tractive performance of tracked and wheeled vehicles is influenced by the strength of the soil being travelled over. Weak soils with high moisture content will exhibit a greater degree of shearing deformity when travelled over than drier, stronger soils. The greater the level of shear stress (deformation) caused by the vehicle to the soil, the greater the effort is required to move the vehicle. The second element is the thrust created by the vehicle's tracks or tyres: Put very simply, tracked vehicles typically have a much larger contact area with the ground than wheeled vehicles, which equates to thrust applied over a greater surface area. This means tracked vehicles can overcome soil slippage and deformation, whereas wheeled vehicles – especially those that cannot adjust their tyre pressures - will tend to create more damage to the

soil and lose traction. J.Y. Wong has used computer simulations to show that on certain soil types, an 8×8 wheeled vehicle will only reach 79.2% of the thrust developed by a tracked vehicle on the same (firmer) soil type. As the soil becomes weaker, this figure decreases and can become as low as 50.4% on loam, which means that a wheeled vehicle will be immobilised sooner than a tracked equivalent.

This is a difficult characteristic to measure as it is almost impossible to model all soil types and the interactions that they have with wheeled vehicles. Professor Richard Ogorkiewicz noted that even with a central tyre inflation system (CTIS) that can increase the contact area of the vehicle (by 5-20%), a 20 tonne vehicle would not be able to move at much more than 20 km/h over wet agricultural soil with

a strength of 200 kPa. The tyre inflation can be reduced further, but this degrades vehicle speed even more. Ogorkiewicz's conclusions are challenged to some extent by technological developments such as the introduction of in-wheel drives, as opposed to axle drives, which may increase the traction of wheeled vehicles. Tyre technology has also improved since many of these models were developed, which suggests that performance may have improved. Bruce Maclaurin, a vehicle mobility specialist, has also explored the available terrain mobility models and arrived at the conclusion that none of them are perfect. However, he indicates that their results broadly support the conclusion that wheeled vehicles have inferior mobility to tracked vehicles, especially in soft soils.

Furthermore, one article published by Singapore's Defence Science and Technology Agency (DSTA) in 2016 indicates that offroad mobility is defined in part by the number of passes that a vehicle must make over certain terrain. The authors state that if the number of passes can be reduced by 30%, the likelihood of the vehicle successfully passing the terrain improves and can become comparable with tracked vehicles on all but the softest terrain. According to the theories that form terramechanics, reducing the number of passes allow for an increase in vehicle weight within a given contact area. However, it would also require estimates about the number of passes over given types of terrain, which might not be possible for most militaries. If more passes than estimated are required, wheeled vehicles will quickly become immobile.



This image shows a Stryker stuck in the mud during n a patrol mission in the Anbar Province. A joint task force of US and Iraqi soldiers had to spend the night nearby to protect the vehicle, which reflects the potential vulnerabilities wheeled vehicles can create.

Put simply, the argument that wheeled vehicles can match the off-road mobility of tracked vehicles does not have a wheel to stand on. Of course, there are exceptions not all wheeled vehicles are the same, and not all tracked vehicles are the same, but generally speaking this will be true of most comparisons.

However, it is worth noting that Wong's calculations indicate that wheeled vehicles can achieve similar traction to tracked vehicles on frictional soils – otherwise known as sand. This is because movement on sand is less dependent on the total contact area as it is on cohesive soils like clay. There are of course other terrains where wheeled vehi-

cles excel, and that is most notable in urban locations or on-road travel in general. A US Army assessment in 1988 compared the mission time required to complete 100 km of travel at various percentages of crosscountry travel. It showed that when around 40% of the mission was travelled off-road in wet soils, a wheeled vehicle could exhibit similar mission times to a tracked equivalent, however the mission times increased dramatically as the percentage increased, reaching 60 hours for a mission requiring 70 km of off-road travel. It follows that as the percentage of off-road travel increases by mission set, the utility of wheeled platforms decreases, especially when the gross vehicle weight exceeds 20 tonnes and when wet weather is factored in. Furthermore, even in areas where wheels shine, technologies such as composite rubber tracks are narrowing the gap, making tracked vehicles more comfortable and reducing their fuel consumption on roads, whilst increasing speed.

The ride quality and handling of wheeled vehicles has improved significantly since the US Army studies quoted above were conducted. Some scholars argued in the early 90s that wheeled vehicles were approaching the comfort levels of tracked vehicles when travelling off-road. This same study also indicated that in some circumstances a 32 ton (29 tonne) 8×8 vehicle would attain similar total mission speeds to a tank when travelling on the same terrain, but raises the interesting concept of the vehicle grey zone. The authors argue that at light loads and for vehicles required to travel long distances on roads, it makes sense to use wheeled vehicles. Equally, very heavy



Tracked vehicles, even those as heavy as an M1 Abrams, will typically exhibit better off-road mobility than wheeled vehicles because of the surface area of their running gear.



When wheeled vehicles are required to perform as IFVs, they may become limited in their ability to bring infantry dismounts onto their objectives.



It is primarily Western states that have driven wheeled vehicle weights up through the addition of armour and design complexity. Boxer is a prime example of this.

combat platforms weighing in excess of 50 tonnes can only be tracked. It is the area in-between that prompts debate.

Finally, there is the issue of cost. Wheeled vehicles are generally assumed to cost less than tracked equivalents, although Paul Hornback, a former Engineer at the HQ TRADOC Combat Development Engineering Division, argued that this comparison might be unfair, since wheeled vehicles tend to spend more of their time travelling on roads than tracked vehicles, which spend more time off-road. He added that tests have shown wheeled vehicle reliability drops the more they travel off-road. This suggests that wheeled vehicles might have similar operational support burdens

to tracked vehicles if they are required to operate off-road extensively. Something to this effect was observed when the US Army deployed its Stryker 8×8s to Iraq. The vehicles were upgraded with additional armour leading to excessive tyre and wheel station wear, as well as damage to the drive train. However, generally speaking wheeled vehicles that are used primarily in urban situations will exhibit better tactical agility and operational mobility than a tracked equivalent at a lower cost. There are multiple accounts of the Stryker family in operation in Iraq to support this.

In sum, the primary limitation of wheeled vehicles is the result of the complex interactions arising from soil mechanics, contact area, and dispersion of ground pressure. This leads to a general loss of mobility on weaker soils and limits the ability of the vehicle's weight to be increased. There is, however, a clear need to appraise what types of mission a country needs its armed forces to complete and assess whether or not wheeled vehicles have a role in peer warfare from there.

Peer Warfare – A Beast of Different Requirements

Assessing the role of wheeled combat vehicles in peer warfare requires a definition of peer warfare. A peer is generally defined as a person or thing "equal to another in abilities, qualifications, age, background, and social status." Debate within the European defence industry typically focuses this definition on NATO and its potential foes, which is unhelpful as these scenarios essentially involve potential world-ending wars that will be of extremely high intensity. If, however, the definition is broadened to include other states, then a peer opponent for Saudi Arabia is probably Iran, for Turkey it is perhaps Syria or Greece, although in all of these examples, one side is arguably stronger than the other in some regard. This means that each country's definition of peer warfare varies and the demands of their vehicles with it. For example, countries that are predominantly covered in sandy terrain with urban settlements, might find wheeled vehicles as effective a purchase as tracked vehicles. This is because wheeled platforms can approach the mobility characteristics of tracked vehicles on sand, and will exceed them on roads. However, a European country would likely have to contend with wet soils that at times are very weak, which severely limits the off-road mobility of wheeled vehicles. It is therefore potentially more useful for the analysis of the role of 8x8 and 6x6 vehicles if a strict idea of peer warfare is abandoned, or expanded to simply mean warfare of a high intensity and high frequency, placing consistent and considerable demands upon an armoured vehicle.

The question of mobility is compounded by the roles that wheeled vehicles are required to perform. They are increasingly procured to operate as infantry fighting vehicles (IFV), which requires them to carry additional armour, infantry, and weaponry commensurate with that role. They are typically unable to carry as much armour as tracked alternatives because the size of the tyres cannot be increased to meet the additional weight. That said,



The BTR-4 is lighter than most western wheeled IFVs and has proven itself to be an effective fighting platform despite lacking the protection deemed necessary by most in Europe.



An important element of off-road mobility is the number of vehicle passes over a given piece of terrain. More passes will degrade soil strength and make travel more difficult for subsequent vehicles.



When the Stryker was selected for the US Army in the 1990s, it was expected to be air transported via C-130 to provide greater strategic mobility. However, it has often been found that in a C-130 compliant configuration the vehicles lack protection, and so must have armour removed before flight. To some, the supposed strategic benefits of 8×8s are therefore limited.

modern designs such as Piranha 5 and Boxer are designed to be fitted with extensive armour suites protecting them from 30 mm rounds across the frontal arc. This limits their mobility characteristics further, which can impact the utility of the vehicles in the IFV role, where they are required to move off-road to support the infantry in dismounted combat. The addition of a turret to carry medium calibre cannons is typical but limits the space for infantry in the rear of the vehicle. If off-road mobility is significantly impacted by the addition of equipment necessary to create an IFV capable of fighting in wet and weak soils, then it will not be able to function effectively. An IFV must fight onto an objective with the infantry it carries. Assuming that the formation is supported by artillery, the effects of a typical fire mission would last about 60 seconds, following which the vehicle has to get within 30 seconds of the objective to deploy its infantry with maximum impact. If it is stuck in mud and unable to close this gap, the infantry will be exposed and vulnerable, or require longer artillery bombardments closer to them as they attack - neither outcome is optimal. It could be argued that the extreme protection requirements are another Western reflection, however. The BTR-3, BTR-4, and BTR-80 vehicles used by Russia and Ukraine are only armoured to protect against 12.7 mm rounds across the frontal arc and armour piercing small arms from the side. Despite this, they have proven themselves to be very effective during the war in Ukraine, especially in their application of firepower using the 30 mm 2A72 and ZTM-1 cannons they carry as a main armament. There is evidence that these vehicles have encountered the limits of their mobility, with some images showing BTR-4s stuck in agricultural fields having left hardened roads, but their lethality and mobility in urban environments has featured prominently throughout the war. Therefore, perhaps there is a case to be made for lighter 8×8 and 6×6 vehicles, but with a greater acceptance of the risk that comes with reduced levels of armour.

Beyond protection, other factors can play a role. The use of large calibre guns can make wheeled vehicles more effective in a range of different situations, Japan for example has bet that the Type 16 mobile combat vehicle with its high pressure 105 mm gun is more appropriate than its tanks in certain situations. The US employed Stryker mobile gun systems (MGSs) with good effect in Iraq and Afghanistan, but found shortcomings with the weapon technology. South



When wheeled vehicles become stuck, they will often need tracked counterparts to recover them.

Africa's armed forces employed the Ratel 90 and Eland 90 extensively during the Angolan Bush War and were ultimately able to defeat some of the T-55 tanks that they faced. This is often held up as a good example of the capabilities of wheeled vehicles, but it is worth noting that 61 Mechanised Battalion Group, which fought those tanks, complained that their guns were not sufficient to face the T-55s and requested that a tank squadron be deployed. The fact is that modern large calibre weapons in 105 or 120 mm calibres can be fitted to wheeled vehicles and equipped with advanced ammunition natures that enable them to adequately face a large proportion of the most likely tank threats that they might encounter. However, doing so sacrifices armour, which is already limited for wheeled vehicles compared with tracked equivalents, and means that they cannot provide the level of protection that tanks do. This means that wheeled vehicles can perform well as large direct fire support platforms, and in some cases against the heaviest of armoured vehicles, but that they cannot absorb the level of fire that a tank can, which is arguably the tank's main benefit.

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The Piranha V is shown here in its IFV configuration for Romania. The turret and armour used to make the vehicle an IFV add significantly to its weight. However, it is ultimately the vehicle's use case and the way that it is employed that will shape how effective it is.

Ultimately, two factors must be considered: the role of the vehicle, and the terrain it is expected to fight over. The additional weight created by adding armour and weaponry to a wheeled vehicle to create an IFV might not be too detrimental for a vehicle fighting primarily in deserts, cities, and countries with extensive road networks or low levels of rain. Conversely, it is clearly possible for some

countries to operate the vehicles at a lower total weight with reduced protection. However, armies that expect to fight in countries primarily made up of wet soils, with high levels of rain, and limited road networks, would find wheeled vehicles' off-road mobility limited when compared with tracked alternatives, regardless of the gross vehicle weight. As the concept of 'peer warfare' cannot be solidly de-



The definition of peer competitors by and large defines the role that wheeled vehicles play in a high intensity war. This image shows an Egyptian BMR-600 deployed during Operation Desert Shield, where its 6×6 configuration would have made it sufficiently mobile for most of the tasks that it encountered.

fined, the role of 8×8s in peer warfare is therefore dependent upon the peers in question, and in large part the terrain that they expect to contest.

War is Hard and Complex

Perhaps the debate around wheels vs tracks – especially when peer warfare is the framing context – is polarising because war is so unforgiving. A force that structures its procurements primarily around wheeled vehicles and finds itself unable to move over the terrain it is defending will likely be punished very quickly – especially in combat with a peer opponent. It is worthwhile noting that whilst western forces have deployed mainly in counterinsurgency and peace support operations since 1991, for many other nations, the 77 years since the end of WW2 have been incredibly violent, requiring frequent stateon-state conflict and combat that has varied between insurgencies and very high intensity tank battles. For many, fighting has taken place over terrain that is conducive to wheeled armoured vehicles, providing that they are in the 6×6 or greater configuration. This suggests that on the balance of statistics, wheeled vehicles are perhaps more important in the entire spectrum of peer warfare than tracked vehicles. This, of course, is an oversimplification.

The reality is that once in combat, the users of wheeled and tracked vehicles will take them wherever they feel they need to. It is unlikely that anyone in the back of a British Boxer will be trying to calculate the individual wheel station load, drawbar pull and braking distance of their vehicle as they traverse Salisbury Plain. The vehicle will either pass the terrain they need it to, or become stuck. If it becomes stuck, it is most likely a tracked vehicle that will recover it. Perhaps then the most important aspect when considering the role of wheeled vehicles in peer warfare is the training that is provided to their users. Adequately informing them of the limits of their vehicles, from the driver to the officers leading operations and planning routes, will help them avoid committing to scenarios that the technology cannot match. This in turn requires armed forces to be honest about what their armoured forces can, and cannot achieve. What terrain they can fight over, and what terrain will be challenging. The utility of wheeled vehicles in peer warfare would then be decided by doctrine, and the ability of the doctrine writers to understand the limits and strength of those vehicles in the scenarios that they expect to face.

Main Ground Combat System (MGCS): A Status Report

Sidney E. Dean

In 2018, France and Germany agreed to jointly develop a successor to their respective main battle tanks (MBTs), the Leclerc and the Leopard 2. Representing next-generation technology, the weapon system – provisionally designated the 'Main Ground Combat System' (MGCS) – will constitute a quantum leap in both offensive and defensive capabilities.

he decision to develop MGCS reflects the fact that battlefield threats to even the heaviest main battle tanks (MBTs) are growing. This includes more sophisticated anti-tank weapons, long-range precision artillery, armed unmanned aerial vehicles (UAVs) s, loitering munitions with shaped charge warheads, and unarmed reconnaissance UAVs to aid over-the-horizon (OTH) weapons in targeting armoured formations. Conversely, improvements in vehicle armour and defensive systems threaten to erode the effectiveness of today's frontline MBTs against the MBT fielded by of peer- and near-peer opponents. Next-generation technologies need to be integrated into MBTs in order to continue to dominate the future battlefield. The current Leopard 2 and Leclerc tank families – while superb weapon systems - have reached the end of their growth potential, and need to be replaced by new designs.

A Multinational Programme

Following years of operational needs analysis and initial concept development, in June 2018 Berlin and Paris formally agreed to jointly pursue the MGCS programme, with the German government taking the political lead on the project. In October 2019, the two ministers of defence reconfirmed their nations' commitment to MGCS. The decision reflects a recent trend toward a multinational approach to major European armament programmes. This trend has been driven by economies of scale. Nextgeneration technologies require financial investments and a broad array of expertise and infrastructure which cannot always be mustered in one nation, which to date has put European industry at a significant disadvantage vis-a-vis the competition from the United States. With future vehicles and weapon systems expected to be fully networked, it also makes operational sense for



Notional MGCS family of combat and support vehicles.

allies who will deploy together to share the same technology.

To ensure harmony – and satisfy domestic lobbies – it was agreed that work would be apportioned evenly to industry from both nations. The obvious choice for prime industry partner was KNDS (KMW+Nexter Defence Systems), a holding company founded in 2015 by German arms producer Krauss-Maffei Wegmann (KMW) and the French defence firm Nexter Systems. The two firms are evenly represented on KNDS' board and in management, and bring undisputed expertise into the programme. KMW manufactures the Leopard 2 MBT, while Nexter produces the Leclerc. Going one step further, KNDS and Germany's Rheinmetall formed a MGCS-focussed joint venture (German: Arbeitsgemeinschaft or ARGE) in December 2019. The ARGE acts as the single contractual party in dealing with the government procurement authorities.

The ARGE's government counterparts are the procurement agencies of the French armed forces (Direction Générale de l'Armement – DGA) and of the Bundeswehr's BAAINBW (Bundesamt für Ausrüstung, Informationstechnik und Nutzung der Bundeswehr; ENG: Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support). The BAAINBW takes the lead as the programme's joint procurement authority acting in the name of both Germany and France. Within the agency, the BAAINBW's Combat Directorate is directly responsible for the MGCS



Image Shows the French Ministry of Defence's concept of MGCS.

programme. Since 2020, the directorate's branch K5.6 programme office is set up as the MGCS Combined Projects Team (CPT), staffed by personnel of both nations, under the direction of a German officer.

Timeline and Major Phases

Going forward, the MGCS programme is divided into three major phases:

- 1) TDP: Technology Demonstrator Phase (ongoing, 2020-2024);
- 2) FSDP: Full System Demonstrator Phase (planned for 2024-2028);
- 3) Implementation and Pre-Production Phase (2028-2035).

Initial fielding is expected in 2035, with full operational capability (FOC) by 2040.

Technology Demonstrator Phase (TDP)

The ongoing TDP consists of two activities running parallel to one another. Both initiatives are being conducted by binational industry teams formed by the ARGE members, under contracts awarded by the BAAINBw. Work is apportioned equally between the partner nations. In principle, these efforts remain open to participation by new industry partners from other NATO or EU nations.

The first element of the TDP is focussed on researching and evaluating key technologies and components for their suitability for MGCS. These include propulsion systems, passive and active protection systems, weapons (including future weapons technologies), sensors, and vetronics. Each of these technologies is being investigated separately at this time.

Simultaneously, other teams are pursuing a multi-part System Architecture Definition Study (SADS). As summarized by Nexter, SADS Part 1 (May 2020 – March 2022) assessed such aspects as: technical feasibility within the projected timeframe allotted for

the programme; ability to fulfil the operational needs of both armies; efficiency and compatibility with national networked command and control systems (SCORPION for France and Digitisation of Land-Based Operations (D-LBO) for Germany). The follow-on architecture studies are currently evaluating the operational utility of various comprehensive platform concepts using digital simulation scenarios of varying intensity. SADS is expected to wrap up in late-2023 and lead to a definitive proposal for the common multi-platform architecture.

Full System Demonstrator Phase (FSDP)

During the FSDP, the most promising system architecture concepts will inform the design and production of one or more full system demonstrators. These will integrate the individual technologies which were determined to be most promising during preceding studies, and evaluate their performance within the operational system. By the end of the FSDP, the complete MGCS design is intended to achieve technological maturity. In April 2022 KNDS co-director Frank Haun, formerly CEO of KMW, expressed support for opening the FSDP for new partners: "Once we complete the system architecture studies, we could add more partners," Haun told the magazine Wirtschaftswoche. He explicitly cited Italy, Norway, Poland and the United Kingdom as welcome additions to the programme. "All of them have technology to offer [...] to an army to be equipped, like Kongsberg from Norway or Leonardo from Italy," Haun said.

Implementation and Pre-Production Phase

The Implementation and Pre-Production Phase is expected to be open for participation by industry from other European nations. This phase will test operational prototypes and lead to low-rate initial production (LRIP), enabling the fielding of MGCS with the first operational units in 2035.

A System of Systems Design Approach

MGCS will not be a single vehicle, rather, it is conceived as a system of systems built around a manned heavy combat vehicle. This core MBT will be teamed and networked with external platforms featuring a variety of capability sets. The team is likely to include both manned and unmanned ground vehicles (UGVs) as well as unmanned aerial vehicles (UAVs). In addition to being a heavily armed combat vehicle, the MBT will thus serve as a "command centre" for the various peripheral systems.

This factor alone underscores MGCS' status as a revolutionary rather than evolutionary development in armoured warfare. For decades, the cumulative strength of MBTs has been defined by a triad of characteristics: firepower, protection and mobility. As Lt. Col. Sascha Uyanik, staff officer in the Land System Roadmap Group of the German MoD's planning directorate, has summarised, changing battlefield conditions require future MBTs to be defined by an expanded set of attributes which include: mobility, survivability, effectors, C4I, and SDRI+T (Surveillance, Detection, Recognition and Identification plus Targeting). This bundle of capabilities can no longer be accomplished by a single vehicle, nor could a single MBT carry all the requisite mission systems and weapons. Multiple platforms working in concert will be required in order to ensure the lethality and survivability of the team as a whole. The MBT's peripheral land and aerial platforms, equipped with specialised sensors and effectors, will assume a portion of the workload under direct or indirect control of the central vehicle.



Notional composition of a multi-vehicle MGCS team.

SDRI & Zielerfassung

- Unterschiedliche Sensoren
- 360° Lagebild
- Sensoren-Effektoren Netzwerk

Mögliches Konzept

Mobilität

- Hybridantrieb
- Leichtbauweise

C41

Graphic: German MoD

- Echtzeit-Lagebild
- Fortschrittliches Feuerleitsystem
- KI & Automatisierung

Effektoren

- Energiewirksysteme
- Bordkanone 120mm+
- LOS/NLOS Wirkmittel

Mehrplattformkonzept

- Eine Kommando/Steuerplattform
- X Effektorenplattformen
- Unterstützungsplattform

Überlebensfähigkeit

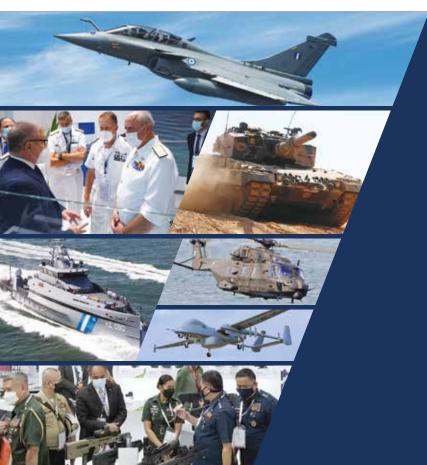
- Aktives Hard-Kill Schutzsystem
- Passive und reaktive Panzerung

Notional composition of a multi-vehicle MGCS team.

The Main Vehicle

The MGCS core vehicle will feature a hybrid propulsion system. In addition to being environmentally friendly during peacetime, this may have operational advantages including a reduced logistics chain, greater operational range between refuelling, lower acoustic and thermal signatures, and a 'silent watch' capability (allowing the vehicle to keep its main weapons and mission systems powered without assistance from the main engine).

Weight management will be another essential factor. Current MBTs have added weight with every new variant and every new component. This ultimately effects transportability, speed, and mobility, including the ability to cross bridges or ma-





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The 140 mm smoothbore ASCALON gun fires telescoped rounds 130 cm long, and is designed for scalable effects. Nexter is proposing the ASCALON as the MGCS main armament.

noeuvre in urban terrain. Higher weight also increases fuel consumption, adversely impacting range, and usually lead to higher wear of the drivetrain and running gear, resulting in lower reliability and requiring increased maintenance. Various measures to limit vehicle weight are being considered, including: reduced crew size by using a two-person turret or even an unmanned turret; use of lighter composite armour; and greater reliance on active versus passive protection - especially active protection systems (APSs), enabling the vehicle to potentially make do with less passive armour. In this context, Nexter is proposing the PROMETEUS (PROtection Multi Effets Terrestre Unifiée) APS it is jointly developing with the Thales Group.

Further concepts include the possibility that the main vehicle's hull could also be used as the basis for support vehicle variants. For example, the German MoD has published a (purely notional) graphic depicting three vehicles based on the same hull, but mounting different effectors: a manned command and control (C2) vehicle with the large-calibre main gun; a manned vehicle with a turretmounted launcher for guided hypersonic projectiles; and an unmanned support vehicle with a high energy laser, a counter-UAV (C-UAV) system, sensors and several on-board UAVs. The graphic indicates that an optionally manned capability for the main gun carrier and the hypersonic effector carrier could be added in the long term, however both France and Germany have underscored that deployment of heavy weapons will always require a 'human in the loop'.

Turret and Main Gun

The MBT will feature a large calibre main gun with significantly enhanced perfor-

Vetronics, Sensors and Automation

Digitisation, maximum application of artificial intelligence (AI) and automation. as well as the development of a secure tactical network will be essential in order to realise the new force concept. The Surveillance, Detection, Recognition and Identification plus Targeting (SDRI+T) mission will be served by a wide range of sensors using a broader band of the electromagnetic spectrum. These sensors will be fitted to the main vehicle as well as on the team's own UGVs/UAVs (to be carried and launched by support and combat vehicles). These sensors are intended to provide the MGCS with improved real-time situational awareness, thereby enhancing both survivability and lethality. Artificial intelligence and augmented reality will be required to reduce the human



KNDS introduced their first joint design, known as the 'Euro Main Battle Tank' (E-MBT) at Eurosatory 2018, informally dubbed 'Leoclerc' at the time.

mance compared to the 120 mm guns used on the Leclerc and Leopard 2.

Nexter is proposing the newly developed ASCALON (Autoloaded and SCALable Outperforming guN) as the MBT's main gun. The 140 mm ASCALON will accommodate a wide range of munitions and enable operators to choose among various desired terminal effects. Projectile range and penetration will be enhanced to defeat reactive armour and other defensive technologies. According to Nexter the gun will also accommodate future intelligent tank munitions capable of engaging targets at beyond-line-of-sight/non-line-ofsight (BLOS/NLOS) ranges. The firm predicts that the technical solutions on which ASCALON is based will be fully mature by 2025. KNDS' ARGE partner Rheinmetall for its part is advocating for its 130 mm Rh-130 L/52 autoloaded smoothbore gun, which also promises a significant improvement in rate of fire, range and penetration over current MBT artillery.

Additional Armament

At some point the MGCS team's arsenal is expected to include a directed energy weapon (DEW) and a hypersonic guided effector. The latter has been discussed as a potential anti-tank weapon for MGCS as early as 2019, with the hypersonic projectile envisioned as a means for overcoming reactive armour as well as APSs. Indirect fire weapons for combatting BLOS/NLOS targets are also likely, at least in the form of loitering munitions carried on vehiclemounted launchers. Other likely additions include a high energy laser (HEL), machine guns or automatic cannons for use in C-UAV and air defence roles, as well as against soft ground targets. An electronic warfare suite is also likely.

crew's workload, helping them focus on primary tasks and maximising their reaction time on the battlefield.

Networking/Data Cloud

Sensor fusion within and beyond the individual MGCS vehicle will be critical to establishing tactical battlefield dominance. Each MGCS team will not only be networked with its immediate component units, but also integrated across the battlefield through a data cloud. This will enable MGCS to access a wide variety of distributed off-board sensors to create a high level of situational awareness and obtain targeting data for BLOS/NLOS targets.

Alternate or Interim Solutions

History has shown that unforeseen technological challenges, as well as political considerations, can prevent major weapons development programmes from completing on schedule. This risk is particularly high when the development project is based on new technologies which were not fully mature when the project began. At best, such obstacles can delay completion of the development programme; at worst, a



At Eurosatory 2022, KNDS unveiled a significantly further developed joint design, this time dubbed the 'Enhanced Main Battle Tank' (EMBT). It could be marketable as early as 2025, and is considered a possible interim solution or alternative to MGCS.

programme can be terminated when it becomes obvious that a key enabling technology cannot be matured within an acceptable timeframe.

It remains imperative for France and Germany to begin replacing their current MBTs in the 2030s (the same holds true for many users of the Leopard 2). Should MGCS run into major delays, an interim solution will become necessary. Fortunately, KNDS and Rheinmetall have presented new concepts which could bridge the gap between retirement of legacy MBTs and the introduction of MGCS (or an alternative next-generation solution).



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Rheinmetall describes its KF51 as the first fully digitalised MBT, suitable for manned-unmanned teaming with other vehicles.

One is the Enhanced Main Battle Tank or EMBT. In 2018 KNDS presented an initial demonstrator consisting of a Leopard 2A7 MBT hull, engine and chassis mounting the Leclerc turret from Nexter. Based completely on mature technologies, EMBT is considered a short-term response to demand for a modern MBT, combining the mobility and robust features of the German tank with the lower weight of the French turret design. According to Nexter, the EMBT retains six tons of growth potential, leaving open the option of integrating future technologies in the medium term. During Eurosatory 2022, KNDS revealed a further-developed example of the EMBT concept, featuring a radically revised turret fitted with Rafael's Trophy APS, a combined commander's independent panoramic sight and remote weapon station (RWS), as well as an ARX30 RWS, which was primarily intended to provide the vehicle with an organic counter-UAV capability. The newer vehicle also featured space for a fourth crew member in the hull, known as the 'system operator', who would be responsible for operating the ARX30 RWS, the battle management system, and UAVs deployed by the vehicle. Also at Eurosatory 2022, Rheinmetall presented a competing solution dubbed the Panther KF51 (KF - Kettenfahrzeug; ENG: Tracked Vehicle). Although based heavily on Leopard 2, the KF51 incorporates numerous new elements which are expected to appear, in some form, on the MGCS as well. This includes a lighter two-person turret (with potential to use an unmanned turret instead), a larger calibre 130 mm autoloaded gun, providing a claimed 50% improvement in kill range, and a loiteringmunition launcher to engage NLOS targets. Rheinmetall stresses the KF51's fully digitised NATO General Vehicle Architecture (NGVA) and Battle Management System (BMS) optimised for networked opera-

tions, including manned-unmanned teaming with UAVs and UGVs, as well as cross-platform sensor-to-shooter datalinks. The firm presented the vehicle as a production-ready prototype rather than as a concept vehicle.

(Corporate) Politics at Play

Twenty foreign countries currently operate either Leopard 2 or Leclerc family tanks, with several more planning to purchase them. Both from a market standpoint and in the interest of interoperability among allies, it is inevitable that the future weapon system will be available for export. France and Germany agreed from the beginning that the MGCS programme would open up at some point to cooperation with additional EU and NATO nations and other security partners. Several countries have openly expressed interest in joining as development partners or observers, but so far none have been invited in. To what extent expansion of the programme can ultimately be implemented will depend on whether the parties can agree on the terms of the development programme. Factors to consider would include national preferences regarding system capabilities, re-apportionment of the development budget, representation of new partners in the government project office, priority receiving the operational system once production begins, and of course, apportionment of work to industry of the new partners. Satisfying all parties without compromising design integrity or production quality, and thereby avoiding a weapon system 'built by a committee', will be paramount.

As it stands, the programme already faces numerous challenges approaching the next phase. As enumerated by German Air Force Colonel Jürgen Schmidt, head of the BAA-INBw Combat Directorate, these include: a definition of contractor structures for

further research and technology activities, assignment of the overall System Demonstrator Phase to a single prime contractor, manoeuvring the very complex balance of strategic interests of the original partner nations, France and Germany, ensuring financing despite the tight budget situation, and meeting the very challenging timeline. [For the complete interview see ESD August 2022, p. 14]

As in previous multi-party arms development programmes, there is some tension between the current participating contractors. Industry observers note that negotiations regarding progression to the next phase of the programme are stagnating. A major stumbling block appears to be disagreement regarding which firm will act as consortium leader going forward. German press reports describe efforts by Rheinmetall to displace KMW in this role, while some French observers accuse Rheinmetall of aiming to derail the programme if the firm cannot gain control. KNDS has called upon the German and French governments to make a definitive decision regarding project leadership, insisting that "this signal must originate at the political level," according to a 21 November 2022 quote in the Frankfurter Allgemeine Zeitung. Already in April 2022, Frank Haun had advocated for "an end to committee proportional representation" in favour of a single firm as consortium leader. Any such decision will need to consider the companies' respective experience and track records in systems integration of various contractors' components. One thing is certain: if a decision is not made in a timely manner, the MGCS' timeline could slip. Depending on the length of the delay, this could risk significant consequences ranging from cost overruns to a potential capability gap if the initial operational capability (IOC) date is pushed too far to the right.

Medium-calibre Weapons: Back to the Future

Sherman Karpenko

Few would argue that medium-calibre cannons are an essential tool of modern warfare. These weapons ranging in bore diameter from 20 mm to 57 mm have been common to armoured fighting vehicles since the 1970s and provide vital fire support to infantry formations and anti-armour capabilities against their opponent's equivalents.

espite their long service history, many of these weapons have remained relatively unchanged with the exception of some improvements to ammunition since entering service. As a result, the Russian and Chinese armed forces still broadly rely upon the 30 mm 2A42 Shipunov cannon developed in the 1970s and its mechanically simpler descendent the 2A72, the UK's Scimitar and Warrior are armed with the 30 mm RARDEN designed in 1966, and the US M2 Bradley retains its capable 25 mm M242 Bushmaster, which was designed in 1976. With the occasional exception of the 40 mm cannons used by the CV9040 and the K21 from South Korea, and a few countries that operate 35 mm weapons, the 30 mm cannon has broadly dominated the medium-calibre market. Nevertheless, times are changing and larger calibres are being developed to meet the perceived need for greater lethality and more complex operational profiles.

The need to modernise many of these cannons has been acknowledged since the early 1990s as increasingly well-protected light vehicles entered service such as the Russian BMP-3. Initial developments took advantage of growth possibilities within existing ammunition natures, leading to the development of the M919 armour-piercing finstabilised discarding sabot (APFSDS) round for the 25 mm M242 Bushmaster cannon that arms the Bradley IFV. Advances in munitions and fire control systems have led to an expansion of the role of mediumcalibre cannons. Some are capable of firing air bursting munitions (ABM), which enable them to engage aerial targets and infantry in defilade. APFSDS rounds are fairly common, bringing significant lethality against lightly armoured vehicles over armour piercing discarding sabot (APDS) rounds that were prevalent following the Second World War and early-mid Cold



Pfc. James Ormsby, assigned to 2nd Squadron, 13th Cavalry, 3rd Armored Brigade Combat Team, 1st Armored Division, prepares to replace the barrel of a M242 Bushmaster 25 mm Chain Gun on an M2A3 Bradley Fighting Vehicle during gunnery training at the Doña Ana Range Complex, N.M..



This image shows the 25 mm ammunition fired by the M242. For most of the service lives of medium calibre weapons, lethality advances have been found through innovations in ammunition design.



The XM913 shown here is designed to enhance the lethality of the US Army's next generation IFV. It is chambered for the 50 mm 'Supershot' cartridge.

War. APFSDS technology for mediumcalibre weapons is particularly significant as the greater length to diameter ratio enabled by the fin stabilisation improves penetration of armoured targets. APDS rounds are spin stabilised, which means that they cannot exceed a certain length without becoming unstable. The 25×137 mm PMB090 APFSDS round, for example, was capable of penetrating 36 mm of rolled homogeneous armour equivalent (RHAe) set at an angle of 60 degrees from a range of 1 km - a 50% increase in penetration over the first generation of M791 APDS rounds developed for the M242. Generally however, the technologies that are currently being explored for the modernisation of the medium-calibre weapons arming armoured fighting vehicles are ironically based on technologies that are as old as the in-service weapons, or have been investigated extensively and discarded by some. There are three identifiable trends as far as the weapons themselves are concerned: Cased telescoped weapons have cornered a small section of the market; Larger calibre conventional weapons are favoured by the major players such as Russia and the US; And some are examining the suitability of dual calibre weapons such as the 50 mm 'Supershot'.

Supershot

The US Army is investigating the utility of Northrop Grumman's XM913 50 mm chain gun, a member of the venerable Bushmaster family. The weapon has two ammunition natures designed for it including the XM1204 High Explosive Airburst Tracer (HEAB-T) and XM1203 APFSDS-T. The XM913's ammunition is noticeably

much larger than the 25 mm rounds fired by the M242, and the barrel too is much larger providing, an effective range in excess of 3 km. However, not all is guite as it seems, the XM913 in fact leverages a cartridge known as 50 mm 'Supershot', which essentially takes the 35×228 mm cartridge used with the Bushmaster III, 'necks-up' the cartridge, widening the neck to make the overall round cylindrical rather than bottleshaped, and increasing the diameter of the projectile correspondingly, resulting in the 50×228 mm 'Supershot' cartridge. The technology has been presented as a new development at times, but the concept can be traced back to the Rh503 developed by Rheinmetall as a replacement armament for the Marder IFV in 1987. The Rh503 was chambered in 35 mm, but could fire a 50 mm round that had the same base diameter and length as the 35 mm round. All that was required to fire the larger round was a new barrel, however the recoil and feed systems for the 35 mm round needed to account for the larger forces and changes in the overall dimensions of the 50 mm round, thereby increasing design complexity.

In 1997 the then McDonnell Douglas formed a consortium with Boeing, Mauser, Alliant, and Oerlikon to promote the Bushmaster III and Rh503 35/50 cannons internationally. In essence, the XM913 which is designed to provide next-generation lethality for the US Army, is a peer of the Anglo-French Cased Telescoped 40 (CT40) weapon. They were developed at similar times to address similar needs, and have both not achieved the attention that they were expected to.

The 50 mm 'Supershot' concept is interesting and does provide an increase in lethality. The much larger projectile – especially when using ABM or high explosive (HE) ammunition natures - and increased range dramatically increase combat reach over the 35 mm alternative. However, because the cartridge size is not the same as a 'true' 50 mm weapon, the projectile travels much slower and carries less energy – thereby producing a less effective weapon when compared with a 'true' 50 mm weapon. Brasseys indicates that the muzzle energy of a 50 mm 'Supershot' is somewhere between a conventional 40 mm and 45 mm weapon. This is not to



Despite its apparent advantages, cased telescoped weapons have achieved limited acceptance amongst users.

say that a 50 mm 'Supershot' is an ineffective weapon; it is more lethal than the 35 mm cannon that it evolves from, and matches a conventional 40 mm round for muzzle velocity, at 1,600 m/s. However, it is important to place the Supershot 50 within the appropriate context. Like most of the cannons considered here, it is not an entirely new development, and there are some, such as the CT40, that seek to offer different capabilities in a smaller package.

The Revolution that Never Was

The idea of cased telescoped ammunition (CTA) has been around since the 1950s and was explored by the US Army and Air Force Combat Vehicle Armament Technology (COMVAT) and Advanced Gun Technology (AGT) efforts respectively, which ran as experimental programmes from 1973 through to the 1990s. The French also launched a CTA development that explored a 45 mm weapon, and the UK's Royal Ordnance examined a similar weapon at around the same time. Despite this, there are only two vehicles armed with CTA weapons - the French EBRC Jaguar and the UK's Ajax.

Cased telescoped weapons promised to revolutionise the world of medium-calibre weapons by reducing the size and weight of larger calibre weapon systems that were thought to be required to defeat evolving threats such as the BMP-3. Weapons in this category employ a tubular ammunition case that surrounds the projectile with the propellant giving the ammunition the appearance of a cylindrical drinks can, as opposed to a bottle shaped round with the projectile protruding from the neck of a cartridge. This ammunition enables a unique type of breech and ammunition handling system. The breech is typically fixed in place, allowing the chamber to rotate, bringing a round to the breech to fire, during which the previous round's casing is ejected by the incoming fresh round.. This reduces the working parts of the system and facilitates a rate of fire of 200 rds/ min in the CT40, although GIAT's 45 mm M911 cannon could achieve 400 rds/min, due to rotating the breech through a smaller angle.

A number of arguments have been advanced in favour of CTA, such as the reduced volume required to store the ammunition compared to conventional bottle-shaped ammunition of the same calibre. For example, in the 1990s, an M2 Bradley and Warrior were reported to be respectively capable of carrying 195 and 70 rounds of CTA, as opposed to 160 and 60 rounds of conventional 40 mm ammunition. The reductions possible in am-

munition length in turn have precipitated advances in breech design, which mean that a 40 mm cased telescoped weapon would only take up as much space in a turret as a 25 mm cannon, whereas a conventional 40 mm cannon requires significantly more. This enables the cannon to be elevated to very high angles, which is of undoubted value in battlefields dominated by small UAVs and urban environments.

At the same time, armour piercing lethality is retained, despite a reduction in the overall size of the round. A CT40 weapon tested by the US in 2000 fired a 250 g tungsten





This image shows the suite of CT40 ammunition demonstrating the encasing of the projectile compared with conventional natures to the left and rear.

monobloc APFSDS penetrator (note: this weight does not include the sabot) with a pull sabot at a muzzle velocity of 1,600 m/s. The velocity decayed at a rate of 120 m/s/km. These figures suggest a muzzle energy of 0.32 MJ, close to three times that of the Russian 30 mm 2A42 cannon, and approximately equal to a 40 mm Mk 1 round fired from the BAE Systems 40 mm L/70B cannon. The round is reportedly capable of penetrating 140 mm of RHAe at 1,500 m, making it competitive with conventional munitions of the same calibre.

The cartridge design allows preformed and consolidated propellant to be used, which can be designed to fit around the projectile and lead to optimal propellant mixtures and quantities, which in turn impacts the muzzle velocity and accuracy of the ammunition, which are both critical characteristics for advanced natures such as APFSDS and ABM. The ammunition handling system (AHS) means that natures can be mixed within a single burst – for instance if dealing with infantry in a building or behind cover, a point detonating (PD) round could be used to knock a hole



The 2538 Derivatsiya-PVO carries a derivative of the AU-220M turret, armed with a 2A91 57 mm cannon. It is designed for short-range tactical air defence although it could also provide direct fire in support of ground formations.

through a wall, and be followed by two ABM through the same hole.

Regardless of the benefits, it is apparent that CTA weapons have failed to revolutionise the medium-calibre market. Working designs have existed since the 1950s and yet the uptake is limited to the UK and France. A CTA weapon is being explored by South Korea as the future main armament of an IFV to replace the K21. It also seems that a weapon was under development in Japan in the 2000s, although it is not clear whether the system ever progressed beyond this phase. Russia's TsNIITochMash signalled in 2019 that it was reviving work conducted in 2010 to develop a 45 mm CTA weapon, which was expected to compete with TsNII Burevestnik's 57 mm 2A91.

S-60: Old Dog, New Tricks

The AU-220M Baikal turret promises to generate a wealth of survivability challenges for NATO states. It is armed with a fearsome 2A91 57 mm cannon against which there are few good survivability options. The 2A91 cannon is itself a modernised derivative of the legacy S-60 air defence cannon chambered in 57×347SR. The cannon is sometimes also referred to as the AZP-57, it is a rifled cannon loaded by four-round clips. The S-60 entered service in 1950 on the AZP S-60 towed anti-aircraft (AA) gun to provide the Soviet armed forces with a replacement for its legacy 37 mm air defence cannons. It served at the divisional level in batteries of batteries of six, with assistance from radar-based fire control systems. By around 1955, the weapon also entered service on the ZSU-57-2 selfpropelled anti-aircraft gun (SPAAG). The weapon was eventually superseded by guided missiles and more effective means of countering air power. However, it remained in the arsenals of many countries and has found a variety of new uses.

Aside from the Russians, other have also experimented with 57 mm armaments. In the 1970s the Bofors 57 mm cannon, chambered in 57×438R, was considered as a possible main armament for the prospective Begleitpanzer 57 fire support vehicle, but this vehicle was ultimately not adopted. Elsewhere, in the 1990s Ukraine's industry mounted an S-60 externally onto a BTR-80, however this too failed to enter service. Since the Syrian Civil War the S-60 has been mounted onto tank and truck chassis to provide direct fire against vehicle-borne IEDs and other targets. More recently the S-60 has been observed mounted onto the load beds of trucks in Ukraine to provide direct fire support.

The S-60 was capable of attaining a rate of fire of 120 rds/min, although the practi-

cal rate of fire is typically given as 70 rds/ min. It was originally developed to fire amongst others - the UBR-281 armourpiercing high-explosive (APHE) projectile, weighing 2.82 kg. At a range of 1,000 m, this round could penetrate 96 mm of rolled homogeneous armour making it a potent anti-armour weapon. Images from the Parola Tank Museum in Finland indicate that it is capable of penetrating the turret of a T-55 from certain angles. Its large projectiles including the UFB-281 high explosive fragmentation (HE-FRAG) round also weighing 2.8 kg, were thought to be capable of downing a jet aircraft with a single shot at the time they were introduced.

The 57 mm cannon has found additional applications in its modified form, the 2A91, which is fitted to the AU-220M Baikal remote weapon station developed by Russia's TsNII Burevestnik, a subsidiary of UralVagonZavod (UVZ) as a possible main armament for Russian IFVs. A modified version of the AU-220M with greater elevation was developed for the 2S38 Derivatsiya-PVO short-range air defence system, which entered state trials in 2018. The first reference to the AU-220M appears to come from 2005, when it was reported that the system had been developed to up-arm the PT-76. At the time it was operated by two personnel and armed with a modernised form of the S-60's main armament including a muzzle brake to reduce the recoil imparted to the vehicle. By 2015 UVZ presented a model of the AU-220M in Abu Dhabi, it was remotely operated by this stage and reportedly fitted with armour, protecting it from 30 mm rounds across the frontal arc. Development continued and in 2019 TASS reported that work was underway to investigate the feasibility of installing the AU-220M onto the entire Russian IFV fleet. If this were to be accomplished, it would extend the reach of Russian armoured vehicles considerably. The 57 mm cannon is theoretically capable of a range of 12 km, although it is realistically designed for engagements at 4 km. This is nonetheless close to double the range of the 30 mm 2A42 cannon used by most Russian IFVs at present. It fires at a rate of 80 rds/min, but would likely be constrained by its limited magazine - also 80 rounds. In 2019 it was demonstrated firing on the move whilst mounted on a BMP-3, indicating that it could greatly increase the lethality of that platform. Furthermore, the greater lethality of

increase the lethality of that platform. Furthermore, the greater lethality of the ammunition would be a considerable boost. It is theoretically possible to armour vehicles such as Puma, Boxer,



Ukrainian army soldiers reattach the barrel of their 2A42 30 mm cannon aboard their BMP-2 before they move onto a gunnery range at the International Peacekeeping and Security Center, near Yavoriv, Ukraine, on February 2017.

and Piranha 5 against 30 mm ammunition from the front, with some capable of carrying that armour on the vehicle sides, too. However, even the legacy 57 mm ammunition for the S-60 leaves the barrel with a muzzle energy of around 1.4 MJ (a 30 mm round is considerably lower at 0.139 MJ for the armour piercing round of the 2A42), although this energy is dispersed over a relatively wide area and would not be as effective at armour penetration as an APFSDS type, it still represents a significant challenge for armoured vehicles up to main battle tanks (MBTs). Then in 2021, imagery surfaced showing an APFSDS ammunition nature for the 2A91, which would massively extend its reach and lethality compared to

older natures. Although the capabilities of the new 57 mm APFSDS round are unconfirmed, a Russian study from 2017 examined the possibility of creating an APFSDS round for the 57 mm cannon. The study's authors suggested that such a round would be capable of penetrating more than 300 mm of RHAe, which massively overmatches the protection of nearly any armoured fighting vehicle, barring the frontal arc of an MBT.

The capabilities of the 57 mm cannon are clear, the primary question is whether or not Russia will be able to bring the system into service. The level of recoil generated indicates that an advanced fire control computer would be necessary to make the system effective. Recent events have shown



The BMP-3 drove much of NATO's search for larger-calibre weapons.



This top down image shows the Northrop Grumman XM813 fitted to a US Army Stryker Dragoon. The 30 mm cannon has been retrofitted to increase lethality of the Stryker fleet.

that Russia is more reliant upon Western microprocessors than originally thought for its more advanced military computers. It follows that if access to these components is effectively restricted (it is worth noting that this is likely a very difficult task) then Russia may not be able to develop and produce the fire control systems necessary to make the 2A91 effective. The effect of Western sanctions should not be overstated, Russia has long experience of avoiding sanctions to acquire dual use goods, but it stands to reason that weapons such as cruise missiles will take priority when competing for potentially limited resources over fire control systems for IFVs.

Casing the PLA

The PLA employs what is widely believed to be a copy of Russia's 2A72 30 mm cannon. The weapon arms the PLA's ZBD-04 and ZBD-03 tracked IFVs, as well as the ZBL-09 wheeled IFV. There is no immediate sign that this weapon is considered insufficient by the PLA, although this may be a result of the organisation's secretive approach to weapon development. However, in 2020 a video was released by a state-endorsed news channel showing a 40 mm cased telescoped weapon carried in a remotely operated turret. It may have

been a further development of an earlier system presented by NORINCO in 2016, which was reportedly capable of firing CS/BAA3 APFSDS ammunition that could penetrate 130 mm of RHAe at 1,000 m and the CS/BTE3 high explosive round, at a maximum cyclic rate of fire of 200 rds/ min. The weapon enabled an elevation of 87 degrees, demonstrating the high elevation range characteristic often associated with cased telescoped weapons. A similar weapon has since been fitted to the CS/VP-16B, a 6×6 all-terrain buggy in service with the PLA, but it is not clear whether it has entered service officially. Strictly speaking, the requirement for a larger calibre weapon to arm its IFVs may not be a driving force at present. The country's two primary land opponents are unlikely to enter vehicles into service that outstrip the lethality of their 30 mm 2A42 clone within the next decade.

"Nope, already been there."

The 1990 film Back to the Future Part III ends with the line, "nope, already been there," when Doc is asked if he will be returning to the future. It seems that medium-calibre lethality is set to return to the state that prevailed during the Cold War. In part, it stands to reason that this is a result of the end of the

Soviet Union - most of the articles discussing medium-calibre developments reference the venerable BMP-3 and its frontal armour designed to stop medium-calibre rounds as the primary threat driver. As the Soviet Union ceased to pose a threat, the need for larger calibres became less pressing. There are multiple combat accounts from Iraq, Chechnya, Afghanistan, and Ukraine to show that the extant calibres are certainly very effective. Others indicate that there was even a trend away from the armour piercing ammunition natures, with a greater focus on frangible and training rounds for their reduced likelihood of causing collateral damage in peace support operations.

Gradually the reduction in the size of armed forces has combined with technological changes in the character of warfare to place greater demands upon AFVs. It is now reasonable to expect an IFV to have some form of counter-UAV capability, even if a kinetic kill is likely less effective than electronic attack when smaller drones such as the DJI Mavic are concerned. There is also a well-understood value in the use of ABM against infantry in pretty much any environment. However, is it reasonable to assume that Russia's horrific acts in Ukraine will drive new developments? It is clear that NATO as a whole is gripped with the need to rebuild land forces and return to a policy of deterrence by denial. However, Russia's fleet of IFVs continues to be based around the BMP-3, BMP-2, and to a lesser extent the BMD-4M. These vehicles are arguably already overmatched by the ammunition available to 35 mm and even 30 mm cannons in service with NATO. Furthermore, with the exception of the MBT-based T-15, Russia's IFVs do not tend to place great emphasis on heavy levels of passive protection, that is a characteristic driven mostly by NATO vehicles

Added to this are the physical limits of medium-weight vehicles. In theory it is possible to armour them against 30 mm and 40 mm weapons, however in practice doing so would mean these vehicles would approach the weight and cost of a tank – especially if protected from all angles – and this may in turn reduce their utility as IFVs. So, whilst the need for a larger calibre weapon has been stated by the US, UK, France, and Russia, it does not necessarily follow that the entire medium-calibre user group will soon be swapping their 30 mm cannons for the CT40, XM913 or 2A91 despite the apparent advantages of those weapons. For many, the weapons they already have are likely sufficient. It is, however, reasonable to assume that if Russia were to adopt the 2A91 on a large scale, that this would in turn drive similar moves across NATO.

Modern Turret Design

Tamir Eshel

The war in Ukraine reignited debates about the role Armoured Fighting Vehicles (AFVs) have today and tomorrow. The advantages and vulnerabilities of armoured vehicles were demonstrated in this conflict, and armies are expected to embrace the lessons learned from the conflict and implement Technologies, Techniques, and Procedures (TTP) demonstrated as superior. The Eurosatory and AUSA exhibitions of 2022 offered combat vehicle designers an opportunity to showcase trends for the future. Among the elements that best demonstrate these new trends are the turrets featured in this article.

Why Turrets?

The first tanks introduced during World War I employed a tracked system to traverse heavy weapons across the rough terrain, crossing the no man's land that separated the combatting armies. Like naval gunships or moving fortresses, the first tanks mounted several machine guns and one or two guns pointing forward or sideways covering the vehicle's surroundings. They were served by a large crew of 8-17 men cramped inside the armoured box to operate those weapons.

For almost two years, these steel beasts evolved into more effective combat vehicles that made their mark on the war. After the war, as tanks evolved into more practical and efficient machines, the gun was elevated from either the hull or sponsons on the sides, to a turret above the hull roof. This position gave the crew better vision through periscopes which provided situational awareness for the crew under the armour protection. The turret's mantlet protected the gun mount, elevation, and traverse mechanisms, enabling the crew to engage targets through 360°. To serve the weapon, turrets were typically designed to accommodate at least three people, a commander, a gunner, and a loader. The driver and a fifth crew member were seated in

As combat vehicles evolved through the two world wars and countless conflicts fought over the 20th century, the design of tanks did not change much. Modern tanks carry larger weapons, some use modern composite armour using ceramics or other materials to provide greater protection than rolled homogeneous armour (RHA) steel. Still, the principles are broadly the same – a moving tracked armoured box powered by an internal



A complex array of sensors and weapons was shown on the EMBT, developed by KNDS.

combustion engine, mounting a large gun in a turret.

Over the past century, combat vehicles balanced mobility, protection, and firepower, considered the classic armour 'triangle.' Each design strikes a different balance of the three - a vehicle with superior mobility will often be lightweight and, thus, less protected. A highly protected platform will be very heavy and degrade mobility in cross country, over bridges, or airlift. A big gun that maximizes firepower would require a heavy and less manoeuvrable platform. Therefore, each design seeks a balance that best meets the user's requirements. Modern designs have added new attributes such as 'connectivity,' 'autonomy,' or 'supportability,' transforming the legacy triangle into a pentagon or hexagon.

Modern turrets are driving this transformation by introducing sensor-based situational awareness and automation of fire control, paving the way for full autonomy with optionally manned and unmanned combat vehicles.

Manned or Unmanned?

Tank turrets reflect army traditions. The turret of main battle tanks (MBTs) always mounts a heavy gun. This manned enclosure requires a high level of protection and a separate ammunition compartment to ensure safety for the crew. An unmanned turret could employ a lower level of protection but requires a complex and heavy automatic loading mechanism for the ammunition. They sometimes also lack

the redundancy mechanisms present in manned designs, which enable the vehicle to keep operating in in the event of some component failures. However, the debate on manned or automatic loading appears to have been settled, as the ammunition used with the big guns of tomorrow will be too heavy for manual operation and require an automated loading system in both configurations.

Some designers are already shifting towards unmanned turrets even with existing 120 mm/125 mm guns. The Russian T-14 Armata and General Dynamics Land Systems (GDLS') AbramsX technology demonstrator are examples of this trend. By contrast, the Franco-German Enhanced Main Battle Tank (EMBT) developed by KNDS and Rheinmetall's KF51 Panther MBT follow a more traditional layout, having two crew members in the turret plus two in the hull.

A vital capability enabled by the modern turret is the Hunter-Killer functionality, achieved by connecting the gunner sights to a separate, panoramic sight operated by the commander. This configuration enables the commander to search for targets and cue targets for the gunner to engage. When several weapon systems are mounted on board, the crew can opt to employ Killer-Killer procedures, theoretically enabling any crew member to operate a remotely controlled weapon station or missile system using their workstation. This capability is enabled using the 'glass cockpit' design. Having several displays stacked on each workstation may pose difficulties for

integration in existing vehicles. However, it is being used in newer vehicle designs, such as the Optionally Manned Fighting Vehicle (OMFV), KF51, T-14 Armata, AbramsX, and the latest versions of Israel's Merkava that embrace some of the technologies developed during the Carmel technology demonstration program.

The concepts demonstrated through the Carmel programme have shown how automation can take over or 'virtualise' many tasks required of the crew members. The concept could employ a 'virtual driver' that follows the commander's orders by automatically driving the vehicle by regular voice commands. A virtual system operator can handle drones, and a virtual gunner could aim the gun for firing upon the commander's order. A virtual commander can supervise all autonomous operations, advising the local or remote crew and following their directions, thus enabling a two-man crew to perform as four. These virtual entities enable a small crew to perform multiple complex tasks with efficiently, on either manned platforms or remotely controlled unmanned ground vehicles (UGVs).

Many armies still follow the manned turret design in their latest combat vehicles. These include the UK with the Ajax and the France Army with the T40 on Jaguar, Australia opted for manned turrets on their Boxer reconnaissance vehicle, and their new Land 400-Phase 3 tracked Infantry Fighting Vehicles (IFV) programme. Italy uses manned turrets on its newest VBM Freccia IFVs, and the Dutch are modernizing their CV9030NL with a more advanced

manned turret. These manned configurations balance the past, present, and future. The crew is seated in a position providing maximum visibility and control of their surroundings. At the same time, turret automation enables more display space, enabling the crew members to perform their tasks by interacting with sensors, battle management systems (BMSs), and weapons over large, interactive digital displays. They may also opt to use more immersive displays, such as Elbit Systems' 'IronVision' or Rheinmetall's Situational Awareness System (SAS), providing the crew the ability to 'see through armour' without the need to open the hatches. Such immersive systems are suited for crewmembers seated in turrets, as they often require more intuitive sensing to 'feel' a remotely operated weapon's line of sight.

Unmanned turrets employ automation to separate the person from the weapons. It uses a turret which can often be mounted on top of the hull without requiring hull-penetration, negating the need for a turret ring or a rotating turret basket. For vehicle designers and users, the main benefit of such a configuration is an increase to the available internal volume in the fighting compartment. This can provide benefits such as accommodating a fully-equipped squad inside the vehicle, as well as safer or more comfortable crew seating, improving a force's capabilities and quality of life.

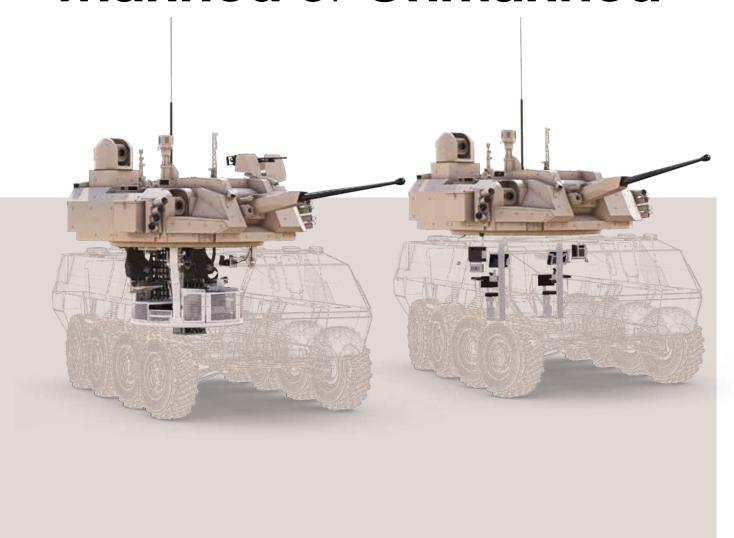
However, removing the crew members from the turret poses a 'cultural change' for armies. Germany and Brazil were among the early adopters of the concept. Germany was among the first to integrate such a highly sophisticated and complex remote turret on the Puma IFV developed by the Projekt System Management GmbH (PSM) consortium of Krauss Maffei Wegman (KMW) and Rheinmetall Land Systems. However, this vehicle has proven problematic and has been suffering teething problems since its introduction in 2018. Brazil opted to install Elbit Systems' UT30 turret on the IFV configuration of its VBTP-MR Guarani 6×6, an integration which has so far proved to be smooth.

Germany and Brazil were followed by Singapore, Lithuania, Israel, Spain, Poland, Romania, and the US Army, among the armies embracing the changes by introducing new unmanned designs. Singapore was the first to employ Rafael's Samson turret on the Hunter AFV, and Lithuania also selected a version of this unmanned turret for its Boxer APCs. The Israeli army opted to develop its design for the Namer tracked and Eitan wheeled APCs. Spain also selected the Guardian-30, an unmanned turret developed by the Spanish company Escribano



A modern crew workstation comprises multiple screens and augmented reality to provide multi-layered situational awareness combined with onboard sensor data and information from vehicles and the BMS.

Manned or Unmanned



Anything else is just an armored TAXI

The 3000 series John Cockerill turret is undoubtedly the best choice that the Bulgarian Land Forces can make. With Modularity ensuring it's combat capabilities into the decades ahead and an unprecedented Industrial plan that provides real opportunity for real growth and export potential.



for the IFV configuration of its new VCR Dragón 8x8, while Poland is fielding the ZSSW-30 unmanned turret developed by HSW as a successor to the OTO Melara Hitfist-30P turret currently used on the Rosomak. The ZSSW-30 will also equip the Poland's new locally-developed Borsuk tracked IFV. The Polish MoD also considers this turret a lower-cost alternative to the manned turret used on the Redback IFV being considered by Australia for the Land 400 phase 3 project.

Turret-Mounted Protection Systems

Passive armour protection represents only one of many layers of the 'survivability onion' model of an armoured vehicle. The turret substantially adds to the overall vehicle's weight. Therefore, removing the crew allows for reducing the turret's size, which in turn requires less or lighter passive protection, contributing to overall weight reduction. Among the survivability aspects related to the turret are its shape and composition. Using cast armour with additional armour plates welded to the outside or making the entire turret out of steel plates are two different approaches. The welded, trapezoidal shape is typical in modern Western designs, while the rounded cast turret was typical of western designs until the 1970s, and most Soviet T-series tanks until the T-90 and T-14.

While the cast turret is cheaper to produce and results in a lower weight overall, adapting add-on armour to the



The EMBT turret was fitted with the Trophy hard-kill APS to improve survivability without adding too much weight.

rounded shape requires complex structural elements of add-on armour that can often leave vulnerable areas around it. The welded turret has a heavier baseline weight, but typically uses hardened steel plates, which add around 10% hardness and offers easier integration of additional passive and reactive protective layers. Introducing active protection systems (APSs) adds significant protection to both types, mainly against shaped charges, thus enabling designers to optimise the passive armour against kinetic threats.

Traditionally, the tank has the heaviest armour up front to protect from threats coming head-on. However, due to the character of modern warfare, tanks have become more likely to be engaged from all directions, including from above or below. Since using heavy armour to protect all directions is not feasible, APSs are increasingly seen as a necessary part of the vehicle's protection package. These using active effectors to intercept, destroy or divert the threat before impact. Current APSs, such as Rafael Advanced Defense Systems' Trophy, protects against shaped charge warheads. Elbit Systems' Iron Fist and Rheinmetall's Strikeshield also add some protection against kinetic energy (KE) projectiles. However, neither can intercept threats coming from above or below the tank. Recent wars have demonstrated that these are the most vulnerable attack vectors threatening tanks and AFVs.

Presently, protection against top attack remains in the realm of 'Soft kill' APSs, which use aerosol or smoke screens to deny the threat's sensors from acquiring the target, rather than defeating the threat on a direct engagement. Such countermeasures are typically emplaced on the sides or the top of the turret, enabling protection against multiple attacks. Rheinmetall's Representative topattack countermeasures are the ROSY obscurant smoke salvos or the Russian 3VD35 aerosol developed by the Central Scientific Research Institute of Precision Engineering (TsNIITochMash) for use by the Russian Armata T-14 MBT and T-15 heavy IFV (HIFV).



Elbit Systems mounted its Sabrah 105 mm gun turret on the ASCOD 2 tracked vehicle for the Philippines.

The radar and optical sensors used by APSs also play an essential role in establishing situational awareness for the crew and the combat formation. These sensors, constantly staring around the vehicle, searching for threats, offer an unprecedented level of situational awareness that enhance more typical early warning systems on board, such as laser warning receivers (LWRs) and acoustic shot detection systems devices.

The Evolution of Firepower

The tank gun enables armoured formations to engage all types of targets encountered in their direct line of sight - tanks and armoured vehicles, anti-tank guided missile (ATGM) teams, attack helicopters, structures, and fortifications. In the 1960s, the 105 mm rifled gun became the standard gun for Western tanks, but most of these were replaced by the 120 mm smoothbore gun around the end of the last century. This gun provided much higher performance, primarily with kinetic energy (KE) projectiles. Despite this shift, the 105 mm rifled gun is still used and has recently been selected for new production series, including General Dynamics Land Systems' (GDLS)



The AbramsX provides the US Army with a range of capabilities that could be integrated into the next modernization cycle of the M1A2 tank or its future replacement, the Decisive Lethality Platform (DLP) expected sometime in the 2040s.

Griffin II, which was chosen for the US Army's Mobile Protected Firepower (MPF) and GDLS/Elbit Systems' ASCOD 2 Sabrah light tanks recently delivered to the Philip-

pines. In both cases the 105 mm rifled gun offers weight saving compared to a larger gun, and adequate firepower for the role. Towards the new millennium, advance-







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ments in electronics, optronics, and automation shaped the modern main battle tank, equipped with high pressure 120/125 mm gun firing KE or high explosive anti-tank (HEAT) rounds that could penetrate almost all types of enemy tank armour. The main difference from earlier generations is the introduction of automatic loading and ammunition handling, enabling the reduction or total elimination of humans from the turret. Most Western armies use manually-loaded 120 mm guns on their tanks, a notable exception being the CIO Centauro II fire support vehicle used by the Italian Army. The vehicle is armed with the 120/45 gun, which is provided with an autoloader installed in the Leonardo Hitfact MkII turret. Today, the Rh120 L55 series represent the West's premier in-service 120 mm highpressure guns, which first saw service with Germany's Leopard 2A6 MBT. The improved L55A1 model has been selected to replace the Challenger 2's legacy 120 mm rifled gun as part of the Challenger 3 (CR3) upgrade, which is due to start entering service around 2027. Having said this, 120 mm gun development continues, as shown recently with the AbramsX demonstrator armed with the new XM360 gun. This model features a higher impulse and chamber pressure, as well as a shorter recoil stroke, and lower felt recoil thanks the addition of a pepperpot muzzle brake.

By the mid-2020s, larger-calibre guns are due to have matured. They are presently being tested for use with the MBTs of the 2030s, with the 130 mm L52 gun developed by Rheinmetall, the ASCALON 140 mm gun designed in France for the future Franco-German Main Ground Combat System (MGCS), and the 2A83 152 mm gun developed in Russia for Object 195. Al-



The Medium-Calibre Weapon System (MCWS) unmanned turret was developed by Rafael based on the Samson design. It was adapted specifically for Stryker.

though Russia's 152 mm gun was dropped in favour of the 2A82-1M 125 mm gun on T-14, the larger 2A83 may yet resurface in a future design.

All designs strive to field projectiles that will overmatch the most potent enemy armour from a longer distance. For guns in excess of 120 mm, specialised systems are required to handle the ammunition and load the gun to serve big guns, as the cartridges are too heavy for manual handling. Thus, the position of loader became redundant, thus the fourth crew member can either be eliminated or moved to the hull to operate other mission systems such as drones. Unmanned tank turrets

are beginning to appear in MBTs such as the Russian T-14 and American AbramsX, which is still a technology demonstrator. The Franco-German EMBT demonstrator has a two-person turret with two crew in the hull, the fourth of which is the 'systems operator'. Similarly, three crew members are the default manning requirement for the Rheinmetall's KF-51, but a fourth can be optionally added in the hull. They are provided with digital displays for operating the weapons and mission systems. The KF51's turret is equipped with a total of 20 ready rounds in two magazines, with fully automatic loading and unloading of ammunition. The system can operate in various degraded modes and use manual override in an emergency.

Electrical drives have long replaced hydraulically-actuated turret traverse and gun-laying systems in MBTs, and advancements in electric propulsion and power generation on board further increase such systems' performance, speed, and response time. Nevertheless, self-propelled artillery systems considered less vulnerable to enemy fire still employ these hydraulic systems.

For the big guns, designers want to place the gun as low as possible, both to more easily enable the tank crew to employ hull-down firing positions in defilade, but also seek to reduce the overall vehicle silhouette, to minimise exposure in the firing position. Modern Western tank turrets tend to use external ammunition stowage placed in the bustle (the back of the turret). This is connected to the turret by a blast door and has blow-out panels designed to



Elbit Systems has developed this turret mounting the new XM913 50 mm automatic cannon for US Army testing under the OMFV program.

vent an explosion to the outside in case the ammunition stowage is compromised. Without this separation of ammunition from the crew compartment, penetration leading to ammunition cookoff can cause the explosion to vent into the fighting compartment, causing a catastrophic kill. This was relatively common problem with Russian tank designs until the introduction of T-14 Armata, which fully isolated the crew from the ammunition.

Smaller turrets with autocannons are more versatile in design. Lighter vehicles are typically equipped with 30 mm automatic cannons, and for many this was an upgrade from the 20 mm and 25 mm cannons fielded with the IFVs of the 1980s. Such automatic cannons include the Rheinmetall Mauser MK 30-2 and Northrop Grumman with the MK44 Chain gun and its XM813 derivative. The MK-30-2/ABM has been used as the main armament of the new German Puma IFV and the Australian Boxer Combat Reconnaissance Vehicle (CRV).

With its distinctive muzzle-mounted ammunition programmer, the weapon is capable of using air-burst munitions, maximising lethality against soft targets such as infantry and drones. Rheinmetall also offers the Skyranger 30 turret, which supports very high elevation (85°) and a rapid traverse rate, intended for the mobile very short range air defence (VSHORAD) role.

The dual-feed XM813 automatic cannon uses the same ammunition as the MK-30-2 but also uses a different explosive airburst munition developed by Northrop Grumman. This munition uses a time-based fuse, which is programmed during firing to trigger the explosive fragmenting charge at a preset time that corresponds with the target range and the travel time of the round. These munitions are particularly effective against drones and personnel in the open.

From its inception, this weapon was offered with 'up gunning' option, enabling turrets to up gun the main armament from 30 mm to 40 mm 'Super Forty' or to 50 mm 'Supershot' with relatively minor changes. While the 40 mm 'Super Forty' offer was not a big success, the XM913 cannon, chambered for 50 mm 'Supershot' ammunition has been selected as the future IFV weapon for the US Army due to its high lethality and extended range. A turret incorporating this weapon was recently developed by Elbit Systems, demonstrating the integration of the XM913 and many of the company's systems. Elbit Systems has teamed with BAE Systems to compete in the US Army's OMFV program. The two companies have successfully cooperated in integrating the Iron Fist APS for the new generation turrets produced for the



Remotely operated weapons enable interesting syntheses of weapons and systems, such as this Mobile Anti Low-Slow-Small Unmanned Aircraft Integrated Defeat Systems - MLIDS Stryker from Leonardo, mounting a 30 mm cannon, 12.7 mm machine gun, and four Coyote II counter-UAV munitions on the RWIP turret platform. This complex system is operated by three crew members

Dutch CV9035NLs and Czech CV90 MkIVs. This turret will soon begin firing trials and is proposed by one of the teams competing for the future OMFV. Another team, including Rheinmetall America, Raytheon Technologies, Textron Systems, and Allison Transmission, is proposing a derivative of the German KF41 Lynx with a turret mounting the same XM913.

Beyond their primary armament, most turrets will typically employ several additional weapons. These include remotely operated weapon stations mounting 5.56 mm, 7.62 mm, 12.7 mm, up to 30 mm or 40 mm weapons. Such weapon stations are being used on manned and unmanned turrets alike. The smaller calibre weapons are used primarily for closer ranges while the 30 mm using airburst munitions is considered a near-term solution against drones.

Another new capability associated with modern turrets is an added weapon compartment used for housing launchers for guided missiles and loitering munitions. Most of the new turrets use a retractable 'pop-up' container protected under armour until it is erected just before firing. Today, these containers are designed to accommodate a specific type of missiles, like Rafael's Spike LR or MBDA's Akeron-MP, or the Uvision Hero-120 loitering munition. Rheinmetall is also considering a solution which fits nine miniature drones, acting as a swarm of loitering munitions deployed from such a compartment.

Human-Machine Integration

A fully equipped unmanned turret provides AFV designers with an excellent opportunity to introduce new capabilities with minimal changes to the platform. Since most sensors and weapons are mounted outside on the turret and remotely controlled from workstations inside the hull, most integration work focuses on the turret. That's why designers employ open systems standards, such as NGVA or MOSA, enabling systems to interface with the same data formats, making integration and upgrades more efficient with less developmental risk.

Integrating all those systems with the crew is not easy either, since new capabilities should also not increase the workload on the crew or impede their function. Situational awareness is a good example of this challenge – an unmanned turret requires providing the vehicle with a greater level of situational awareness, since the commander cannot look out of the turret to get a first-hand understanding of their surroundings.

Different sensors operating in other modes are essential to monitoring the battlespace around the combat vehicle. Using a combination of standardised operating consoles, digital displays, and wearable immersive augmented reality (AR) vision systems can provide a more intuitive and realistic operating environment that young soldiers have already developed in gaming and implemented in real life.

SITREP – The US Army's Optionally Manned Fighting Vehicle (OMFV)

Sidney E. Dean

The US Army's Optionally Manned Fighting Vehicle (OMFV) programme remains on schedule and is set to enter Phase 3 in early 2023, replacing the legacy M2 Bradley Infantry Fighting Vehicle (IFV). In this sitrep, Sydney E. Dean examines the programme's progress.

he Bradley has undergone repeated upgrades since entering service in 1981, but has now reached the limits of its growth potential. A new, modern design is needed in order to incorporate future technologies and achieve new capabilities required to retain battlefield superiority in coming decades. The OMFV will assume such classic IFV missions as battlefield infantry transport, fire support, and direct engagement of enemy vehicles.

According to an Army statement dated 28 February 2022, OMFV is "tasked to manoeuvre through the enemy's security zone as part of a combined arms team for the purpose of creating an advantageous position, relative to the enemy, and providing protection and direct fire lethality while manned or remotely operated. In the close fight, the OMFV enables the ability of dismounted elements to manoeuvre by detecting and destroying targets at a range beyond the enemy's

The Army expects the new vehicle to significantly outperform the M2 by providing "transformative flexibility and lethality capabilities to future battlefield commanders." Two of these transformative attributes will be the ability to be remotely operated by a dismounted crew, and to operate seamlessly with fully unmanned Robotic Combat Vehicles (RCV) currently under development. The vehicle is also expected to mount improved sensors and weapons as well as enhanced survivability features.

OMFV is the first major ground combat vehicle development programme relying on digital engineering during the primary design phases. The programme is divided into five phases (dates refer to the US government fiscal year or FY which runs from 1 October through to 30 Septem-

- 1) Market Research and Requirement (2018-2020).
- 2) Preliminary Design (2021–2022).



The M2 Bradley is armed with a 25 mm automatic cannon, two TOW ATGM, and a 7.62mm MG.

- 3) Detailed Design (2023-2024).
- 4) Prototype Build and Test (2025–2027).
- 5) Production and Fielding (2027–2030).

Preliminary Design Results

The Preliminary Design phase of the programme was initiated in July 2021 with the award of contracts to five contenders. As the industry teams worked on development of digital designs utilising modelling, simulation and analysis of varying designs' capabilities, the Army continued to flesh out its requirements. The military and the industrial teams maintained close contact, and new requirements or preferences were constantly passed on to industry to flow into the design process. All designs were formally reviewed and revised three times during the Preliminary Design Phase to ensure maximum orientation to Army priorities, which became more precisely focussed during the course of Phase 2. The deadline for the industry teams to for-

mally submit the completed preliminary

designs was 1 November 2022. All five contestants met that deadline. The Army will review the designs over several months. Based on the results of this review, the Pentagon plans to award up to three contracts for the Detailed Design Phase (programme Phase 3) by April 2023. The Army had announced a full and open competition for Phase 3, meaning that firms which had not participated in Phase 2 would still be eligible to submit proposals. Whether any other firms chose to do so has not been made public. The known active contenders for the OMFV programme are: American Rheinmetall Vehicles (ARV); BAE Systems Land and Armaments; General Dynamics Land Systems (GDLS); Oshkosh Defense; and Point Blank Enterprises (PBE). Given the intense feedback and interim reviews by the Army during the course of Phase 2,

This especially true for the hardware characteristics. All designs feature a tracked

the designs of the five competitors be-

came increasingly similar as the submis-

sion deadline neared.



Soldiers board an M2 Bradley IFV during a combat patrol in Tall Afar, Iraq, in 2006.

hull with hybrid diesel-electric drive, an unmanned turret mounting a 30 mm to 50 mm automatic cannon, and a vehicle crew of two (down from the Bradley's three). Additional features include the ability to carry anti-tank guided missiles (ATGMs) as well as an integrated Active Protection System (APS) against ATGMs and RPGs. The majority of these attributes had been presented by the Army as "preferred" rather than required, but ultimately industry understood that designs not incorporating these features would be at a distinct disadvantage going into the downselect to Phase 3. One area where the Army was forced to compromise was passenger capacity. All designs can accommodate six armed infantry soldiers. The Pentagon had initially hoped to transport a complete nine-person squad in one vehicle. Ultimately the weight and size limitations for the OMFV - crucial to ensure transportability and mobility goals - turned out to be too restrictive to accommodate this objective.

Intangible Aspects

All designs are required to meet certain criteria. One of the most critical is a Modular Open Systems Architecture (MOSA) based on Army-designed and owned standards. The relevant MOSA for OMFV and other armoured combat vehicles is the Ground Combat Systems Common Infrastructure Architecture (GCIA). To comply with this standard, each vehicle platform must feature standardised hardware, software and data interfaces which will facilitate exchange or addition of mission systems over the decades of expected service life via 'plug-and-play' functionality. However, the vendors' responsibility regarding MOSA extends far beyond the interface configuration. They must ensure that each and every hardware and software component going into the OMFV is itself GCIA-compliant. Overall, the Pentagon and the industry teams have remained fairly tight-lipped regarding details of the invisible features of their designs, such as the level of automation and artificial intelligence (AI), electronic warfare capabilities, or the precise composition of the vectronics suites. Given the reduced crew size, Al will be particularly important for enhanced situational awareness and targeting as well as navigation. Another automated capability which the Army values is predictive maintenance. The ability of onboard sensors to constantly monitor vehicle health and warn the crew before key components break down is expected to significantly boost mission availability while reducing the support burden. Military and industry personnel agree that the automation element poses the greatest challenge of the entire program. This holds from an operational standpoint (determining which functions are most suited to automation in order to relieve stress on a smaller crew, with AI effectively acting as the "third crewmember") and from a technological standpoint (determining what is or is not currently

Another Army priority is a required margin for growth, which will permit integration of future technologies including enhanced armour, vectronics, and – potentially – jammers and directed energy weapons (DEWs). Given that OMFV is expected to serve through 2080, and that many incremental and breakthrough technological developments are expected over the coming decades, the winning designs may ultimately be those which display the greatest future growth potential.

Contenders

Given the multiple key technology areas flowing into the IFV, each prime contractor has partnered with several firms, each of which brings in special expertise in crucial areas. Details regarding their respective designs have emerged in recent months, with some firms being more open than others. Despite the overall similarities of the designs, the various prime contractors have been quick to point out special advantages presented by their own particular works.

American Rheinmetall Vehicles

American Rheinmetall, partnering with Raytheon Technologies, Textron Systems, L3Harris Technologies, Allison Transmissions and Anduril Industries, is basing its OMFV design on the KF41 Lynx IFV which is currently being acquired by Hungary. 'Team Lynx,' as the partners call themselves, showcased a mock-up of its



The Lynx OMFV's turret, designed by Raytheon, supports a 50 mm automatic cannon, a Multi-Mission Launcher for ATGMs and attack drones, and a next-generation array of sensors including 3rd Generation FLIR and 360° surround vision.

OMFV at the October 2022 Association of the US Army (AUSA 2022) exhibition. The Lynx OMFV has been significantly redesigned to meet US requirements. In that context, the size and weight of the original vehicle was reduced, at the expense of cutting passenger capacity from eight to six soldiers. The OMFV also features a new, US-designed turret with a Northrop Grumman XM913 50 mm automatic cannon, a Raytheon Multi-Mission Launcher capable of deploying TOW and Javelin ATGMs, as well as Coyote loitering munitions, 3rd-Generation FLIR sights, 360° local situational awareness, and Rheinmetall's Strikeshield APS. Raytheon describes the multi-mission launcher as unique across the market, delivering a new level of tactical flexibility. ARV has also emphasized the role of Anduril in the team, referencing the firm's expertise in automation and AI, software development and sensor fusion.

BAE Systems Land and Armaments

BAE Systems, builder of the M2 Bradley, took a clean-sheet approach to OMFV. Its partners in the programme include Elbit Systems of America, Curtiss-Wright Defense Solutions, and QinetiQ Limited. Elbit is providing its UT50 unmanned turret armed with the XM913 50 mm automatic cannon and ATGMs. Curtiss-Wright assisted BAE with MOSA design and is collaborating on vectronics and control systems. QinetiQ is supplying the electric cross-drive transmission, based on its Modular E-X-Drive transmission, to be integrated into the hybrid electric drive which it is co-developing with BAE. While BAE has made the same effort as the competition to minimise vehicle weight, the firm is also offering a modular add-on armour option to enhance survivability in certain high-risk warfighting scenarios where weight might be a less critical consideration. The most revolutionary aspect of the BAE design is the propulsion and power system. Instead of a single large engine at the front of the vehicle, BAE's team developed a 'serial' hybrid engine system. It consists of several smaller engines which are distributed throughout the sponsons on both sides of the vehicle. This arrangement significantly reduces thermal signature and acoustic signature. It also eliminates the risk of the vehicle being immobilized by a single penetrating hit to the engine compartment. The 798 kW (1,070 hp) power train promises to provide a 700 kW power growth capacity, sufficient to support future installation of high-energy lasers (HELs) or other counter-drone weapons, which are currently not part of the Army's requirements list. The OM-FV's high-capacity batteries will currently provide power for nine hours of silent overwatch or 2.5 km of silent manoeuvre.

General Dynamics Land Systems

As builder of the M1 Abrams MBT family, GDLS brings considerable heavy-vehicle experience into the programme. For OMFV, the firm has contracted with GM Defense, AeroVironment, and Applied Intuition. According to GDLS, the OMFV concept was designed from the inside out by selecting enabling technologies to meet specific performance parameters including cybersecurity, autonomy and advanced threat protection, then designing the vehicle around those technologies. The firm states that this approach concentrated on selecting mature, lowrisk technologies which, taken together, promise to provide the "revolutionary" capabilities increase demanded by the Army. The team underscores its emphasis on maximising modularity to ensure growth potential over the vehicle's service life. Unlike its competitors, GDLS has yet to reveal concept art or a mock-up of its OMFV design.

Oshkosh Defense

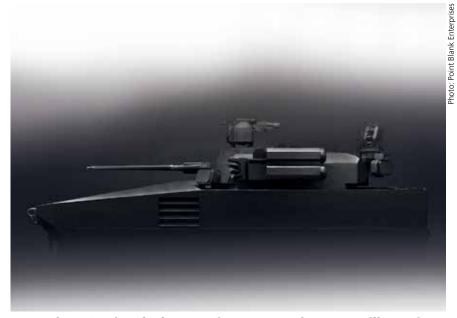
Oshkosh Defense, which to date has produced a large line of tactical trucks but no large tracked armoured fighting vehicles, is presenting a design based on the



Conceptual CG render of BAE's OMFV design.



The Oshkosh OMFV design is derived from the Hanwha AS21 Redback depicted here.



In March 2022 Point Blank Enterprises presented a concept illustration of its OMFV.

AS21 Redback IFV platform developed by its primary partner Hanwha Defense USA. The Redback, which is currently under consideration by the Australian army, is itself a derivative of the K21 IFV in service with the South Korean army. For the OMFV competition the existing Redback design had to be slimmed down to meet the US Army's size and weight requirements, at the expense of reducing carrying capacity from nine soldiers to six. Another change is the replacement of the Redback's EOS T2000 manned turret (which is itself a derivative of the Elbit MT30 manned turret) with Rafael Advanced Defense Systems' SAMSON 30 unmanned turret. Unless a larger calibre gun is developed for the RWS, this will make the Redback-based OMFV the most lightly-armed contender.

Other partners for OMFV include Pratt Miller Defense, QinetiQ, and Plasan. These firms contribute expertise in vehicle engineering, digital design, C5ISR and autonomy, and in Plasan's case, vehicle survivability solutions. Oshkosh promises a very high degree of automation of most on-board systems, to reduce the cognitive burden of the crew as well as the logistical burden of the brigade.

Point Blank Enterprises

Point Blank Enterprises, which has no previous experience in vehicle production but has developed vehicle and helicopter armour solutions, touts its experience in leading teams consisting of numerous other firms. PBE's primary OMFV partner is Keshik Mobile Power Systems, although the firm also refers to a large

number of additional (but unspecified) specialised contractors. Point Blank has selected the Cummins Advanced Combat Engine (ACE) to power the OMFV. The PBE website states that the vehicle has a "clean-sheet design engineering with a fully modular technology-agnostic approach," but overall, the firm has been least forthcoming regarding details of its design concept.

Timeline Moving Forward

As previously noted, the Army plans to downselect to three competing designs in the second quarter (Q2) of FY2023. The three contract awards will simultaneously cover both Phase 3 and Phase 4 of the OMFV program, with the same vendors automatically being chosen for both segments of the program.

Detailed Design Phase

The Detailed Design Phase (Phase 3) will run for 18 months. The preliminary designs will undergo further development, culminating in late FY 2024 with a Comprehensive Design Review (CDR). The CDR will determine whether prototype designs meet baseline requirements and demonstrate technical maturity and manufacturing viability.

Prototype Build and Test Phase

Designs which pass the CDR will enter the 36-month long Phase 4 of the program, which runs from Q1 of FY2025 through Q4 of FY2027. Each participating industry team will be required to submit between seven and eleven physical prototypes of the production-model design, plus two ballistic hulls and turrets, armour coupons, and digital engineering data. The vehicle prototypes will be tested and evaluated against the Army's OMFV performance specifications. A Limited User Test (LUT) will be conducted late during Phase 4.

Production and Fielding

One of the three competing designs is expected to be selected for acquisition at the end of FY2027. The award of the Low Rate Initial Production (LRIP) contract will initiate Phase 5 of the OMFV programme. Following rigorous operational testing of the first production vehicles, the Army expects to equip the first mechanized infantry unit during FY2029. A full-rate production (FRP) decision is expected in Q2 of FY2030. Procurement is expected to run for two decades. The total value of the contract award, over time, could come to USD 45 Bn.

Protection Racket

Thomas Withington

At first blush, Russian tank casualties in the ongoing war indicate a weakness in Russian vehicle protection. The truth, however, maybe more nuanced.

he statistics are damning. Since Russia's invasion of Ukraine on 24 February 2022, the country's armed forces have lost 1,450 Main Battle Tanks (MBTs), according to the Oryx Blog, which stated that of this total circa 900 have been damaged or destroyed. The International Institute of Strategic Studies (IISS) calculates that Russia possesses around 3,300 MBTs. These are distributed across its army, naval infantry and airborne forces. A loss rate of 900 MBTs represents 27% of the fleet over ten months up to December 2022. If losses continue at this rate, Russia will lose all her tanks by late March 2025, assuming the war continues until then and these losses are not replaced.

It may sound obvious, but tanks are vital to the Russian Army. The seminal 2016 publication of the US Army's Foreign Military Studies Office 'The Russian Way of War' by Russian military experts Dr. Lester Grau and Charles Bartles underscores just how important they are. Tanks are used closely during manoeuvre with army Motorised Rifle Divisions/Brigades (MRD/Bs). Defensively, MBTs support mechanised infantry by repelling enemy attacks, and performing counter-strikes and counter-attacks. Offensively, tanks help exploit breakthrough, perform deep strikes and support engagements and battles. MBTs are organised into their own tank brigades and divisions. Each MRD/B will also have an organic tank battalion of between 30 and 41 tanks. A tank brigade comprises three tank battalions. Taking an average of 35 tanks per battalion, 26 of the army's 95 tank battalions have been destroyed in Ukraine. Russian MBT losses have provoked significant debate over the future of the MBT in land forces manoeuvre. It is not the intention of this article to regurgitate

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these discussions. Instead, we will discuss what these losses mean for Russian MBT Active Protection Systems (APSs). Specifically, we will analyse those Russian APSs relying on radar, and how these maybe defeated.

Drozd and Arena

The Soviet Union (USSR) was an early adopter of APSs for its tanks and armoured vehicles, says a source highly familiar with Russian armour design and its performance in the ongoing Ukraine conflict. Open sources say that although Soviet interest in APSs commenced in the

the tank. The grenade would either destroy the incoming round or the explosion would knock it off course. Drozd was sufficient to engage missiles or rockets travelling at 700 m/s (2,519 km/h). Russian sources note that two Drozd variants were produced; the baseline version equipping MBTs and the later, more refined Drozd-2 modular variant, which could be fitted to both MBTs and other armoured vehicles.

The sensory component of the Drozd was a K-band radar transmitting in frequencies of 24.5 GHz. As observed in an article by armoured vehicles expert Richard M. Ogorkiewicz, Russian engineers



Drozd was the Red Army's first APS. It is seen here mounted on the side of this T-55AD tank, with launchers unloaded. Its use of K-band radar continued into later Soviet and Russian APSs like Arena and Afghanit.

1960s, it would not be until 1983 when the USSR's Naval Infantry fielded the first such system known as the 1030M Drozd. This adorned the T-55AD main battle tank relying on a hard kill system to destroy incoming rounds. Incoming rounds threatening the tank were detected at ranges over 150 m (492 ft). Once the round was detected, a grenade armed with a 107 mm high explosive fragmentation (HE-FRAG) munition was launched. This would explode 6.6 m (21.7 ft) from

pioneered the use of radar to support APSs. The choice of K-band was interesting. On the one hand, K-band transmits very short signal wavelengths of 10 mm. Wavelength is the measurements of the distance between two peaks and two troughs in a radio signal. These short wavelengths are very useful for precisely detecting and tracking small targets like incoming missiles or rockets. This was imperative to ensuring Drozd would select whichever of the system's four launchers

was in most favourably angled toward the threat.

On the other hand, while K-band is a good choice for capabilities needing this level of precision it has a disadvantage. Radars transmitting such short wavelengths are prone to a phenomenon known as rain fade. This is where precipitation like rain or snow in the atmosphere causes interference or 'clutter' in the radar, potentially hampering its ability to detect and track a target. To further complicate matters, the ordnance earmarked to be engaged by Drozd had a low Radar Cross Section (RCS). For example, a mortar shell has an RCS of circa 10 mm2, which would be comparable to some of anti-tank weapons Drozd was intended to protect against. During inclement weather the K-band radar will be looking for a small target hidden in clutter. Not the easiest task at the best of times.

Open sources note that one approach taken by Soviet engineers was to include filters in the radar to discount everything but targets flying within the speed thresholds associated with antitank ordnance. An article by Captain Tom J. Meyer in the May-June 1998 edition of the US Army's Armor magazine noted another radar shortcoming. It could not accurately determine the elevation of the incoming round. Nonetheless, Drozd did boast an 80% success rate against ordnance during the Soviet war in Afghanistan between 1979 and 1989. The source familiar with Russian armour in Ukraine revealed that at least one T-80UM2 equipped with Drozd was destroyed in the conflict. However, they emphasised that Drozd and other Russian APSs have not been widely deployed in the war so far.

RF detection was revisited for the Arena system which debuted in the mid-1990s. The system was built around an omnidirectional radar continually scanning for incoming threats to the tank. Like the Drozd, this too used a K-band radar, most probably transmitting on similar wavebands. The radar detects its target at between 7.8 m (25.6ft) and 10 m metres (32.8ft) from the tank. Arena's computer then selects the appropriate launcher for the threat and launches a directional HE-FRAG projectile upwards which, after a brief delay to gain, then detonates, directing its spray of fragments into the path of the round. The protection system typically engages the threat at ranges of between 1.3 m (4.3 ft) and 3.9 m (12.8 ft) from the vehicle. Notably, Arena and the more modern Arena-M variant do not appear to have been deployed op-



The Arena system followed Drozd as a radar-based APS. Despite its development, it does not appear to have been adopted by the Russian Army so far.

erationally. "They never really entered service," said the source. Pictures have been seen in the public domain of the equipment being trialled for the purposes of upgrading T-72B3 and T-90M tanks, but they have yet to progress beyond this. Nonetheless, Russian reports in September 2022 stated that T-90M, T-80BVM, and T-72B3M tanks should begin receiving the Arena-M from 2025. Whether this occurs remains to be seen.

Afghanit

Afghanit is the latest APS developed for the Russian armed forces, but has not entered service. Radar is once again being used for the detection of the incoming rounds. Open sources say that Afghanit can intercept rounds at a range of 20 m (65.6 ft) from the vehicle. Nonetheless, the reliance on radar for systems like Afghanit and Arena-M is a potential weakness. A 2020 paper published in the Journal of Physics on APSs warns of shortcomings. Radars are vulnerable to clutter, as noted above, and their other potential weakness is jamming. A K-band radar can potentially be attacked by a jammer emitting on similar wavebands. For example, a jammer could be used to jam the APS radar while an attack takes place. However, while not impossible, this would be risky. The narrowness of the K-band radar beam would mean the jammer would need to be in a direct line of sight with the radar antenna. Moreover, these antennas are small and the tank, and its turret where the radar is mounted, will most probably be moving. This would make it difficult to keep the jamming signal on the radar for sufficient time for the attack to take place. Moreover, a K-band jammer will suffer the same degradations in jamming signal range and power in bad weather. Afghanit also uses an ultraviolet (UV) system to detect incoming missiles, and it is possible that these may partially compensate for the radar if operating under degraded conditions.

That said, UV is by no means perfect. Detection of the hot exhaust plume of an incoming missile can be obscured by smoke or obscurants. This can reduce the detection range of the UV sensor or eliminate it altogether if these obscurants are thick enough on the battlefield. Although Russian APSs may not be widely deployed in Ukraine, the Drozd-furnished T-80UM2's destruction shows that some MBTs equipped thus may be encountered in theatre.

Vulnerabilities

Although jamming radar-equipped APSs could be difficult, it may not be impossible. Ukrainian forces may be able to use civilian technology to jam K-band radars. Some speed detection radars operate in similar wavebands, with K-band a popular choice. This is used on account of its ability to provide highly accurate detection of the target's speed in a system easily installed at a roadside vantage point. A burgeoning trade has

emerged with companies offering civilian radar detectors. These are favoured by drivers wanting to break the speed limit while avoiding the radars. Militaries use Electronic Support Measures (ESMs) to detect radio signals. However, the problem is that the ESMs used by land forces are typically optimised to detect signals across wavebands of 3 MHz to 6 GHz. This is because land forces are

the radar is in front or behind them. It may be possible to combine two detectors a set distance apart to triangulate where the threat is.

Civilian radar jammers may also be effective. Some motorists are not content with merely detecting where a radar might be and altering their speed accordingly. They may also want to jam the radar. Civilian radar jammers are of guestionable legal-

Russian armoured vehicle engineers have adopted a radar as the primary sensor for the Afghanit APS, as seen here. The radar is located in the lower portion of the turret cheek, below the UV sensor and Laser Warning Receiver (LWR), which are both typically covered up by a protective plastic cover, as seen here.

primarily concerned with detecting and locating hostile radios. Detecting radio emissions lets you determine where hostile troops are located by locating these signals. It may even be possible to track the movement of these forces using their radio signals alone. These Communications Intelligence (COMINT) systems may be able to demodulate and decrypt some radio signals. As a result, hostile radio traffic can then be exploited for tactically or operationally useful intelligence.

Unfortunately for land forces, many CO-MINT ESMs do not stretch upwards to the wavebands used by K-band radars. Could forces looking to counter the capabilities of radar-equipped APSs refashion civilian traffic radar detection systems to alert them that such a radar may be operating? One challenge of using this technology is that the detector may not give an exact indication of where the threat might be. Traffic radar detectors tend to provide a directional indication of where the radar is located. This may tell the motorist that

ity in many countries. Nonetheless, a range of products including those which jam K-band signals are freely available on the internet and are relatively inexpensive to procure. Using a civilian K-band jammer to attack an APS radar may not be as straightforward as it seems. Firstly, the jammer will need to be powerful enough to reach the radar antenna and then to drown out the radar's own signal. A rule of thumb in electronic warfare says that jamming is always directed against a radar or radio's receiving antennas. Most radars and radios use a single antenna to transmit and receive. When a radio signal is transmitted from a radar it leaves the antenna with a certain level of power. The signal travels through the ether, hits a target and is reflected to the radar. This round trip causes the signal to expend energy, and this energy loss is further compounded by the fact that small RCS targets in particular may only reflect a portion of the total energy transmitted back to the receiver. The net result is that the radar signal is comparatively weak when it returns to the radar compared to its power level when transmitted. Having a jamming signal which is stronger than the power of the returned signal simply 'drowns out' the original signal amidst a cacophony of noise.

We cannot discount the possibility that these radars may have so-called electronic counter-countermeasures (ECCM) to nullify this tactic. Their software maybe designed to recognise incoming high-power signals and to ignore these. Instead, they will only accept signals at power levels the radar would expect from those reflected by a target. The radar may also rapidly and pseudo-randomly change frequencies. Once again, the software may discard signals that do not appear to follow the profile of the kind of signals the radar would expect to receive. Some of these questions could be cleared up through the sampling of signals transmitted by these radars. This would give clues on some of the countermeasure techniques that could be used to jam these APSs. As noted above, these systems are not widely deployed in Russian service, which might make recording these signals problematic. Moreover, much like radar signals, jamming signals can also be detected and located. A risk here is that troops using a jammer against a radar might advertise their own position with potentially dangerous consequences. That notwithstanding, it will not be beyond the expertise of Ukrainian engineers and software experts to develop capabilities which could fool Russian radar-assisted APSs.

The Future

Are we likely to see the widespread adoption of APSs on Russian armour in the future? The source thinks not. "Active vehicle self-protection systems add weight," they say. "A lot of Russian armour is pretty mobile. The Russians are unlikely to want to add the extra weight of an AVSPS which may reduce this." Moreover, the performance of explosive reactive armour already "covers many of the threats" that would otherwise be addressed by an APS. Nonetheless, the architecture these systems currently use, particularly regarding radar, does introduce potential vulnerabilities. These vulnerabilities maybe exploitable by Ukrainian forces battling Russian armour. Moreover, this may be possible by using commercially available technology modified for military use. At a stroke what the Russian Army hope may protect its tanks could become a critical vulnerability.

Poland and South Korea's Growing Defence Ties

Robert Czulda

The multi-billion-dollar agreements recently signed between Poland and South Korea are unprecedented – they are the largest arms contracts in the recent history of Poland and in the history of South Korean military exports. Both Warsaw and Seoul hope they could use them to develop deep military ties and strategic industrial cooperation.

t is not clear yet how much Poland will pay for the equipment ordered from South Korea, with talks regarding financial and technical details presently ongoing. Contracts already signed have a value of approximately EUR 12.78 Bn, but further deals, including those covering technology transfers and additional batches of main battle tanks (MBTs), self-propelled howitzers (SPHs), and multiple rocket launchers (MRLs), are just a matter of time. According to some Polish estimates, the total could end up reaching as high as EUR 21.3 Bn. The shopping list includes foremost the K2 MBTs. All 180 K2s from the first batch, valued at EUR 3.16 Bn, are to be delivered by 2025. Additional tanks are due to follow, consisting of 820 that are to be built locally from 2026 onwards. These locallyproduced tanks will be a newer variant, known as K2PL (the full technical details are yet to be agreed, but they are expected to have enhanced armour, an active protection system, Polish 12.7 mm heavy machine guns (HMGs) and be compatible with US-made programmable munitions). Despite initial plans, K2PLs will not get an additional pair of roadwheels. Tanks from the first batch are expected to later be upgraded to the K2PL standard. Accompanying these orders for MBTs are large ammunition requirements, and in December 2022, Poland issued a foreign military sales (FMS) request to the USA for 120 mm munitions for various MBTs, including K2s. In total, Poland requested the following munitions:

AUTHOR	Autl	hoi	r
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Designation	Ammunition Nature	Quantity
M829A4	APFSDS-T	60,000
M829A3	APFSDS-T	2,000
M829A2	APFSDS-T	50,000
M830A1	MPAT-Ts	10,000
M908	HE-OR-T	60,000
M1147	HE-AMPs	70,000



A K2 MBT from Poland's first batch, which arrived in the port of Gdynia on 5 December 2022.

First ten K2s arrived in Poland in early December 2022 via the seaport of Gdynia. This was a special moment for the Polish Army – the last time it received completely new-build tanks was in 1978 with the delivery of their T-72s, with other tanks since then acquired from surplus stocks. The first Polish unit equipped with K2s is a tank battalion in Ostróda (temporarily based in Morąg), which is subordinated to the 20th Mechanised Brigade in Bartoszyce, which is part of the 16th Mechanised Divi-

sion in Olsztyn. According to Warsaw, the K2 MBTs are better-suited to operate in Northeastern part of Poland (Warmia and Mazury), which is muddy, boggy and hilly, than the heavier Abrams tanks. Further K2s will be used by two tank battalions of the 9th Armoured Cavalry Brigade in Braniewo (part of the 16th Mechanised Division), which are presently armed with PT-91s. SPHs were next on the list, during an official ceremony in Morag in August 2022 Poland ordered 212 K9 SPHs for EUR 2.28



The K239 Chunmoo MRL on order by Poland represents a significant improvement to Poland's indirect fire capability, providing improved range and accuracy compared to Poland's in-service systems.



The AS21 Redback IFV, here shown in scale model form, has also been offered to Poland as a complement to the indigenous Borsuk IFV.

Bn. The first batch, consisting of 48 K9A1s is expected to fill the gap created when Poland donated some of its indigenously manufactured AHS Krab 155 mm SPHs to Ukraine. According to initial plans, further K9s (more than 800) are to be produced locally, in the K9PL variant. The first batch of 24 K9A1s, still in South Korean camouflage, arrived in Poland in late 2022 and they were deployed to the 11th Mazurian Artillery Regiment in Węgorzewo, which was subsequently transformed into the 11th Mazurian Artillery Brigade, subordinated to the 16th Mechanised Division. Poland will also receive K239 Chunmoo

Poland will also receive K239 Chunmoo MRLs, which are intended to serve as a response to Russian BM-30 Smerch MRLs and 9K720 Iskander SRBMs. A deal, worth

EUR 4.36 Bn, was signed in early November 2022 between the Armament Agency and Hanwha Aerospace. 218 launchers are to be delivered under the current contract, which also covers training and logistics. Poland will also get "several thousand" missiles of two types: 239 mm (80 km range, 12 missiles per launcher) or a theatre ballistic missile (290 km range, one missile per launcher). Deliveries are planned to take place from 2023-2027. The first Polish K239 Chunmoo division, comprising 18 launchers, will be subordinated to the newly established 18th Artillery Regiment in Nowe Debno, and is expected to declare its initial operational capability (IOC) by the end of 2023. In total Warsaw expects to procure 288 K239s. They will give Poland a major boost to its indirect fires capability, as current artillery systems of the Polish Army, such as the Krab 155 mm SPHs and the WR-40 LANGUSTA wheeled MRLs, do not use guided munitions and their range is just roughly 40 km. The Chunmoo will become Poland's longest-range systems since Poland retired their 9K79 Toczka theatre ballistic missiles in 2005. In order to make full use of the K239's long-range strike capabilities, Poland will have to either develop its own reconnaissance and targeting capabilities or cooperate closely with its allies. The first batch of twelve KAI FA-50 jets are expected to land in Poland in August 2023. They will be used by the 23rd Tactical Airbase in Mińsk Mazowiecki, which has been using the MiG-29s. This purchase, the most controversial among all orders made recently in South Korea, is expected to allow the Polish Air Force to phase out ex-Soviet MiG-29s and Su-22s. Operationally, the FA-50s will be used for training and to replace F-16C/Ds in some duties, mainly peace-time air-policing. In total 48 jets will be procured, with 36 of these in the FA-50PL variant, which includes an AESA radar, as well as compatibility with AIM-9X Sidewinder and AIM-120 AMRAAM missiles. The deal marks KAI's largest ever

Poland might also order the AS21 Redback IFV, which was tested in late 2022 at Nowa Deba by the 18th Mechanised Division, in the same variant that was offered for Australia's Land 400 Phase 3 programme. A vehicle sent to Poland was equipped with the Elbit/EOS T2000 turret, but it "has not been ruled out" that the Polish variant could be integrated with locally designed ZSSW-30 turret, with the resulting variant designated PL21. According to the Polish MoND, Redback would complement the locally designed and manufactured Borsuk IFV, which is due to be the basic vehicle of Polish armoured and mechanised units. It has been speculated that Redback could serve in the 18th Mechanised Division along with the Abrams MBTs (consisting of new M1A2 SEPv3 and used M1A1 FEP tanks), while other units, such as the 16th Mechanised Division, would be based on amphibious BORSUKs and K2s. A potential order could include 300 Redbacks. Both Redback and Borsuk vehicles would replace the BMP-1 family, which is locally known as BWP-1.

export order.

Financial Challenges

The main question that numerous experts in Poland ask themselves is: how to fund such massive procurements? To understand the context, it is worth mentioning that in 2022 Poland planned to spend at least EUR 14.9 Bn on defence, while in 2023 this amount is expected to grow to EUR 20.65 Bn, equating to 3% of GDP. Of this total for 2023, EUR 5.81 billion was earmarked for major modernisation initiatives. Such gargantuan spending – at least by Polish standards - require additional sources of funding. The Homeland Defence Act of March 2022 created the so-called Armed Forces Support Fund (Fundusz Wsparcia Sił Zbrojnych, FWSZ), which replaced the Armed Forces Modernisation Fund (Fundusz Modernizacji Sił Zbrojnych, FMSZ). It is now one of three sources of funds for technical modernisation, with the other two being the state's budget and the sale of stocks in defence companies. However, in October 2022 the Polish government classified all the details. It is widely believed that this was the result of the Polish Development Bank's (Bank Gospodarstwa Krajowego; BGK) failure to sell state debt obligations. BGK did not explain why the planned sale was cancelled, and so one can only guess that the reason could be a lack of interest from buyers.

Tomasz Dmitruk, one of Poland's leading defence experts, noted in an article published by Dziennik Zbrojny website that:



The Krab has been a noteworthy example of Polish-Korean industrial cooperation. Consisting of a K9 hull mated with the AS90 'Braveheart' turret, the vehicle is a capable SPH which has performed in Ukraine.

"the Polish taxpayer will not find out how technical modernisation of the Polish military is to be funded by the FWSZ. This is even one third of the total expenditure planned for this purpose, which in 2023 is to reach nearly EUR 31.96 Bn. In addition, this decision will mean that the Ministry of Defence will no longer have to publicly explain itself for failing to implement FWSZ's income and expenditure plans. This approach may certainly prove to be politically beneficial, considering

that the parliamentary and local government elections are scheduled for 2023". Lack of transparency regarding the FWSZ and challenges in gathering additional funds are not the only obstacles casting a shadow over large-scale defence procurements. The Polish economy is presently in crisis, with growth drastically slowed. According to the IMF, in 2023 Poland's GDP will grow just 0.5% instead of the 2% initially forecast. Similarly, the European Commission estimated Polish





The FA-50 jet represented an attractive offer for Poland, due to its compatibility with their existing weapons and KAI's industrial cooperation offer.

GDP growth in 2022 at 4% instead of 5.2% and 0.7% in 2023 rather than 1.5%. Furthermore, inflation reached 17.4% in November 2022, and looks set to increase. In other words – the economic situation is becoming more and more difficult, which puts high defence spending into question.

The current geopolitical situation in the region has resulted in widespread public support for boosting military capabilities. Nevertheless, public enthusiasm has its limits. According to a poll carried out in late October by United Surveys for Dziennik Gazeta Prawna daily, more than 60% of poll participants agree with plans to increase the number of soldiers in the Polish Armed Forces. Among the supporters of the ruling party, Prawo i Sprawiedliwość (PiS), as many as 80% of respondents support such an idea. However, when it comes to the financial aspect, the situation is less clear-cut. Dziennik Gazeta Prawna noted that 80% PiS supporters believe that Poland should spend more on defence even if it means budget cuts in other sectors or incurring new debts. In turn, almost 60% of opposition supporters are against it. The survey also noted that:

"Criticism towards higher defence spending grows with higher education. Almost 60% of those with a primary and lower secondary school education are in favour of cutting other expenses and increasing the public debt, while in a group of those with higher education it is only 41%. More than 50% of respondents are

against it. Rural residents are the most opposed to incurring debt for defence purposes."

Korean Attractiveness

What factors have drawn Poland to Korean hardware so heavily? First of all, this is the result of past experience. Polish-Korean defence cooperation is not new – as early as in 2014 Poland's Huta Stalowej Woli (HSW) received a license from Samsung Techwin to locally manufacture the K9 hull for their Krab SPHs. The deal came around because Poland's defence industry failed to produce its own hull for the Krab, and had to acquire the know-how abroad. However, such cooperation has borne fruit – Krabs are still in production and are considered to be highly effective.

Secondly, Seoul's offer was seen as the most attractive, and South Korea promised to deliver equipment much faster than other suppliers. Before Poland requested FA-50s, it was hoping to buy used F-16s. However, even in 2016 such procurements – either from Denmark or Belgium – were considered technologically unpromising and financially unprofitable. Obtaining used F-16C/Ds in good condition from the United States also became impossible.

The same applies to MBTs – all attempts to find used Leopard 2 MBTs in good condition failed, while Berlin was either unwilling or unable to meet Polish needs,

which have been growing. Currently the Polish Armed Forces have 150,000 soldiers and almost four divisions, though the fourth (the 18th Mechanised Division in Siedlce) is still being formed and is expected to become fully operational in 2026. However, according to current plans, the Polish Armed Forces are expected to ultimately grow to 300,000 soldiers. Two new divisions are to be established in central Poland, and the 16th Mechanised Division is planned to have four brigades instead of three.

Rapid delivery timescales are extremely important to Poland because a significant part of its equipment, including MBTs and SPHs, was transferred to Ukraine. Reportedly, this comprised over 200 T-72M1Rs and some PT-91 Twardy MBTs donated by Poland to Ukraine, in addition to Krab 155 mm and 2S1 Gvozdika 122 m SPHs. Therefore, Poland has to urgently fill the gap in its armoured units. Local upgrades of the Leopard 2A4s to 2PL/ M1 standard are too slow - all 142 are due to be upgraded by 2027. The programme, which was carried out in cooperation with Rheinmetall, was launched in 2015 and was initially expected to be completed by 2021. This is much slower than planned deliveries of South Korean K2 tanks (180 by 2026) and US-made M1A2 SEPv3 (250 tanks by 2026), not to mention used (ex-USMC) M1A1 FEP (116 by 2023). Additionally, K2PLs are to be manufactured locally (at least partially), while Germany has never established similar production facilities in Poland. As a result, the country can only carry out minor upgrades and maintenance works for its Leopard 2 fleet.

Thirdly, Korean equipment is modern and meets Western standards. It is also not without significance that the Polish military has not encountered any interoperability problems between Korean and Western systems. Commonality is also an important factor. For example, South Korean K9s have a very similar design to Polish Krabs, which are based on the K9 hull. According to the Polish government, one of the decisive factors in obtaining the FA-50 was the fact that they share 80% systems commonality with the F-16s.

Fourthly, defence cooperation with Seoul is part of Warsaw's broader ambition – to increase Poland's power and independence, including politically visà-vis its European partners. In recent years, Poland has been suffering from a political conflict with the European Union, mostly with Germany. Berlin has been using EU instruments, including the EU's judicial system and funds, to

subdue Warsaw's anti-federal resistance and to subordinate it to its own interests. Cooperation with South Korea therefore gives Warsaw hopes for reinforcing its selfhood.

This ambition also covers an industrial aspect, Warsaw wants to upgrade not only its military, but also indigenous defence industry, which desperately needs new technologies. South Korea has offered a wide range of cooperation and technology transfer opportunities. It is too early to present any details, since negotiations have not been concluded yet, however some proposals were made public. For instance, KAI has been tempting Poland with a vision of deep industrial cooperation, which could, at least according to KAI, include an MRO (Maintenance, Repair and Overhaul) centre in Poland and local production of components. Moreover, KAI mentioned the possibility of Poland joining the KF-21 Boramae aircraft development programme.

A further industrial aspect has been the opportunity for local equipment integration. From the outset, Poland's K239 Chunmoo launchers are due to be integrated with PGZ's 8×8 Jelcz wheeled vehicles, communication, and the WB Group's Topaz Integrated Combat Management System (ICMS), which has already been used by other Polish artillery systems, such as Krab, WR-40 Langusta (122 mm), M120 Rak (120 mm), Dana-T (152 mm) and the 2S1 GVOZDIKA (122 mm). In the next phase, the Polish Armed Forces are to be supplied with launchers and missiles produced by Polish industry, which will have acquired South Korean know-how.

Regarding tank acquisition, PGZ state-owned defence consortium is expected to establish a joint venture with Hyundai Rotem, which will be responsible for a production of the K2PL variant. Polish K2s will be manufactured in WZM (Wojskowe Zakłady Motoryzacyjne) in Poznań, while Poland's K9PL SPHs are planned to be manufactured by ZM Bumar-Łabędy. It has been hinted that if an appropriate industrial base is created locally, Poland could become a regional hub for production and logistical support.

Many Questions Remain

Multi-billion-dollar contracts with South Korea raise many unanswered questions, not only related to the financial side. For instance, why buy K9s if Poland has its own Krabs? Initially this procurement was justified by the plan that K9PL would be based on the K9A2 variant with an automatic ammunition handling system, but now it seems that



K2 MBTs and K9A1 SPHs being received by Poland in the port of Gdynia.

K9PL will be a simple upgrade of the less advanced K9A1, which is not superior to Polish Krabs in any way. Secondly, what is the future of the Borsuk IFV if Warsaw orders the Redback? According to Polish media, during local field trials in late 2022, Borsuk performed much better than AS21. Moreover, what are details of Poland's classified agreements with South Korea? Will Poland join South Korean R&D initiatives?

Some voices of concern coming from the Polish defence industry can be heard. On the one hand it, gets a chance to receive new technologies, which could bring Poland's industrial complex to a new level. On the other hand, however, the Koreans took over some of the orders that the Polish industry could count on (SPHs, AIFVs, grenade launchers). For this reason, the President of HSW Bartłomiej Zając resigned in August 2022 in protest. Concerns about the Polish Defence industry's final share are reinforced by reports such as the one of late November 2022, when PGZ announced that Poland would build "roughly 500" K2 tanks, in addition to Armoured Recovery Vehicles (ARVs), while initially it was stated that the Polish industry would manufacture 820 MBTs. Moreover, "Poland's Ministry of National Defence has imposed very ambitious timetables that put the industry in a difficult position and in a worse negotiating position, because there is less time to establish production" - noted Jedrzej Graf, editor-in-chief of Polish Defence24 daily. Graf added: "a priority for the Ministry of Defence is to have the equipment in line as soon as possible,

but this does not go hand in hand with the interests of industry".

Massive procurements in South Korea have not gone unnoticed abroad. According to Dmitruk's financial analysis, in the absence of industrial 'Polonization', South Korean companies would be responsible for 28% of Polish modernisation efforts, while US share would drop to 33%. European involvement would be just 12%. According to Politico, the South Korean industrial offensive in Poland have been "causing some jitters in the US Defence industry" due to "concern from U.S. industry that this won't stop with Poland".

Pro-German and pro-European circles argue that Poland should spend money in Europe, not in distant Asia. However, it is hard not to notice that the European partners failed to prepare a comparable offer. For example, in the past Poland expressed interest in joining the Franco-German Main Ground Combat System (MGCS) future tank programme, but ultimately was not invited. After the outbreak of this year's Russian aggression, Warsaw initially tried to get tanks from Germany, but it was not possible, so Poland looked for other suppliers. As a result, Germany irrevocably lost a massive market for its tanks. The same applies to nuclear energy issues – Poland has long been looking for a strategic partner to build its first nuclear power plants. France did not even try to win Warsaw's interest and its offer was considered poor. It is little wonder then, that Poland ultimately chose the United States' and South Korea's proposals.

Japan's Wheeled Vehicle Programmes Race for the Finish Line

Shinichi Kiyotani

On 8 December 2022, the Japanese Ministry of Defense (MoD) selected Finnish company Patria's AMV as the replacement for Self-Defence Force's (JGSDF) Type 96 8×8 armoured fighting vehicles (AFVs). However, the path which had led to this point was not the most straightforward.

The Type 96 successor programme was initially named the 'Improved Wheeled Armoured Personnel Carrier' with successors proposed by Komatsu and Mitsubishi Heavy Industries (MHI). Komatsu proposed a vehicle developed based on their 8×8 'NBC Reconnaissance Vehicle', while MHI proposed a 'Mobile Armoured Vehicle' (MAV) based on their 8×8 Type 16 Mobile Combat Vehicle, with prototypes being developed between Fiscal Year (FY) 2014 and FY 2016, and various technical and practical demonstrations conducted between FY 2016 and FY 2018.



The Patria AMV was selected as the eventual winner of Japan's Type 96 replacement programme.

Following initial testing, the Komatsu proposal was adopted. However, in June 2018, it was announced that the development would be discontinued due to problems with the performance of the armour and other issues uncovered in subsequent tests

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The MoD therefore went back to selecting a replacement for the Type 96, as the new 'next generation armoured vehicle' in FY2022. The bids comprised MHI offering the MAV, NTK International and Patria offering the AMV, and Sojitz Aerospace and General Dynamics Land Systems Canada (GDLS-C) offering the LAV 6.0.

The MAV had already been selected under a separate eight-wheeled armoured vehicle procurement programme named, the 'Common Tactical Wheeled Vehicle' (CTWV) and was selected for testing. However, the LAV 6.0 offer was dropped because the test vehicle could not be delivered in time for the end of FY2022.

This led to a one-on-one battle between the MAV and the AMV, with the AMV ranked superior in the basic performance required by the MoD, both vehicles equal in terms of logistics support and production infrastructure, and the AMV superior in terms of cost. Consequently, the AMV was selected as the next Armoured Personnel Carrier (APC) for armoured personnel carriers.

However, the AMV is to be produced under licence in Japan, which is currently being coordinated by Patria, and the Japanese company in charge of production has yet to be decided.

At an 8 December 2022 briefing on this matter, in response to ESD's questions, the MoD explained that if a licence production company is not decided, or if the conditions are not met, such as an increase in the unit procurement cost, there is the possibility that the contract may be cancelled. However, the MoD has already requested JPY 23.2 Bn for 29 AMV in the 2023 budget, with deliveries of this first tranche slated for completion in 2026.

Japan plans to procure a family of vehicles based on the AMV, which is set to include armoured personnel carrier (APC), command and control (C2), ambulance, logistics support, and engineer variants.



Despite being selected for Japan's CTWV programme, Mitsubishi Heavy Industries' MAV did not make the final cut to replace the Type 96.

However, at present the Japanese MoD has not revealed the final details of the number of vehicles to be procured or the total value.

As mentioned above, the MAV has been adopted by the CTWV programme, and development is underway for an infantry fighting vehicle (IFV) with a Mk44 Bushmaster II 30 mm automatic cannon and Mk52 Bushmaster 7.62 mm machine gun mounted in an unmanned turret, as well as a reconnaissance variant with the same weaponry albeit using a manned turret provided with a sensor mast, and a mortar carrier variant armed with Thales's 120 mm Rifled Recoiled Mounted Mortar (2R2M).

The CTWV programme has faced some challenges. So far each variant has seen system integration failures and consequently development has been delayed. As such, the ultimate future of both the CTWV programme and Type 96 replacement programme is still not fully secure, and care will be required to ensure their success.

Closed Down but What a View!

Tim Guest

Knowing what's going on outside your armoured vehicle without having to open a hatch and risk losing your head, has become increasingly achievable in recent years, as new technological solutions and possibilities to deliver comprehensive situational awareness under armour have entered the battlespace.

losed down, armoured vehicles and tanks have never really had great situational awareness (SA) in the past, with crews confined behind several inches of thick, steel and/or ceramic armour, often with only passive, narrow, periscopic views of the outside world available to them. Starting with a brief look at activities in Ukraine, this article takes a look at how this situation has changed, at why closed-down AFV crews need the best local area SA capabilities available to them on the battlefield, and at a handful of technological solutions now solving SA challenges.

Sobering Events in Ukraine

It's not been a good year to be a member of a Russian tank or armoured vehicle crew fighting in Ukraine. In the first month alone, some 400 tanks were reportedly lost, a number of these to fire from the likes of US-made Javelins and Ukrainian Stuga-P ATGMs, as well as aerial attacks from Baykar Bayraktar TB2 armed drones. Even anti-tank mines laid without camouflage on roads have taken a fatal toll on Russian armour, which seemingly operated without effective SA, or effective infantry support. Combined arms support in an era of multi-domain operations seems to have been left seriously wanting and Russian AFV crews have suffered as a result. Even advanced tanks like the T-80BVM and T-72B3M have succumbed and it's not down to their battlefield capabilities, which should not be underestimated. One of the major problems, if not the major problem, has been they've just had little infantry support to clear ground in front and to the sides; the crews have not, it seems, really known what's going on around them before incoming, armour-stopping munitions have struck. They have been seriously let down in terms of tactics.

What of their own awareness of their surroundings? RUSI has recently reported that while their sights and fire control systems have been "generally less modern than their peers," the Russians had made improvements prior to the 2014 annexation



This CG render illustrates some of the basic systems needed for see-through-armour situational awareness. As well as being offered on newer vehicles, it is also possible to retrofit legacy vehicles with these systems.

of Crimea with the procurement of Thales' infrared (IR) sights, giving them an ability to fight closed down, at night or other lowlight conditions, and in smoke. While not a dedicated SA sensor, per se, a thermal imager (TI) equipped sights certainly provides some feedback to the crew in such conditions, offering a degree of SA of their immediate surroundings. Since that initial procurement the Russians have attempted to manufacture the thermal imagers themselves, with some success, though the final number of vehicles equipped with these in time for the war with Ukraine is unclear. Russia has also developed at least one touchscreen-based 360° situational awareness system for use with its latest AFV designs, including the T-14 main battle tank (MBT) and T-15 heavy infantry fighting vehicle (HIFV) from the Armata family, the B-10 APC and B-11 IFV based on the Kurganets-25 platform, and the K-17 Bumerang 8×8 IFV. Despite these vehicles offering a significant capability boost over many of its existing vehicles, Russia has yet to bring any of them into active service. As the war effort continues to compete for funding, and sanctions restrict Russian procurements, the prospect of their introduction

looks less and less likely as time goes on. Ukraine had also been making efforts made efforts to improve its vehicular SA during this time. In late 2016 it was reported that the Ukrainians had been using the first iteration of Microsoft's Hololens - released in 2016 - to develop their own 'see-through-armour' capabilities for their vehicle crews to gain local SA (LSA) from beneath armour. Working with Hololens and their own technologies, Ukraine's 'Limpid Armor' went on to develop its Land Platform Modernisation Kit (LPMK), unveiled at first trials in 2019. The system included augmented reality (AR) smart helmets to be worn by the crew, enabling enhanced SA to easily identify friend or foe on the battlefield, as well as to monitor the vehicle's own critical systems. Cameras and sensors on the outside of a vehicle link with a helmet incorporating the Hololens headset, to give the wearer a 360° panoramic view of their surroundings, on which AR notations and operational information can also be overlaid, without the user having to turn their head. Following those first December 2019 trials on a BTR-4E IFV, Limpid conducted further trials in 2020 prior to intended delivery of five systems to the Ukrainian Forces, but what has happened since is uncertain. At that time, the company was a participant in NATO's Research Task Group (AVT-290 RTG) for Standardisation of Augmented Reality for Land Platforms in Combat Environments, which was due to run for two years until December 2020

In Parallel, Another 360

As Limpid was starting to develop its LPMK using the first Hololens in 2016, Israel's Elbit Systems launched its own See-Through-Armour (STA) system to provide SA from under closed hatches. Today, the company calls its STA system, IronVision, a panoramic observation solution enabling operators to understand and experience their environment from a single stitched-together image. It uses algorithms to process and join imagery collected by high-resolution, dayand-night video cameras installed around the outside of the vehicle, to give commander and crew a seamless 360°, realtime panoramic view. IronVision uses legacy heads-up-display technology from Elbit's aerospace business, transferred to the AFV domain, to help generate imagery so armoured vehicle and tank crews can overcome inherent visibility limitations, while improving mission efficiency and safety. Real-time, zero latency, high-resolution video is transmitted to a crews' IronVision helmet-mounted displays (HMD), providing a natural, conformal view of the vehicle surroundings. The system is fully integrated with battle management, warning and control systems, enabling tactical Information feeds from all of these to be presented on the HMDs in AR form. During daytime conditions, IronVision can detect a human from >200 m and a vehicle from >300 m away; at night, those detection distances drop some 50 m in both cases.

Indian 360 Innovation

Another 360-degree view of the world has been developed more recently by Indian company, AjnaLens under the government's 'Make in India' initiative to encourage companies to develop, manufacture and assemble products in India, but suited and destined as much for export as for domestic customers. AjnaLens has indigenously developed a see-through armour solution, the Ajna Enhanced Situational Awareness System (AjnaESAS). This uses Al and AR technologies to navigate vehicles through challenging terrain by eliminating blind spots and providing clear imagery even in the most obscured conditions, whether navigating through dust, sand,



IronVision uses legacy heads-up-display technology from Elbit's aerospace business, transferred to the AFV domain.

haze, smoke, thereby increasing survivability of vehicle and crew.

The low-power-consumption, MIL-SPEC system is said by the company to be cost-effective and comprises an intricate camera system mounted on the vehicle and an augmented reality helmet-mounted display (AR-HMD) worn by the crew members sitting inside. This gives an armoured vehicle or tank crew a 360° in azimuth field of view from inside their closed down vehicle, improving their SA and keeping drivers informed of their surroundings. In addition to providing panoramic vision, the camera system gives the crew night-vision and 4X-zoom capabilities. The system can also be

enhanced with additional features, such as identification friend or foe (IFF) capabilities and can be further customised to suit the mission and vehicle type.

Talking to ESD, Rishi Desai, AjnaLens marketing and growth manager, said that the company plans to further integrate IFF and Blue Force Trackers into AjnaESAS, "to empower our soldiers with object identification and enemy-tank tracking capabilities even from a distance and in all weather conditions. After object detection, the process of identifying and locking the target can also be automated, leaving only the decision to 'engage' to a human". Asked if there was interest from the Indian Forces,



AjnaESAS gives an armoured vehicle or tank crew a 360° horizontal field of view from inside their closed down vehicle, improving their SA and keeping drivers informed of their surroundings.

Desai confirmed, "Yes, we've built this with the support from the Ministry of Defence and it is soon going to be deployed in the Indian Forces." He added that there has also been recent interest from overseas forces. He said the AR-HMD headset would be worn by commander and crew with four connection points expected for the headsets inside an MBT, although "data is transferred wirelessly". The AjnaESAS has so far been trialled onboard BMP 2 and BMP 2K vehicles. As for detecting overhead threats, Desai confirmed that only horizontal threats could be detected by the system at this time. As to when best to fit the system, Desai said, "AjnaESAS is ideal for installing during vehicle production, but primarily it's designed for retrofit of existing fleet vehicles. We are doing some final trials and design upgrades and the system will be ready for mass production by the end of 2023."

Honeywell's 360

Adding to the 360° club, in October 2022 at the AUSA exhibition in Washington DC, Honeywell announced the arrival of its Honeywell 360 wearable display, intended to provide seamless SA for rugged ground vehicle operators and pilots in low-visibility conditions. The 360° HMD simulates natural vision with a high-resolution, ultra-low-latency view of what is happening around the vehicle, allowing users to safely manoeuvre around potential risks. This wearable, stereoscopic, mixed-reality HMD uses a series of sensors and exterior cameras to feed information directly to the headset, improving a crew's SA by increasing visibility and reducing the need to consult additional instruments. It combines the outside camera feeds with sensor and tactical information to provide a 360° field of view that can integrate multiple databases, including terrain, traffic and weather in an AR-augmented view. The lightweight display has been designed for comfort and extended use. In tests, the type of nausea sometimes experienced with head-mounted systems has not been experienced. Ricky Freeman, President of Defense and Space at Honeywell Aerospace, said the new system "helps enable the battlefield of the future" with its realtime data to improve the reaction time of users so they can make timely, wellinformed decisions. The mixed-reality system avoids the need to consult fixed displays. The Honeywell 360 Display has been tested extensively on ground vehicles, including in rough terrain.

Of the crew who would use this, a Honeywell spokesperson told ESD that, "The



Honeywell's 360 wearable display was unveiled at AUSA in October in Washington DC.

Honeywell 360 display is capable of supporting multiple crew members. It's been demonstrated on the Honeywell Hummer in various environments and conditions, such as urban, off-road, desert, day and night." As to whether the system is capable of monitoring vertical, overhead threats, the spokesperson told ESD, "The Honeywell 360 Display is camera/sensor agnostic and can be integrated with the camera/sensor systems available on the vehicle to display up to a full, 360° view dome." The spokesperson added that the system can be installed during vehicle production or as a retrofit to existing fleets.

SETAS Latest

A system we've looked at and described previously in ESD is the Hensoldt See Through Armour System, SETAS. This day/ night, high-performance local situational awareness system for use on any type of armoured vehicle provides the crew of a closed down vehicle with a 'high degree' of SA from inside. The high-resolution optronic vision system can recognise a human out to a range of 300 m with the HMD effectively enabling the wearer to see through the vehicle to the world outside. Threats like snipers or RPGs can be detected within their operating range.



The SETAS high-resolution optronic vision system can recognise a human out to a range of 300 m, with the HMD effectively enabling the wearer to see through the vehicle to the world outside.



Crew inside an AFV linked into the SETAS system.

The high vertical field of view makes the system superior for environments like the urban terrain and for threats from above. The modular system accommodates two powerful sensor systems: high-definition (HD) colour day cameras and uncooled TIs. The mission-approved uncooled TI is already mounted on several military vehicles worldwide. Single external units (camera modules) can be replaced in the field.

Depending on the type of vehicle, number of crew/occupants, SETAS can be scaled for use by a single individual or by as many as eight people – crew or mounted troops, so that each person can observe their own area of interest and responsibility. With hatches closed down, SETAS provides day or night 360° close area observation, threat identification and tracking, as well as data exchange with other vehicle systems.

For the latest on this important SA-underarmour system, ESD spoke with Hensoldt's communications manager, Alex Ogger, who said that SETAS had, among other recent appearances, been on display at this year's DVD in Millbrook on a KMW RCH155 and Hensoldt's own Mercedes Sprinter 4×4 technology demonstrator, then at a British Army Expo on Salisbury Plain, where it was showcased on Foxhound 4x4 protected patrol vehicle. Ogger told ESD that SETAS is designed to work as a standalone, retrofitted system, or fully integrated on the production line of new platforms. "Due to high possible level of integration to the platform, it is recommended, but not mandatory, to involve the platform supplier [in such work].'

He said that, "When SETAS is fully integrated to the platform network, it can show its full capability, interfacing with

various platform systems like the BMS, map systems, threat detection systems [such as laser warning receiver, or acoustic gunshot detection system], Active Protection Systems, main commander or gunner sights, to bring added value to these systems." He added that the system's open architecture, fully supports Generic Vehicle Architecture (GVA) and NATO Generic Vehicle Architecture (NGVA), so that even customer-owned proprietary algorithms will, in future, be able to run within SETAS' processing unit. Ogger confirmed to ESD Hensoldt's working relationship with KMW on SE-TAS, adding, "Due to our long and good co-operation with various platform suppliers we know which features might suit the customers' needs in the future. That's why we developed SETAS in the past, so it would be ready now to integrate to any and all platforms."

As to what AFVs have had a taste of SE-TAS for trials, so far, Ogger said that an evaluation by the British Army ATDU, trialling SETAS on a Foxhound, has, at time of writing, just finished and that with KMW an RCH155 pre-series vehicle is equipped with and has been demonstrated with SETAS on several occasions. KMW has also equipped a new version of its RCT30 with SETAS. In addition, Ogger said, "A US platform will be equipped with SETAS within the next two months for demonstration starting 2023." He added a final list of other vehicles which have so far been trialled and evaluated with SETAS, which are: GDELS Eagle (4×4 and 6×6), Patria 6×6, BAE CV90 and Warrior IFV. "Like you can see," Ogger said, "on the platform suppliers listed for SETAS demonstrations we are talking to suppliers all over the world, not only within Europe. Since we started to present the concept of SETAS, there has been great interest." And although Alex Ogger was only able to confirm that SETAS has been sold to just a single customer so far, he said it "is available as a prototype system with a maximum of processing power and up to eight individual users", but added that, "SETAS will be under contract soon!" ESD asked Ogger about SETAS capabilities referencing the context of the Ukrainian conflict and how it might handle overhead SA to cope and protect against top-attack threats, such as drones dropping AP munitions right on top of a closed-down tank, or air-to-ground AT weapons from ground-attack fighters. Ogger stated "The SETAS architecture and stitching algorithm, producing the seamless 360° image for each individual user, allows more Hensoldt integrated camera modules to be connected than the standard four units. In that way it is also possible for a hemispherical camera to be connected and introduced to create the users' virtual dome." Hensoldt has previously demonstrated hemispherical cameras as far back as 2011.

He continued, "The biggest advantage is for 'watching the soldiers back' – they cannot see and identify all 360° threats at the same time, so its advanced image processing capability and AI algorithms can do that job and analyse all live camera images for threats." He added that SETAS' powerful processing capabilities bring the advantage of reduced burden to each single crew member. "The system's AI algorithm could detect and analyse objects approaching and depending on their behaviour, [way of movement], they probably could be recognised or even identified. Here the available extreme high-resolution daylight camera of SETAS, combined with the uncooled TI, are providing the required image information."

Thales CDP

While not a single-vehicle SA-under-armour system in its own right, the Thales Combat Digital Platform (CDP) is a single system merging all operational functions required to accelerate situation analysis and SA, decision making and action and, in effect, can provide SA information to multiple closed down vehicles at the same time. A spokesperson for Thales told ESD that, "As the volume of battlefield data increases every day, coming from sensors, effectors, drones, robots, interconnected units, the automatic processing of this huge amount of data by the Thales CDP



Graphic showing the envisaged connectivity-based situational awareness which could be provided by Thales CDP.

drastically reduces cognitive workload of crews, eases use, training, mission preparation and deployment." They said the CDP performs services relevant to all unit levels taking information from collaborative observations of sensors of all kinds. It takes SA data feeds, like those of full motion video from vehicle optronic sights, alerts from gun-shot detectors, bearings from RF

direction finders or radar tracks, and then, using AI, extracts 'objects of interest' it finds in those sensors feeds. It performs multi-sensor, multi-vehicle data fusion to create combat tracks and displays those tracks on a local situation map, broadcasting the combat tracks and situation map on all relevant units' tactical radio network in 'reflex time' (sufficient time to react to

threats). The CDP effectively combines the under-armour SA of multiple sources and disseminates all that information across the relevant battlespace, enabling closed-down AFVs and MBTs to 'see' their wider surroundings and react to potential threats in time to survive.

The CDP has been carefully designed with an easy-to-use interface. Command phrases and operational gestures are simple and familiar, keeping cognitive workloads low. The platform provides continuous information sharing at all levels of command, augmented SA thanks to cooperation between sensors and effectors, smart services and Al-powered decision-making aids to lighten cognitive workloads, and easy integration of UAV/UGVs and dismounted soldiers to multiply presence.

The platform, operating from the brigade level to vehicles out on the front line, is comprehensive and provides services that aid command and control (C2) of tactical units, as well as aiding in observation, protection, the decision-making cycle and action at all levels. Thales' CDP is built on a cloud-ready digital platform, and is compatible with connectivity solutions such as Software Defined Radio and LTE to provide its collaborative combat SA capabilities.



Still Searching for Clarity – British Armour Programmes

David Saw

It is hard not to be cynical when looking at British defence programmes, or to be more precise the management of those programmes. Over the years British defence procurement has been characterised by short term thinking and ineffective financial management. This has led to cost overruns and seemingly an inability to deliver the end-user a system that meets the operational requirement, works properly, can be sustained in service, and actually arrives on time and on budget. Getting procurement right still remains an oft spoken ambition, but making it a reality has proven to be elusive.

ritain is not alone in having major problems with defence procurement and defence budgeting, other nations across Europe are experiencing similar difficulties. However, in Britain it always seems that it is only a matter of time before unpleasant procurement news will surface and, depending on its importance and visibility, create a scandal, or a resigned shrug where a negative result is somehow expected. Despite this, there are times when there is an outbreak of optimism and a belief that this time, finally, the Ministry of Defence (MoD) will manage to get its spending plans under control and that hitherto unsuspected and unused programme management skills will emerge. Then as the MoD, the procurement authorities and the end-users enter the sunlit uplands of controlled spending, effective procurement and long-term support plus happy end-users, the obvious truth that this can only be fiction emerges and all parties concerned resume the normal state of depression and resignation that the system will never be fixed.

Despite all of this negativity, all of a sudden some positive events were happening for the MoD. In November 2020, the British government delivered good news to the MoD. The UK's Treasury announced that the MoD would receive GBP 16.5 Bn of additional funding, over and above the funding that they had expected to receive between 2021-2022 and 2024-2025. Then came the publication of two important defence strategy documents in March 2021: "Global Britain in a Competitive Age, the Integrated Review of Security, Defence, Development and Foreign Policy" and the MOD Command Paper on Defence (CP411) "Defence in a Competitive Age."



How the British armour future was supposed to look (from left to right): the Warrior Capability Sustainment Programme (WCSP) upgrade (now cancelled), Challenger 2 upgrade to Challenger 3, Ajax, and Boxer for Mechanised Infantry Vehicle (MIV) requirement.

With these documents Britain had established its defence policy/strategy for the next decade.

According to the National Audit Office (NAO) in their report on the value for money aspects of the MOD 'Equipment Plan 2021 to 2031,' the MoD believed that: "the combination of these reviews (the two strategy documents) and the settlement (the extra funding) represented a real chance to remedy the affordability problems it had struggled with in its equipment planning over many years, as well as a chance to make a step-change in defence capability."

Dealing with Realities

On paper this all sounded grand, the problem is that the MoD and defence policy do not act in isolation, there is more going on outside the British defence ecosystem than the MOD can adequately plan to confront. Events in London and beyond challenge the assumptions that the British government had in 2020 and 2021, the world is a very different place today than it was in 2021

and the defence and foreign policy challenges facing Britain today are far more complicated than they were in 2021.

On a political level, the Conservative government had a substantial majority from its victory in the December 2019 election. It moved forward on resolving the issue of Brexit, which further solidified its voting base. However, what would transform the political and economic situation in Britain were the three waves of COVID that rolled in across 2020 and 2021. The measures taken to control COVID gradually exhausted the political capital of the government, challenging its power, authority and eventually the legitimacy of its leadership. The economic consequences of COVID, especially the massive increase in government expenditure would have increasingly negative impacts. The loss of faith in the economic competence of the government, would further weaken their position.

The 'Global Britain' integrated review and the Defence Command Paper of March 2021 were documents prepared by a confident government, but by the end of 2021 it was a government lacking confidence. Even so, nobody could predict what was going to happen in 2022 and the possible implications of those events for the future of major British defence programmes.

In early 2022 British Prime Minister Boris Johnson was beset with domestic political problems. Internationally, his provision of extensive support to Ukraine in response to the Russian invasion demonstrated unexpected leadership and political acumen. However, once members of his own government started turning on him, his reign was over in July. Then followed a leadership election in the governing Conservative Party and Liz Truss became Prime Minister in September, she lasted some 49 days, and was succeeded in late October by Rishi Sunak.

In the midst of all of these changes of government, it suddenly became obvious that Britain had major economic problems. There was excessive government debt, inflation was rising, the economy was anaemic with low or zero growth, and the country was essentially in a recession. To be fair, post-Ukraine invasion, most of Europe was in an uncertain economic situation. The reaction of the Sunak government was somewhat old-fashioned, it would attempt to control spending whilst increasing taxes. It is having to deal with a wave of strikes and its popularity looks likely to plummet even further. It remains to be seen if the Sunak government will be up to meeting these economic challenges.

Dangers in Defence

While the Johnson government might have been ideologically committed to increasing defence expenditure and looking to play a more overt role in support of its 'Global Britain' agenda, the same cannot be said of the Sunak government. The crux of the matter is this – "Can a less than popular government justify, or be prepared to justify, increased defence expenditure and major defence procurement programmes in the midst of an economic downturn?" The most probable answer to this question is that they will desperately try and avoid making any decisions whatsoever. The problem with that is that eventually you will have to make a decision and by that point, any decision that you make could well be ill-considered.

All of which means that defence spending and procurement promises that seemed so certain even a few months ago, must now be considered in doubt. We will have an indication of what direction the government intends to take, most probably by the end of March 2023. This will see the issue of the Treasury's Spring Statement which should provide an idea of how the government sees its financial situation and constraints. In the same time period, the government is due to publish and updated version of the 'Integrated Review' and in the wake of that the MOD will publish its updated Defence Command Paper. Only then will the official policy direction be known.

Being realistic, it is hard to see any grounds for confidence that the British and other European economies will experience any real economic improvement in 2023. Energy will remain a major issue in the first quarter, with matters not helped by the fact that the global economy is also likely to be dealing with an uncertain future. Added to which, matters will not be helped by the continuing COVID crisis in China, the true magnitude of which remains uncertain, as is its potential impact on the global economy.

The British government will be under an immense amount of fiscal pressure in 2023, inevitably this must have an impact on defence spending. If the current government wishes to remain in office, it has all of 2023 and the majority of 2024 to put the economy on the right track and restore its popularity. To win that future election, the government will have to make difficult decisions in 2023 and hope that they get the payoff in 2024. This is hardly the environment for a considered long-term defence strategy and effective procurement planning.

Armour Modernisation

In an environment where funding is uncertain and where the commitment of the current government to defence modernisation is in doubt, this brings us to the current state of play in British Army armour programmes and the future of these programmes in the face of these doubts over political support and funding. At one stage there were four major armour programmes being worked on, these were: Warrior Capability Sustainment Programme (WCSP), Challenger 2 upgrade, Ajax, and the Mechanised Infantry Vehicle (MIV) for which the Boxer had been contracted in November 2019.

Even after more money had been promised to the MoD in late 2020, and after the release of the Integrated Review and the Command Paper in March 2021, the British Army nonetheless found itself with WCSP, one of its four major programmes, cancelled in March 2021. It is true that this programme was running late and was over budget, but the programme did look to be salvageable. However, the programme was cancelled primarily to save money, although at the time the implication was that cancellation was caused by a lack of confidence that the programme could successfully deliver.

With no WCSP, the existing Warrior fleet will remain in service for lack of an alternative, but with the originally stated out of service date being 2025, there is going to be a major capability gap after this point unless some of the vehicles are kept on. In an ideal world there would be an IFV programme to replace Warrior, unfortunately such a programme does not exist at this point.

Over the years there have been mixed signals concerning the British Army Challenger 2 tank fleet, but eventually they embarked on the Challenger 2 Life Extension Programme (LEP). This gradually grew in scope until it evolved into the Challenger 3 upgrade programme and on May 7, 2021, RBSL were awarded a GBP 800 M contract to upgrade 148 tanks out of a current fleet total of 227 to the Challenger 3 configuration. In an answer to a Parliamentary question in December 2022, the Secretary of State noted that: "Challenger 3 is scheduled to enter service in 2027, with an out



The Boxer was chosen to meet the British Army Mechanised Infantry Vehicle (MIV) requirement and, at the present time, this is one of the rare British Army procurement programmes with no problems. In total 623 Boxers are on order in a fully funded procurement.



On the training area at Bovington in March 2021, an Ajax vehicle working up for a British Army capability demonstration. During 2021 noise and vibration issues halted the Ajax trials programme. These solutions have been found, and the trials programme will re-commence in January 2023.



A Household Cavalry crew during the Ajax trials programme in 2021. The reliability and growth trials for Ajax are due to restart in January 2023 and are expected to last from 18 to 24 months. Officially, according to a written answer in Parliament, there is no firm forecast In-Service Date (ISD).

of service date of 2040." The British Army desperately needs the capabilities of this upgraded tank, but in the current environment, some might ask if spending GBP 800 M on a tank intended for 13 years of service is a logical course of action?

This brings us to Boxer, in a recent Parliamentary answer the current state of play on the programme was described as follows: "623 Boxer armoured vehicles have been ordered against a funded provision of 1,016. The 1,016 includes potential future variants which are being explored on a longer-term basis with allies and industry in line with the Land Industrial Strategy." There is great enthusiasm surrounding the Boxer programme, costs are under control and no technical catastrophes have been encountered. Indeed, it almost seems that if a new armoured vehicle-related requirement emerged at the MoD, Boxer would be the first suggestion to meet it!

Then we come to the Ajax programme which has found itself mired in controversy for some considerable time. The NAO described the programme status in a March 2022 report: "The [MoD] has a GBP 5.522 Bn firm-priced contract with General Dynamics Land Systems UK (GDLS-UK) for the design, manufacture and initial in-service support of 589 vehicles. At December 2021, the Department had paid GDLS-UK £3.167 billion and, at this point, GDLS-UK had designed the vehicles, built 324 hulls and assembled and completed factory acceptance testing of 143 vehicles. The Department had received 26 Ajax vehicles, as well as associated training systems and support."

In its report on the Ajax programme, the NAO contends that both the MOD and the contractor did not understand the scope and complexity of the programme. Difficulties with the programme caused the date for Initial Operating Capability (IOC) to be pushed

from the initially envisioned 2017 out to July 2020, however this date was also not met, and IOC was pushed to June 2021. Once again this IOC date was not met, but at this point it was the least of the problems facing Ajax, as significant noise/vibration issues had led to the trials programme being halted in November 2020. A solution was apparently found, and trials commenced once more in March 2021, then safety concerns resurfaced, and the trials were halted again.

The Ajax programme was in serious trouble, but by December 2022 the situation had changed somewhat, with the publishing of the MoD's 'Ajax Noise and Vibration Review' policy paper, in which the MoD stated that there was a system to manage noise and vibration problems. The solutions comprised noise-cancelling headsets for the crew to reduce the effects of noise, and unspecified "system adjustment", along with "managing exposure times" for the crew to reduce vibration issues. Neither of these seem like particularly permanent solutions, but they are evidently seen as sufficient to allow trials to continue. Answers to Ajax-related Parliamentary questions in December 2022 on the Reliability and Growth Trials revealed that: "Work to recover the Armoured Cavalry Programme is well underway and will be taken forward for formal approval by Ministers from this Department and His Majesty's Treasury early in the New Year." A question on how much time would be necessary to complete these trials revealed that: "The Reliability Growth Trials and subsequent analysis are expected to last 18 to 24 months." There is no question that Ajax is a critical

programme for the British Army, it is central to its future organisation and strategy. The crux of the matter is whether there is enough faith that the MOD can manage the programme and deliver the desired capability in an acceptable time scale. There are two schools of thought here, the first of these is that the programme is now on track and there is no alternative except to continue. The other is that the programme cannot be recovered and should therefore be cancelled, an option which would only benefit lawyers who would be involved in litigation surrounding a cancellation. Then there is the challenge of what to do instead, can a suitable replacement capability be found, and could it be afforded?

Of the four major armour programmes that we have discussed, Boxer and Challenger 3 are both on course, while Warrior is cancelled. As for Ajax, it appears that it has managed to claw its way back from the edge of the grave. The question now is has Ajax done enough to survive? The answer to this question should emerge in the first quarter of 2023.

Armoured Engineer Vehicles Play a Key Role

Christopher F Foss

Armoured Engineer Vehicles (AEVs), or Combat Engineer Vehicles (CEVs) as they are also referred to, play a key role not only on the battlefield, but also have a role to play in disaster relief as they are well equipped to rapidly clear roads and other obstacles using their specialised front end equipment (FEE).

The traditional role of the AEV has been clear obstacles that are hindering the advance using their front mounted dozer blade, preparing firing positions or using their on board crane which can be fitted with various attachments such as a bucket, auger or pincer. AEVs have a flexible design as the dozer blade can rapidly be replaced by plough or roller type mine clearing devices as well as installing a clear lane marking system either side at the hull rear.

MBT-Based AEVs

The majority of heavy AEVs are based on a Main Battle Tank (MBT) platform, or use components from an MBT for fleet commonality. To ensure that AEV can support MBTs during ground manoeuvre operations, the ideal solution is to field the AEV at the same time as other specialist vehicles such an Armoured Vehicle Launched Bridges (AVLBs) and Armoured Recovery Vehicles (ARVs). However, all too often AEVs are procured many years after the introduction of the MBT, with the German Army's experience being a good example of this

The Krauss-Maffei Wegmann (KMW) Leopard 2 MBT entered service with the German Army as far back as 1979/80 but ever since then the standard AEV of the German Army has been based on the Leopard 1 ARV hull (Bergepanzer 2), with the final version being the Pionierpanzer 2A1 Dachs. Much later, the first Leopard 2 based AEV was developed as a private venture (PV) between Rheinmetall (Germany) and RUAG (Switzerland) called Kodiak. The first version of Kodiak was based on a surplus Leopard 2 hull with a brand new welded superstructure, it was provided with a hydraulically operated dozer blade and a hydraulic arm which can be fitted with various attachments such as a bucket. The first customer was Switzerland who took delivery of 12 units based on surplus



Kodiak AEV using its front mounted dozer blade to start filling in a trench and with the hydraulic arm with bucket attached extended over the front of the hull

Leopard 2 MBT hull and since then additional sales have been made to Netherlands (10), Singapore (18) and Sweden (six). The latest customer was Germany, who placed a contract in May 2021 covering the supply of 44 units for delivery from 2023 through to 2029 under the designation 'AEV3'.

The German company Flensburger Fahezeugbau GmbH (FFG) has considerable experience in the overhaul and upgrade of tracked Armoured Fighting Vehicles (AFV) for the German Army and various export customers. Using PV funding, FFG developed the Wisent 2 Armoured Support Platform (ASP) which is based on a Leopard 2 platform, with the turret removed and replaced by a new armoured superstructure housing the crew of three. A unique feature of the Wisent 2 ASP is

the flexibility of the modular design, which according to the company allows it to be re-roled from the ARV configuration to the AEV configuration in just five hours. Standard equipment for the AEV includes a front mounted dozer blade, winches and a hydraulic excavator arm on the right side that can be fitted with various tool attachments such as a bucket or gripper. In addition to AEV, ARV and Minefield Breaching (MB) kits, FFG has also completed a concept for carrying and deploying an MLC 80 tactical short bridge by the Wisent 2 AEV model.

The vehicle has been sold to Canada (18), Norway (12), Qatar (6), United Arab Emirates (4) and Hungary (5) with some of these being direct sales while others are part of a package. Qatar's contract was



Wisent 2 Armoured Support Platform in AEV configuration using its front mounted dozer blade and with crane with bucket attach in stowed position

through KMW and also included 11 mission kits, of which four were AEV, three ARV and four Minefield Breaching (MB). To meet the requirements of Finland, the local company of Patria developed the Heavy Mine Breaching Vehicle (HMBV) and completed 10 production vehicles. This was also based on the Leopard 2 platform, with turret removed and fitted with a new welded superstructure. The hull front has been designed to accept the Pearson Engineering Combat Dozer Blade (CDB), Full Width Mine Plough (FWMP) or Surface Mine Plough (SMP) with a Pearson Engineering Clear Lane Marking System (CLMS) either side at the rear which dispenses marker pennants into the ground as the vehicle moves forward clearing the mines.

Most of the Leopard 2 based AEVs were based on surplus hulls, but as these have all now been used up, new Leopard 2 based AEVs are based on new-build hulls, so have a comparatively longer life than their predecessors.

To support their large fleet on Hyundai Rotem K1/K2 MBTs deployed by the Republic of Korea Army, a family of support vehicles have been deployed including an AEV which is based on the K1 ARV. This can be fitted with various front end equipment, and a hydraulic crane is fitted at the front left side of the hull which can be fitted with various attachments.

The British Army had a competition for the Engineer Tank System (ETS) which was won by Vickers Defence Systems who developed the Trojan breacher and the Titan AVLB with a total of 33 production systems of each completed. Trojan breacher is based on Challenger 2 components and can be fitted with a front mounted Pearson Engineering CDB or a FWMP. On the right side of the hull is the hydraulic arm which can be fitted with various attachments. It can also tow a trailer fitted with a Python rocket-propelled mine-clearing line charge (MCLC), as well as carrying pipe fascines to drop into ditches, allowing other vehicles to cross.

For many years the standard AEV of the US Army was the M728 based on the M60A1



British Army Trojan breacher deployed to Afghanistan and fitted with Pearson Engineering Full Width Mine Plough in raised position and pipe fascine carried at rear

series MBT and fitted with a dozer blade, A-frame crane boom, and a turret mounted 165 mm demolition gun. This was due to have been replaced by the General Dynamics Land Systems (GDLS) Grizzly AEV, based on the M1 Abrams MBT platform, but this was cancelled. However, the US Army later procured the M1150 Assault Breacher Vehicle (ABV), which was also based on the Abrams platform.

The ABV was originally developed to meet the requirements of the US Marine Corps (USMC) but subsequently adopted by the US Army. As part of the process of modifying the Abrams platform to its new role, the vehicle's turret was removed and fitted with a superstructure, with mounting points for explosive reactive armour (ERA) added over the frontal arc for higher survivability.

The M1150 ABV can be fitted with the Pearson Engineer FWMP or CDB, and mounted on the hull rear are two launchers for the Linear Demolition Charge System (LDCS) which fires a solid propellant rocket attached to a line charge containing high-



Hyundai Rotem AEV based on the K1 ARV, showing crane with bucket traversed to rear and fitted with Pearson Route Opening Mine Plough in deployed position



US Assault Breacher Vehicle showing Pearson Engineering Full Width Mine Plough lowered to the ground and rocket propelled mine clearing equipment deployed at the rear

explosive which is launched, trailing the line charge behind it. Once the line charge has landed on the ground, the charge is then initiated, with the resulting explosion detonating the mines by subjecting them to overpressure.

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The Lynx Family

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Lighter Tracked AEVs

In addition to AEV based on a heavy MBT chassis, a smaller number of dedicated AEV have been developed and placed in service. For many years the British Royal Engi-

neers (RE) deployed the Royal Ordnance Factory FV180 Combat Engineer Tractor (CET) and took delivery of 143 with export sales made to India (15) and Singapore (54). In British Army service this has now been replaced by the Vickers Defence Systems Terrier CEV with a total of 60 production vehicles being delivered from the Newcastle-upon-Tyne production line by 2014, after which the factory was closed and sold to Pearson Engineering.



Turkish Armoured Amphibious Combat Earthmover is fully amphibious being propelled in the water by rear-mounted two water jets.

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REPORT

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Photo: Pearson Engineering

British Army Terrier Combat Engineer Vehicle carrying pipe fascines at front and rear and crane deployed to front



The Royal Army of Oman has taken delivery of a fleet of Turkish Pars III vehicles including six configured as Engineering Vehicles which can be fitted with various FEE such as this Pearson Engineering dozer blade



Spanish GDELS Santa-Barbara Sistema's Dragon (8x8) fitted with the Pearson Engineering Vector plough type mine clearing device on the front of the hull, in the raised position.

Unlike the CET, the Terrier CEV is not amphibious and is fitted with a front mounted bucket which can be replaced by Pearson Engineering mine clearing equipment, ripper attachment or forks. It is also fitted with a scissor-type hydraulic arm which can be fitted with various attachments such as a bucket, earth auger or lifting hook. Terrier can also carry pipe fascines to drop into trenches or tow a trailer carrying mine clearing or other engineering equipment.

Elsewhere, Turkish company FNSS Savunma Sistemleri developed the Armoured Amphibious Combat Earthmover (AACE), also referred to as the 'Kunduz,' to meet the requirements of the Turkish Army and a total of 12 were delivered by early 2013, although the system is still being marketed. The vehicle is operated by a crew of two and is fully amphibious, being propelled in the water by two water jets at a maximum speed of up to 8.6 km/h. In addition to clearing battlefield obstacles AACE is also used to prepare bridge crossing points, has a recovery winch and can tow a trailer.

In many respects the FNSS AACE is similar to the US BAE System M9 Armored Combat Earthmover (ACE) which has been built in large numbers for the US Army as well as some export customers, but production of this was completed some time ago.

Wheeled AEVs

An increasing number of countries are now deploying wheeled AFVs, especially and some of these countries have already fielded dedicated AEV, which is normally based on a modified armoured personnel carrier (APC).

A good example is the US Army who has developed a large number of variants of its Stryker Infantry Carrier Vehicle (ICV), with the baseline model being the M1126. The US Army has also fielded a dedicated Engineer Squad Vehicle (ESV) designated the M1132 which can be fitted with Pearson Engineering plough or roller type mine clearing devices.

Oman placed a contract with FNSS of Turkey for 172 of the latest PARS III wheeled AFVs, which consisted of 13 variants, of which 145 were in 8×8 configuration and 27 in 6×6 configuration. Included in the batch of 127 8×8s were a batch of six AEVs which could be fitted with a variety of front end equipment from Pearson Engineering, including a hydraulic crane, dozer blade and mine clearing ploughs. The Swiss Army has a large fleet of General Dynamics European Land Systems

(GDELS) Mowag Piranha (8×8) vehicles and in May 2021 the Swiss Army placed a contract for 60 Engineer Vehicles based on the Piranha IV (8×8) platform, with deliveries to run from 2026 onwards.

To further expand its range of countermobility and mine clearing systems, Pearson Engineering have developed a new self-protection mine plough called 'Vector,' which has already been demonstrated on a GDELS Santa Bárbara Sistemas VCR Dragón (8x8) vehicle. Vector consists of two plough blades with each of these covering at least the width of the vehicles wheels. Each plough blade brings buried mines to the surface and moves them into 'spoil heaps' either side of the vehicle.

The standard AEV of the French Army today is the Nexter Engin Blinde du Genie (EBG) (Combat Engineer Tractor) based on the AMX-30D ARV. A total of 71 were built and 54 of these were subsequently upgraded at Roanne, which included the removal of the 142 mm demolition gun and the capability to lay anti-tank mines. The French Army has now moved to almost a complete wheeled fleet, apart from the Leclerc MBT, and in the future will replace the EBG with a wheeled solution which is referred to as the Engineer Combat Support Vehicle (ECSV), and will probably in an 8x8 configuration.

The Future

Developing an AEV from the ground up is a very expensive and time-consuming process, so the trend is to base the vehicle on an existing platform, modified for its new mission with the ability to be rapidly fitted with front end equipment to meet specific operational requirements. Using an existing platform not only reduces costs but and



General Dynamics Land Systems Tracked Robot 10 ton (TWRX) fitted with the Pearson Engineering obstacle clearing pack which includes a front mounted V-obstacle blade

makes training and logistic support that much easier. Recent AEVs have been developed for world-wide operations rather than operations in Europe, and so an air conditioning system is now fairly standard.

They will also be fitted with a battle management system (BMS) to exchange information with other platforms. Some AEVs, for example the British Terrier, are already fitted with a system for remote control from a safe distance. Unmanned Ground Vehicles (UGV) have a potential use and at AUSA 2022, General Dynamics Land

Systems showed their 'Tracked Robot 10-ton' (TRX) unmanned technology demonstrator. This uses a flatbed design to accommodate different mission payloads, and has already been demonstrated to the US Army. At AUSA 2022 it was shown fitted with the Pearson Engineering obstacle clearance mission pack and was called the RCV-Pioneer in this configuration. The mission pack included a front-mounted V-shaped obstacle clearing blade as well as a robotic arm to pick-up, drag and move items that hinder the advance.



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Hybrid Propulsion on the Battlefield – The Wave of the Future or the Wrong Direction?

David Saw

Carl Benz ran his first gasoline-driven engine at the end of 1879. Development continued and by 1885 Benz had developed a two-seat gasoline powered automobile. Then in July 1886, the three-wheeled Benz Patent Motor Car, model no. 1 made its public debut and the automotive age had begun. Other powered mobility solutions followed, but at this point there was no agreement on the most effective solution to provide motive force for these new vehicles. Would it be gasoline, steam or even electric power? A similar debate is rearing its head once again.

nterestingly steam-powered cars, such as the Stanley Steamer, remained competitive in the US vehicle marketplace as late as 1918/1919, but in reality it was the gasoline Internal Combustion Engine (ICE) that had emerged as the vehicle powerplant of choice, offering greater fuel efficiency and power than their competitors. Added to which, another ICE option had appeared in the 1890s when Rudolf Diesel developed the diesel engine. Electric powered vehicles had initially proven very attractive in the vehicle marketplace, but as the ICE improved in performance and came down in cost it soon came to surpass the electric alternative.

The ICE would come to revolutionise ground transport, but it would also make aviation a real possibility, adding another aspect to its transformational progression. As the ICE grew more and more important, it also reinforced the strategic trend to have secure sources of oil. However, even before the First World War, having a secure oil supply had become a priority for Britain, as in 1911, Winston Churchill, at that time the First Lord of the Admiralty, the civilian head of the Royal Navy, had decided that the Royal Navy, at that time the largest navy in the world, would switch from coal to oil as its source of energy.

The Importance of Oil

As time went on the importance of the ICE and oil grew even faster, and by the start of the Second World War, it was clear that access to oil was a strategic necessity. The kind of war that was going to be fought required oil and yet one side had a domi-



A Leclerc tank of the 5e régiment de dragons (5e RD), French Army. The future of the French Army tank fleet is based on the Main Ground Combat System (MGCS), but the Leclerc will continue in service until that arrives and there are suggestions that a hybrid propulsion upgrade for Leclerc could make sense.

nant position in terms of access to oil. The Allied powers effectively had control of some 90% of global oil output, in contrast the Axis powers only had control of 3% of global oil output. Oil was essential for industrial age warfare, and when you look at who had the oil, the result of the conflict was arguably pre-ordained. Unless the Axis powers could gain control of more oil resources or interrupt oil supply to the Allied powers, they would inevitably lose. As they could not achieve either of these objectives, it was increasingly inevitable that their ability to sustain combat operations would diminish.

In the post-1945 era, oil was cheap and there was a seemingly endless supply, helping to speed recovery from a ruinous global conflict

and sustaining nearly thirty years of economic growth in the major global economies. From a strategic point of view, it seemed that there was no need to worry about securing oil supplies, as sources of supply were so diverse that it was impossible to conceive of any serious interruption in supply.

Supply diversity also saw important developments in Europe, for example the Groningen gas field in the Netherlands was discovered in the late 1950s. This was a major gas find on a global scale and was successfully tapped for many years, yet unfortunately the gas extraction process started causing earthquakes, leading to extraction levels being reduced and finally, a decision was taken to close the field, with this to be achieved after 2025.

Where Europe would discover major oil and gas resources was in the North Sea, the two major beneficiaries of this were Norway and Britain, with Denmark, the Netherlands and Germany also sharing offshore resource areas. By the late 1960s, significant gas and oil discoveries had been made, but offshore resource extraction in the hostile environment of the North Sea was both dangerous and expensive. It would take events elsewhere to change the viability of the North Sea.

What changed the economics of oil and destroyed the existing global economic growth model was the October 1973 Arab-Israeli War, or rather its aftermath. The Arab oil states introduced an embargo on the supply of oil, the economic impact of this move was felt almost immediately and although supplies were resumed, the age of cheap oil was over. Oil prices rose and oil price volatility became an issue, the downstream impact of this was the cost of power, heat and transportation increased and this led to price increases and inflationary pressure across national economies. It also demonstrated that Western countries were now in a position of strategic vulnerability as they could not guarantee their oil supplies.

The 1973 oil embargo saw a number of responses within Europe, North Sea oil and gas became more important in the European energy mix and its extraction cost was covered by the rise in oil prices. France took a different approach towards energy security, deciding in 1974 to embark on a nuclear power plan that would eventually supply more than 70% of its electricity requirements. Unfortunately, the lessons of the need for energy security were forgotten across much of Europe over the years, leading to the energy price and supply chaos that Europe has experienced since the Russian invasion of Ukraine in February 2022.

Everything's Gone Green

Cheap and abundant power is essential for the modern state, that is an inescapable fact, yet that truism was no longer enough to justify how the necessary power was obtained. In Western societies there were increasing concerns about pollution, these grew into broader concerns about the environment and the environmental movement was born. Over time these issues moved from being fringe concerns to becoming an accepted part of social and political discourse. Not unlike today, there were warnings of an approaching climate crisis and the suggestion that the world was running out of critical natural resources, especially

fossil fuels such as oil. Justifiable concerns over pollution and environmental degradation continue to grow. Outside of Europe, as countries seek economic growth and development, led by China and India, demands for power and resources grow and in those situations environmental concerns often take second place.

In Europe, many governments took the position that vehicles must become less polluting and more fuel-efficient, one aspect of this was the stress on the fuel economy advantages offered by diesel-powered vehicles. While they delivered on the fuel economy front, an unanticipated side effect was the pollution they produced through the emission of particulate matter. What changed the game in the automotive sector came at the end of the 1990s with the arrival of the first Hybrid Electric Vehicle (HEV) in the form of the Toyota Prius.

Since the Prius arrived, the automotive sector has changed totally and this process of change will continue. Most significantly, the age of the conventional ICE vehicle is coming to an end in Europe. The UK was the first to move on this, with petrol or diesel-fuelled ICE cars to be banned from sale in the UK from 2030, small diesel-fuelled trucks from 2035 and diesel-fuelled trucks with a weight of over 26 tonnes will be banned from 2040, or earlier if possible. In June 2022, the European Parliament voted to confirm a European Commission plan that calls for a ban on all ICE powered cars, both petrol and diesel, from 2035 onwards.

The plan is that post-2035 it will only be possible to purchase Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEV), powered by hydrogen. Hybrids like the Prius, because they use an ICE as well as an electric motor, will be a victim of the EU ICE ban. It is important to note that the ban of ICE vehicles and hybrids will only effect vehicles purchased in 2035 and after, meaning existing vehicles can be used post-2035.

The fact that these bans exist will obviously change the dynamics of the car, bus and commercial vehicles marketplaces. Even before the passage of the EU legislation, Volvo Trucks was committing to BEVs; stating that 50% of their truck range would be BEVs by 2030 and 100% by 2040. Beyond this, hydrogen fuel cells are being seen as a good power source for locomotives in those areas where lines are not electrified. All things considered, the end of the ICE in Europe is due from 2035 onwards. California will impose similar rules post-2035, as will a number of other states in the US.

Inevitably, doubts have been expressed over the wisdom of betting the future on BEVs, this is based on the uncertainty of who will deliver the charging stations and whether national electrical grids will have the capacity to cope with the increased demand from charging BEVs. Such problems have already arisen in at least one case – during bad weather in late 2022, California asked its inhabitants not to charge their electric cars in order to save power.



A French Army Griffon armoured vehicle of the 2e régiment d'infanterie de marine (2e RIMa), based at Champagné. In September 2020, the French Ministry of Defence announced that they would be looking to fit a Griffon with a hybrid propulsion package for proof of concept testing.



A Challenger 2 of the Queens Royal Hussars, with a dozer attachment fitted, breaks through an abatis obstacle on a training exercise in Estonia. Thought has been given to a hybrid or a full electric propulsion system as a replacement for the conventional engine system in the Challenger 2.

Where To Next?

The fact that conventional ICE-powered vehicles will no longer be available post-2035 creates a problem for military users, especially if the major truck companies build their product ranges on BEVs. Requiring military logistics vehicles, the majority of which are based on commercial trucks technologies, to find charging stations in an operational environment is not a very practical proposition. Of course, if your vehicle batteries could hold charge for far longer than is currently practicable, work efficiently in hostile conditions and deliver predictable and reliable performance, one might be willing to trust a BEV logistics truck. However, recent news coverage of BEVs in the US being marooned because their batteries lost power in cold weather hardly fills military vehicle users with confidence in an electric vehicle future.

It is clear that there is political pressure on the military to follow the zeitgeist of environmental politics and make its contribution to confronting the climate crisis. There are ways that the military can meet these requirements, for example the use of sustainable fuels and other measures to reduce carbon footprint. What the military cannot do is sacrifice equipment performance and operational capability to meet environmental goals.

Some years ago in France, the armoured and logistics vehicle manufacturer Arquus decided to study whether an electric drive system could replace the ICE on a VAB armoured vehicle. Their study came to the conclusion that if you wanted a vehicle that had the autonomy to conduct a three-day mission, you would need a 25 tonnes vehicle with 11 tonnes accounted for by the batteries alone, even then your BEV would not be able to conduct the desired mission. Current battery technology would still be unable to meet the mission parameters defined in this French study.

Where military vehicles can go some way to meeting goals to reduce emissions by decreasing reliance on ICE powerplants, is through embracing hybrid solutions. These can deliver the necessary performance, whereas BEV solutions still cannot. There have been some interesting studies in Britain of non-traditional power options for a Challenger 2-sized tank. The current power pack of a Challenger 2-sized tank weighs some 5.9 tonnes, the accompanying diesel fuel system weighs 1.5 tonnes. Altogether that is 7.4 tonnes and that occupies a volume of 5.7 m3. Replacing that traditional system with a BEV system of similar power and endurance would require a Lithium-Ion battery system with a weight of 28 tonnes and an electric drive system weighing 2 tonnes. Altogether, the BEV option would weigh 30 tonnes and would occupy a volume of 21.2 cubic metres!

Therefore, transitioning from a conventional power pack solution to a BEV solution would add 22.6 tonnes in weight and would require nearly four times the volume. Obviously that is a complete nonstarter, but what of the hybrid solution? This would comprise of a diesel fuel system with a weight of 1.1 tonnes, an engine/generator at 2 tonnes, a Lithium-Ion battery system at 0.4 tonnes and an electric

drive system at 2 tonnes. Total weight of the hybrid solution is 5.5 tonnes in a volume of 4.8 m3, resulting in both a weight and space saving, which on an armoured vehicle is always appreciated. On top of that, the British study indicated that a hybrid solution would be half the price of the BEV solution!

There are also operational advantages to be gained from a hybrid system, Arquus have developed the Scarabee 4×4 vehicle for reconnaissance and other missions to meet the French Army Véhicule Blindé d'Aide à l'Engagement (VBAE) requirement to replace the existing VBL vehicle. The electric drive system of the Scarabee would substantially reduce is noise signature in reconnaissance missions, increasing operational capability and survivability. Other hybrid projects at Arquus include a joint effort with the Direction générale de l'Armement (DGA) on a hybrid solution for the Griffon armoured vehicle that could potentially be applied to other French wheeled armour such as the Jaguar and the VBCI.

There are also hybrid developments under way in the US. At the AUSA 2022 exhibition in October, General Dynamics Land Systems (GDLS) displayed the AbramsX. This is effectively GDLS suggesting a number of possibilities for the future evolution of the M1 Abrams tank family, and notably the power solution selected by GDLS was hybrid.

Hybrid power solutions are increasingly becoming a viable alternative to the ICE in many military mobility applications. Although interest in hybrids is being driven by current political concerns and fashions, there are areas in which the hybrid can offer real advantages. On the other hand, unless there is a revolution in battery capability, we are a long way from BEV systems in many critical military applications.



At the AUSA exhibition in Washington DC in October 2022, General Dynamics Land Systems (GDLS) displayed the Abrams X, their view of a possible series of evolutionary developments for the Abrams tank using currently available technology. The Abrams X features a hybrid propulsion system.



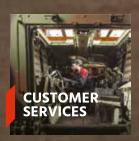
Nexter, land defense architect and system integrator in France, is a major reference in armored combat systems, artillery, and in the ammunition field. Nexter designs innovative solutions for land, air, sea and security forces, in order to bring French and foreign armed forces a decisive operational advantage.











Cold-Weather All-Terrain Vehicles: NATO Member Programmes

Sidney E. Dean

The combination of climate change and increased tensions with Russia is increasing NATO nations' focus on security interests and military operations in the Arctic and other cold-weather zones. A significant number of NATO members already operate vehicles optimised for these zones. Several are currently upgrading or replacing their cold-weather fleets.

Several categories of vehicle are designed or optimised for cold-weather operations, including snowmobiles and similar open configurations. This article will focus on medium-sized, enclosed vehicles frequently designated as Coldweather All-Terrain Vehicles (CATV). These CATVs feature very broad tracks which distribute vehicle weight, reducing ground pressure far below that of wheeled or standard tracked vehicles. This enables them to traverse deep snow as well as ice and broken ground, including steep mountainous terrain. They are also capable of crossing other difficult terrain, including marsh and bogland, as well as sand. In fact, many of the same NATO units which deploy their CATVs for Arctic and European mountain operations have also dispatched them on missions to Africa, the Middle East and Afghanistan. Depending on configuration, they can be used for personnel transport, medical/casualty evacuation, engineering and logistics vehicles, or as sensor and weapons platforms.

BAE Hägglunds

BAE Systems Hägglunds AB currently is the clear market leader. Its vehicles predominate in the current CATV fleets, and are among the frontrunners in ongoing competitions for new vehicle acquisition. Headquartered in Sweden, the firm is currently a subsidiary of BAE Systems AB, BAE Land Systems and, ultimately, of UK-based BAE Systems.

The majority of BAE Hägglunds' CATVs have designators beginning with Bv (Bandvagn, Swedish for tracked vehicle), although some users assign each class a different name. The typical configuration consists of a front and rear cab connected via a coupling link and electric cables. This articulated assembly enhances



Royal Marine BvS 10 Viking Vehicle ploughing through the snow on training area in Harstag Norway.

manoeuvrability over difficult terrain. The engine (optionally gasoline or Diesel) and driver reside in the front cab. The tracks of both cabs are powered by electric motors. The Bvs are amphibious. In water they are propelled by the paddle-effect of the tracks. The vehicles are airmobile (sling-load under a heavy-lift helicopter or internal carry in a C-130 equivalent tactical transport).

Bv206

The Bv206 family of vehicles became operational in 1980. More than 11,000 units were sold globally. The Bv206 remains active with the armed forces of 25 nations, although the majority of vehicles are nearing the end of their service life. The unarmoured personnel carrier carries the driver plus five soldiers in the front cabin and 11 in the rear; the armoured variant carries four plus eight dismounts. Variants include a flatbed cargo carrier,

a tactical operations centre, an anti-tank platform armed with a recoilless rifle or anti-tank guided missiles (ATGM), and an ambulance.

The nominal successor to the Bv206 family is the BvS 10 (Bandvagn Skydder 10 or Protected Tracked Vehicle 10). It was originally designed jointly by Hägglunds and the British Ministry of Defence (MoD). First deliveries to the British Royal Marines began in 2005 under the designation All-Terrain Vehicle (Protected) or ATV-P, although the Marines refer to it as the 'Viking'. It is currently in service in Austria, France, The Netherlands, Sweden and the UK. In some services the BvS 10 is known as the Bv210.

While externally similar to the Bv206, the BvS10 is considerably larger, and comes with a newly designed hull and chassis, as well as a stronger engine. Other improvements include greater ground clearance, higher road speed (70 km/h versus 50

km/h), and up to 6.35 tonnes (7 tons) of payload capacity – around double that of the Bv206. The 8 m long amphibious armoured vehicle has a gross vehicle weight of 15.5 tonnes. In the troop carrier configuration, it carries 12 combatequipped soldiers plus the commander and driver. The design is semi-modular, permitting reconfiguration of payloads, weapon mounts and add-on armour options. The hull is protected to STANAG 4569 level 2 as standard, but this can be optionally enhanced to level 4. Standard Remote Weapon Station (RWS) mounts accommodate machine guns up to 12.7 mm as well as 40 mm grenade launchers, but the BvS10 can also be configured as a mortar or missile carrier (anti-tank or air defence). Operations are possible at temperatures between -46 °C and +46 °C.

Bv410

The BvS 10 Mk IIb is the most advanced variant of the armoured BvS family, and is sometimes also designated as the Bv410. The underbody of the new vehicles has been upgraded to provide improved mine protection. Cargo capacity has also been improved. Additional variants include air defence missile carrier and artillery hunting radar carrier. Seven countries currently operate the BvS 10 Mk II/Bv410. The vehicles can be further customised to meet national requirements. The BvS 10 AUT, which entered service with Austria's 6th Mountain Brigade in 2019, is often considered the most advanced configuration due to its advanced sensor package and Combat NG battle management system.



The Italian Army's Alpine regiments rely on the BV206 S7 for mobility.

Beowulf

The Beowulf is the unarmoured version of the BvS 10, and was unveiled in 2015. It features a redesigned cabin with a modernised user interface, and can accommodate the two-person crew plus 12 dismounts, or alternately 7.25 tonnes (8 tons) of cargo. The Cummins Diesel engine, Allison transmission and hydraulic system of the Beowulf (and the entire BvS 10 family) are made in the USA.

Singapore Technologies Kinetics

Singapore Technologies Kinetics (STK) is attempting to challenge BAE Hägglunds for a slice of the CATV market. The Bronco All-Terrain Tracked Carrier (ATTC) family introduced in 2001 is currently only in service in Singapore and Thailand (the British army operated the Bronco 2 under the Designation Warthog from 2009-



British Royal Marine BvS 10 Viking vehicles conduct an amphibious landing at Fort Lejeune, North Carolina.



The STK Bronco 3 completed Arctic trials in Finland, and is being marketed to European and North American customers as a potential replacement for the Bv206.

2014). According to STK, the vehicles can traverse 82 percent of the world's terrain in adverse environments including Arctic conditions. A wide array of configurations for various combat support and combat services support functions are offered. Variants include troop carrier, ambulance, command vehicle, fuel carrier, counter-rocket radar carrier, engineering vehicle and repair and recovery vehicle. A special variant designed in cooperation with the Singapore armed forces, serves as a 120 mm mortar platform.

The latest iteration is the Bronco 3, which was presented at DSEI 2017. The armoured vehicle is designed along similar lines as the Swedish Bvs, with two articulated cabs and amphibious capability. The firm touts the digital vehicle architecture which optimises man-machine interface; the 360° camera/situational awareness system with night-vision and infrared sensor capability; and internal ergonomics intended to increase crew comfort and accommodate personal equipment. With a re-engineered chassis, the 10.2 tonne Bronco 3 is around 2 tonnes lighter than its predecessors, but has a larger capacity for both personnel (total of 12 including commander and driver) and cargo (6.3 tonnes). It has a V-shaped underbelly fashioned from a single plate to improve vehicle and crew mine protection, and features enhanced all-around armour protection compared to predecessors. Performance trials, including cold-weather testing in Finland, have proven the vehicle's reliability at extreme temperatures ranging from -45 °C

to +49 °C. The firm is openly targeting countries in North America and Europe which will soon need to replace their aging Bv206 fleets.

North American Procurement Programs

US Army CATV

In June 2020 the US Army issued the Request for Prototypes Proposals for what is officially designated as the Cold weather All Terrain Vehicle or CATV acquisition program. The CATV programme aims to

replace the Bv206 units currently operated under the designation 'Small Unit Support Vehicle' (SUSV), which the Pentagon has classified as no longer sustainable. In April 2021 the Army awarded competitive prototyping contracts to two contenders: a team of two BAE divisions – US-based BAE Land and Armaments L.P. and BAE Hägglunds – which presented the Beowulf; and a team consisting of Oshkosh Defense and STK, proposing the Cobra 3. For the American procurement programme, the two US-based firms took the lead in each team.

The competitors supplied two prototypes each, and field testing was conducted from August 2021 through January 2022. The final phase of the competition involved intensive testing under operational conditions in Alaska. Each contender was evaluated on such factors as readiness and reliability in extremely cold weather, navigating complex terrain, amphibious operations, and handling in deep snow. Soldier feedback was considered a major factor in the ultimate ranking.

The Pentagon decided in favour of the Beowulf. On 22 August 2022 the procurement contract for 110 vehicles was signed, with the total requirement being 163 units. The first units are to be delivered in the fourth quarter of Fiscal Year 2023 to the US Army Northern Warfare Training Centre at Fort Wainright, Alaska. Deliveries of all vehicles are to be completed by 2029. Both the active duty Army and the Army National Guard will receive vehicles. The majority of the CAT-Vs will be operated by the US Army's 11th



BAE's Beowulf undergoing testing in Alaska for the US Army CATV program.



Bv410 AUT of the Austrian 6th Mountain Brigade.

Infantry Division based in Alaska. The unit – unofficially dubbed "America's Arctic Airborne Division – is being optimised for sustained operations in the Arctic as well as in other extreme cold weather environments. To support these capabilities, the Beowulf will be tasked with tactical personnel and supply transport, medical evacuation, and command and control missions. The CATV is expected to provide a significant performance and survivability improvement over the SUSV in extreme cold-weather, mountainous and high-latitude environments.

Canadian Army DAME

The Domestic Arctic Mobility Enhancement (DAME) project aims to replace Canada's Bv206 vehicles with a mediumsized, amphibious, high mobility vehicle. The stated goal is to enhance the Canadian Armed Forces' domestic operations reach, in alignment with Canada's strategic objectives for the North and Arctic. Groundwork for the DAME project began in 2015. Progression has been slower than initially anticipated. Canada published an official Expression of Interest to industry in May 2022, with an opportunity closing date of 2 June 2023. The most recent Canadian MoD information anticipates beginning implementation of procurement in the 2025-2026 timeframe, followed by deliveries commencing circa 2028 and running through 2030. The official requirement range is currently 126-170 units, covering four variants: troop transport, logistics transport, command vehicle, and ambulance. Likely candidates

are considered the BvS 10 (including the Beowulf), and the Bronco 3.

Europe's Collaborative All-Terrain Vehicle (CATV) Programme

The Collaborative All-Terrain Vehicle programme is being financed through European Union funds, and aims to jointly procure Bv410 CATVs for several European armed forces. Initially formed as a bilateral partnership between Germany and the UK in 2019, The Netherlands and Sweden joined in 2020. The programme remains open for other EU member states to join. In December 2021 the Swedish government, acting as the programme's lead country and central purchasing body, issued an invitation to tender to BAE Systems Hägglunds for a total potential procurement of 500-900 vehicles. On 23 November 2022, the Swedish MoD and BAE Hägglunds signed a contract for delivery of an initial 436 units. Once delivered, the vehicles will be customised to national specifications using locallydeveloped mission systems by contractors in the receiving countries. Primary configurations will include troop transport, ambulance, logistics (flatbed) and communications variants.

This procurement order is in addition to national acquisition contracts recently placed or currently planned by several governments. Germany is expected to receive 140 units from the joint CATV order in the 2024–2027 timeframe, replacing a portion of the mountain brigade's Bv206

fleet. Britain's Royal Marines, which upgraded nearly 100 of their roughly 150 BvS 10 Viking ATVs to the Bv410 standard in 2016, will be replacing the remaining Vikings through the CATV program. The Swedish army, which operates circa 1,100 Bv206 and more than 150 Bv410, signed a national acquisition contract for 127 additional Bv410 systems in May 2021. Deliveries are expected to be completed in 2024. Additionally, up to 200 of the vehicles ordered under the joint CATV contract are slated for Sweden.

The Netherlands is also pursuing a dualtrack approach to refreshing its inventory. In June 2021 the Dutch MoD announced plans to procure 179 Small All-Terrain Vehicles to replace a portion of the Bv206D and Bv10 currently deployed by the Netherlands Marine Corps. This Future Littoral All-Terrain Mobility Patrols Vehicle (FLATM PV) project will both modernise and expand the ATV fleet. To save time, the MoD is planning to choose an as yet unspecified vehicle which is already in production or production-ready. Requirements include a minimum capacity of four soldiers and the ability to incorporate the latest communications and data systems. Deliveries are supposed to take place in the 2025-2028 timeframe, to ensure "future-proof, all-terrain and snow mobility for the light amphibious units." Previously, in an October 2020 announcement Amsterdam stated they would procure 124 replacement vehicles through the joint Collaborative ATV programme in the 2024-2027 timeframe. In an early 2022 interview the director of the Dutch Defence Materiel Organisation, Vice Admiral Arie Jan de Waard, confirmed that Amsterdam still intends to procure replacements for the Dutch Marines' all-terrain vehicles through the European CATV program.

Increasing Demand

The next few years should see a flurry of acquisition activity as the Bv206 fleets of another 20+ countries approach the end of their service lives. Both STK and BAE are stepping up their marketing activities to take advantage of the impending demand. To date, BAE Hägglund's position as market leader remains intact. The recent US Army CATV contract marks the first order for the unarmoured Beowulf. So far, the majority of armed forces continue to favour the protected vehicles of the BvS 10 family. Given the rising tensions with Russia, in particular, it seems likely that vehicle protection will remain a desired attribute for Arctic operations.

Getting High

Thomas Withington

Ultra High Frequency (UHF) radio, despite being over eight decades old, is still indispensable for military communications. How did this vital technology evolve and how does it work?

alling it Ultra High Frequency is a misnomer, compared to other frequencies in the radio part of the electromagnetic spectrum. Judged by today's standard, UHF is not all that 'high', for instance X-band (8-12 GHz) and Ka-band (27-40 GHz) frequencies are much further up the spectrum. This was not the case back in the early 1940s when UHF was pioneered. Long- and Medium-Wave (LW/MW) transmission techniques were perfected in the early 20th Century. Longwave was so-called because it was precisely that. Still in use today, LW signals exceed lengths of 1,000 m (3,281 ft), corresponding to frequencies of 300 kHz and above. MW uses frequencies of 520 kHz to 1.611 MHz (or up to 1.710 MHz when using North American standards). This produces wavelengths of between 576.5 m (1,891 ft) and 186 m (610.2ft) in length (or 175 m (574.1ft) when using North American standards).

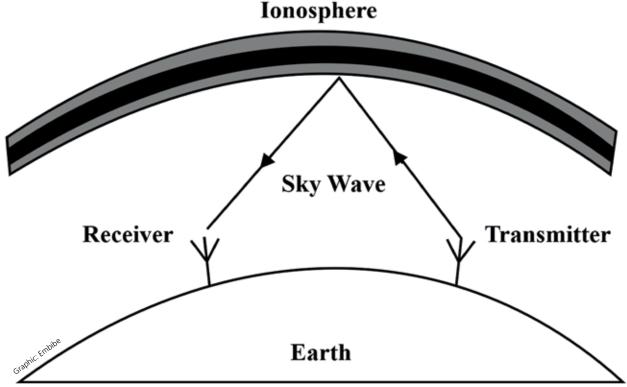
The problem with LW and MW signals is that they need large antennas. A rule of thumb says antenna length must be one half or one quarter of the wavelength it transmits. An LW antenna transmitting 300 kHz signals must be between 500 m (1,640 ft) and 250 m (820 ft) long. An MW antenna handling signals of 520 kHz must be between 288.3 m (945.9 ft) and 144.1 m (472.8 ft) long. Such antennas need very tall towers capable of mounting these antennas vertically, or alternatively, large arrays comprising several towers with the antennas mounted horizontally can be used.

High Frequency

An important breakthrough occurred in June 1923, when radio pioneer Guglielmo Marconi, together with his assistant Charles Franklin, showed short wave radio could be used for long-distance transmis-

sions. Short wave comprises signals in the 3-30 MHz frequency range, with 99.9 m (327.8ft) and 9.99 m (32.8ft) wavelengths. Using an antenna built at Poldhu Wireless Station in Cornwall, southwest England they showed that signals could be transmitted to Mr. Marconi's steam yacht Elettra. The vessel was located 4,142 km (2,236 NM) away in the Cape Verde islands off the West African coast.

High Frequency (HF) voice communications had been proven. HF and shortwave monikers were used for years, although HF is the preferred term today. Like LW and MW, HF transmits across thousands of kilometres. It does this by aiming transmissions at an angle towards the ionosphere. This is an ionised part of the atmosphere 48,000 m (157,480 ft) and 965,000 m (3.1 million ft) above Earth. As HF signals cannot penetrate the ionosphere, they are bounced back to the surface. This lets them 'skip'



This diagram neatly illustrates how HF skywave transmissions use the ionosphere to avoid potential obstructions to radio signals caused by the curvature of the Earth.

over the curvature of the Earth, a process known as Skywave transmission. HF signals can also be used for point-to-point transmissions provided the transmitting (Tx) and receiving (Rx) antennas have an unobstructed Line-of-Sight (LoS) between each other.

HF brought some advantages. Antennas were smaller, between 49.95 m (163.9 ft) and 2.4 m (7.9 ft) in length depending on the operating frequency. Thus, HF antennas were more practical than LW and MW for installation on aircraft, ships, and land vehicles. Nonetheless, HF had disadvantages. Although smaller than LW and MW antennas, some HF antennas remained large. Secondly, Skywave HF signal quality was at the mercy of the ionosphere which was at the mercy of the sun. Sunspots and solar flares can greatly affect the ionosphere, which in turn affects HF signal propagation. This made using an HF radio as much an art as a science, demanding skilled operators. Today, much of this work is done using software.

HF Shortcomings

By WWII, wartime exigencies demanded radio become more practical. Help was at hand from the cavity magnetron, itself a spin-off from radar engineering. Radar had previously been successfully demonstrated as means of detecting and tracking aircraft in February 1935, and would become vitally important for all sides during the Second World War. The Royal Air Force's (RAF) Type-1 Chain Home radar network along Britain's coastline helped detect and track Luftwaffe (German Air Force) aircraft so they could be engaged by RAF fighters. This helped the RAF win the Battle of Britain in the late summer of 1940.

These Type-1 radars used frequencies of between 20 MHz and 50 MHz to indicate enemy aircraft locations so fighters could be vectored towards them. Nonetheless, the Type-1 had shortcomings. The radar needed towers 110 m (360.9 ft) high to hold the transmitting antenna strung between them, while two towers 73 m (239.5 ft) high supported the receiving antenna. These heights afforded the radar its 190 km (118 NM) range. Yet these large installations were easy to find, and the Luftwaffe attacked several Type-1 radars at the start of the Battle of Britain.

As such, the trend moved toward smaller radars operating at higher frequencies, which were more difficult to locate and easier to transport. Additionally, operating at frequencies beyond 50 MHz also promised sharper radar beams, which meant more accurate location of enemy aircraft, improving the efficacy of RAF air defence.

Cavity Magnetron

A technology to generate these microwave frequencies was found in the cavity magnetron, which was pioneered in 1940 at the University of Birmingham, by physicists John Randall and Harry Boot.

A cavity magnetron consists of a cathode (negatively-charged electrode) attached to a filament which heats the cathode, mounted at the centre of the magnetron. The cathode and filament is surrounded by

inner grooves to oscillate, or move back and forth, to and from neighbouring grooves along the outer ring of the cathode. This causes the grooves to alternate between positively charged (caused by losing electrons) and negatively charged (caused by gaining electrons) states, forming an alternating electric field between the two sides of the cavity. In addition to inducing oscillation, the electrons zooming past the cavities also impart some of their energy onto the electric field in the cavities.



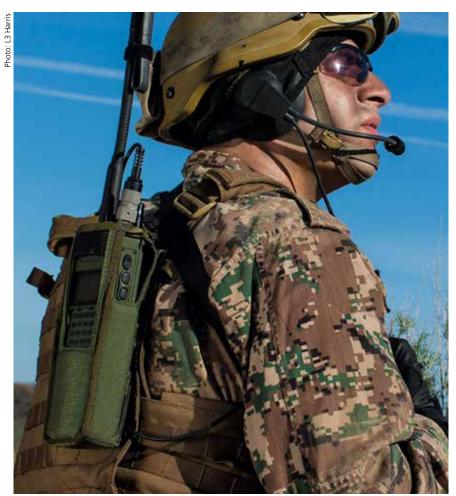
This photo of a cavity magnetron clearly shows the space in the centre for the cathode and the entrances to the cavities orbiting the hollow space between the cathode and the surrounding anode's inner wall.

a large hollow cylindrical anode (positivelycharged electrode), with several cavities cut at regular intervals along its inner walls, known as 'resonating cavities'. There is a vacuum gap between the anode and the cathode, and permanent magnets are mounted above and below the anode, opposite poles facing one another, providing a magnetic field along the longitudinal axis of the anode.

As the cathode heats up, electrons 'boil' off it in a process known as thermionic emission. The magnetic field curves the travel path of the electrons during their journey through the hollow between anode and cathode. As the electrons coming off the cathode zoom past the inner grooves of the cavities, they cause electrons inside the

As this oscillation process occurs, the resonating cavity generates electromagnetic waves, with the frequency determined by the cavity dimensions. This electromagnetic wave can then be collected by a 'tap' – either an antenna or waveguide, and emitted. This process can be likened to blowing across the top of a bottle to produce a sound, however the end result here is the generation of electromagnetic waves rather than sound waves.

Microwaves have frequencies upwards of 300MHz and wavelengths downwards of 1 m (3.3 ft). These wavelengths and frequencies provided the desired improvements in radar accuracy. They resulted in smaller radars and radios, as smaller antennas below 500 mm could now be exploited.



Ultra-High Frequency radios remain popular with militaries around the world. This is thanks to their good performance in built-up areas. Nevertheless, commercial pressures could see military tactical communications migrating to higher bandwidths in the future.

UHF

Cavity magnetrons led to the birth of Very High Frequency (VHF) and Ultra High Frequency (UHF) radar and radio. The latter uses frequencies of 30 MHz up to 3 GHz. VHF and UHF is routinely used for military communications, particularly tactical radios for land forces and for airborne communications.

Today's UHF radios commonly use crystal oscillators to generate their signals, and have an interesting means of generating an Alternating Current (AC) signal from a Direct Current (DC) input. In DC, the electrons flow in one direction, maintaining a constant voltage, while in AC, the electrons alternate their direction of flow back and forth along the circuit, between an alternating positively- or negatively-charged region which respectively work to attract or repel electrons.

A crystal oscillator consists of a suitably shaped/dimensioned crystal made out of a suitable material such as quartz, sandwiched between two layers of conductive metal on either side, each of which is connected to an electrode. It should be noted that the final frequencies generated by the crystal oscillator are determined by the size and dimensions of the crystal, so once it has been cut, it has a fixed operating frequency range. The frequency can also be affected by factors such as temperature.

Applying a DC voltage to the crystal causes it to deform sharply, in a process known as the Inverse Piezoelectric effect. This rapid deformation causes the crystal to resonate briefly, not unlike a bell will resonate when struck, creating a rapidly-diminishing audio signal. In much the same way, the application of DC voltage to the crystal causes it to briefly resonate. This mechanical resonance causes the crystal to emit a brief AC electrical signal whose frequency is determined by the shape and size of the crystal. This signal can then be sampled and amplified, and reapplied to the crystal in the same phase in a process of positive feedback. This causes the crystal to continue to resonate, generating a highly-stable AC signal.

This AC signal provides the basis of a carrier wave, and can then be sent to an antenna to generate the electromagnetic wave for transmission.

Compared to cavity magnetrons, crystal oscillators can be smaller helping reduce the size and weight of equipment like radios. Unlike HF signals, VHF/UHF signals achieve impressive data speeds. The latest HF radios carry data at speeds of up to 120 Kbps, compared to rates measured in Mbps for VHF/UHF transmissions. This is because VHF/UHF radios have wider channel bandwidths available compared to HF. To use an analogy, you can get more cars moving faster down a six-lane highway than you can with the same number of cars using a narrow country road.

Mobile phones use VHF/UHF and a standard fourth-generation mobile phone achieves data speeds of 100 Mbps with a 20 MHz channel bandwidth. The sheer amount of data that can be moved with VHF/UHF makes it attractive to militaries. This makes it possible to not only send and receive comparatively clear voice communications, but also data-heavy traffic like photos and video.

UHF suffers less electrical interference from sources such as high voltage power lines compared to other frequencies. VHF signals of 30-300 MHz struggle to penetrate obstructions like walls. These are less of a problem for UHF, which performs better in urban areas. Nonetheless, neither VHF nor UHF can achieve the intercontinental ranges of HF. Although UHF can penetrate walls, like VHF it is still largely used for LoS voice and data traffic. LoS restrictions force tactical VHF/UHF radios to use Mobile Ad Hoc Networking (MANET). MANET alleviates problems when the path between two radios is blocked by the horizon or a similar large obstacle. One radio will transmit its traffic to another in range, this radio transmitting the traffic to another, and so on, until the traffic reaches its recipient.

UHF has been widely used by militaries since the Second World War and will continue to be for the foreseeable future. The major pressure on UHF military use comes from the commercial world. As noted above, cellular communications also use UHF. Parts of the UHF spectrum reserved by governments around the world for military use may be auctioned off to private cellular network operators, which could put pressure on the size of the UHF wavebands available to militaries. One solution could be to migrate some military radio communications to higher frequencies like terahertz (300 GHz to 3 THz). That, dear readers, is a discussion best left to a future article.

Germany Finally Settles Assault Rifle Requirement

David Saw

In a news release issued on 14 December 2022, the German Ministry of Defence stated that the Budget Committee of the Bundestag had released funding for a number of defence programmes. Amongst these was the System Sturmgewehr Bundeswehr, a programme to acquire a new assault rifle for the German Army to replace the existing G36.

The new assault rifle is the HK416A8 from Heckler & Koch (H&K) and will be procured in two variants: the G95A1 with a 16.5 inch barrel and a carbine variant, the G95KA1, with a 14 inch barrel. German Special Forces already use the HK416A7 which was given the G95 designator. According to the German Ministry of Defence statement, budgetary approval means that: "The Bundeswehr can now procure 118,718 new assault rifles for around EUR 209 M. The

troops will receive their first weapons in 2024." The G95A1 and the G95KA1 will be equipped with the HKV main military combat sight, supplied by Leonardo Germany and Raytheon ELCAN based on the SPECTER DR 1-4x optic.

Then at the end of their statement, the German Ministry of Defence noted that: "The selection decision had already been made in spring 2021, but a review procedure against the decision by an unsuccessful bidder had delayed

the conclusion of the contract." That all sounds pretty normal, unsuccessful bidder mounts protest against selection decision is nothing unusual. However, there is far more controversy and complexity involved in the path to selecting the System Sturmgewehr Bundeswehr than might be expected.

The H&K G36 5.56×45 mm assault rifle entered service with the Bundeswehr from 1997 onwards, replacing the G3 battle rifle in 7.62×51mm as the standard service





In December 2022 funding was released to allow the System Sturmgewehr Bundeswehr acquisition to proceed, under which 118,718 Heckler and Koch HK416A8 rifles could be procured in two variants: the G95A1 with a 16.5 inch barrel and a carbine variant, the G95KA1, with a 14 inch barrel.

weapon. The G36 was also widely adopted by Special Forces and Police around the world, within NATO it became the standard rifle of Spain, Latvia and Lithuania. Then matters became complicated, in 2012 a controversy emerged regarding G36 performance with the Bundeswehr. This centred on allegations that the G36 was unable to maintain zero in hot weather conditions. The end result being lots of me-

dia coverage, leading to the G36 becoming a political issue. In an effort to avoid further embarrassment on the rifle issue, the decision was taken to open up a competition for a new rifle, the System Sturmgewehr Bundeswehr, to replace the G36, with the competition officially getting underway in 2017. It was hoped that a winning system could be announced in 2018, with initial deliveries from 2019 onwards.



Bundeswehr soldiers equipped with G36 rifles taking part in the Schneller Adler exercise in May 2022. Although the G36 is to be replaced by the G95A1 and the G95KA1 (HK416A8), it will still remain in German service for many years to come.

A number of contenders emerged for the German requirement, amongst which were H&K with the HK433, Rheinmetall and Steyr Mannlicher (now Steyr Arms) with the RS556, Haenel with the MK556, FN with the SCAR and SIG Sauer with the MCX. All weapons were in 5.56×45 mm calibre. By late 2017 SIG Sauer had exited the competition citing ITAR concerns, then in April 2018 it became clear that the competition was a two horse race between H&K and Haenel. Haenel, was owned by the EDGE Group of the United Arab Emirates (UAE), a state-owned defence and technology company, meaning that Haenel had the resources to meet the German requirement if selected.

The testing process of the remaining bidders commenced, but failed to yield a result and by this point the programme was running late. By the end of 2018, progress on the assault rifle programme had come to a halt. For many this was yet another indication of the disfunction within the German procurement system. Despite this, in 2020 the System Sturmgewehr Bundeswehr came back to life, technical evaluations had been completed and the two contenders were invited to submit a Best and Final Offer (BAFO) by mid-year. Then on 15 September 2020 the German Ministry of Defence announced that Haenel had won the programme, would supply 120,000 rifles and that budgetary approval would be forthcoming by the end of the year.

Then on 9 October 2020, the German Ministry of Defence announced that on 30 September H&K had submitted a protest on the contract decision and that after investigation patent infringements and other concerns had been identified, consequently the rifle order with Haenel was cancelled. Haenel launched a protest against this decision and this led to the German court system becoming involved in deciding on the issue of patent infringement and whether there was just cause for cancellation.

Into 2021 it became clear that there could be no progress on the System Sturmgewehr Bundeswehr until the court reached a verdict, but by this point the HK416A8 had emerged as the favoured candidate for the programme. Then on 22 June, the court in Düsseldorf issued a verdict rejecting the complaint by Haenel and confirming patent infringement. With this matter settled the path to awarding H&K the System Sturmgewehr Bundeswehr was finally clear.



Viewpoint from London



The Peace Dividend is Over, What Now for the UK?

Sam Cranny-Evans

n the late 1980s and early 1990s, economists and politicians spoke of a Peace Dividend; the idea that with the collapse of the Soviet Union there would be no need for the states involved in the Cold War to invest enormous sums in their defence. Instead, it was hoped these sums would be diverted to social projects, and improving the lives of the populace. For the UK, this was mostly the case despite a few sharp shocks such as the Gulf War. Defence spending as a percentage of gross domestic product (GDP) fell from its 1991 peak of 4.12% to a low of 1.95% in 2018. As this happened, the UK's economy improved, so spending in USD increased from USD 47.05 Bn to USD 55.68 Bn over the same period, according to data from MacroTrends. Nonetheless, important procurements were either pushed to the right or downsized. The procurement of AS90 self-propelled howitzers (SPHs) was delayed, meaning that a beleaguered British Army was forced to deploy to the Gulf War with its ageing fleet of M109s. Many other programmes have suffered similar fates; the FV432 Bulldog, a tracked APC in service with the British Army entered service in the 1960s, and is yet to be replaced. More prestigious programmes have also suffered through the Peace Dividend. In 2015, David Cameron's government confirmed that it would buy 138 F-35Bs to meet the UK's needs. This number is now 48, although in 2021 Boris Johnson's government did express the goal of pushing that figure higher. It should now be abundantly clear that the Peace Dividend is over. Russia's invasion of Ukraine has thrown into sharp relief the nature of wars for survival between large militaries. Both sides have consumed vast quantities of ammunition, a troubling concept for the UK's 3rd Division - its largest warfighting formation - which consumed its entire supply of ammunition during a simulated 10-day exercise in 2021. Losses of equipment have been extensive; The Oryx Blog indicates that Russia has lost 61 fixed wing combat aircraft. The UK previously procured 160 Typhoons, of which 30 are to be retired early, leaving a total fixed wing combat fleet of 178. If the UK suffered the same losses as Russia in a major war, it would represent over a third of its fleet. Personnel losses are also significant, a report from the Royal United Services Institute (RUSI) indicates that Ukraine has lost as many personnel as there are infantry in the British Army. The British Army is expected to have 19,400 infantry by 2025 – which are presumably a reduction over current levels. If typical casualty figures are factored in, which analysts typically assume to be 3-5 personnel for each fatality, Ukraine's casualties would likely exceed the total number of personnel in the British Army. It is apparent that the UK's armed forces, if they were to fight a peer opponent today, would likely lack the mass or magazine depth to be successful. The UK's answer to future threats is Multi Domain Integration (MDI), a concept that draws broadly on the US' Joint All Domain Operations. It holds that by integrating the effects from across all five domains into a single chain of command, the UK will be able to achieve superiority at a time and place of its choosing without the need for added mass. The theory would technically enable the UK to achieve more combat power with less mass, or at least fully exploit the combat power it has. However, as the UK embarks upon the early stages of exploring this concept, its GDP is facing turbulence, with Goldman Sachs anticipating a "deeper recession than previously expected" by the summer of 2023. So, as the British MoD seeks to get more for its money, it will likely have to take account of the fact that in the short term at least, its defence budget will shrink in real terms, even if it is maintained as a percentage of GDP. It follows, that if the UK is to take deterrence seriously and rebalance its armed forces such that they can fight and win in a war for survival, the British government will have to decisively increase its defence spending to ensure that its forces can be recapitalised and modernised in the coming years. However, with the cost of living crisis beginning to seriously bite, and years of austerity that have left schools, hospitals and critical national infrastructure under-funded, achieving this will be a difficult sell for any British government. At present, it seems most likely that the British Armed forces can expect more of the same: Minimal budgets and small packets of sophisticated capabilities.

Lessons from Ukraine: Armoured Fighting Vehicles

Sherman Karpenko

As the war in Ukraine rages there have been multiple attempts to draw lessons from the conflict. The multitude of social media platforms carrying footage from the conflict have made it feel uniquely accessible and given many an insight into war that is otherwise difficult to gain without becoming a combatant.

his has empowered many to draw analysis from the conflict and seek to apply them to war as a whole. However, it is important to exercise caution on two fronts. First of all, conservative estimates indicate that there are more than 200.000 combatants in this war, and whilst there is a lot of footage available it does not cover the full experience of the enormous front line. It is consequently a limited form of information, that in any case lacks context, and so should be regarded as only part of the story. For instance, no quantity of videos showing tanks falling prey to anti-tank guided missiles (ATGMs) can serve as evidence that the tank has had its day.

The second is the peculiar nature of this war. Russia and Ukraine had both attempted to modernise their forces since 1991 and the collapse of the Soviet Union, but neither had taken considerable strides away from the artillery-centred doctrines that they inherited from the USSR. Russia had realised some of its late Soviet ambitions - not least the principle of being able to target an enemy's critical national infrastructure, whilst also modernising its fleet of armoured fighting vehicles (AFV), but it remained an artillery army with a lot of tanks. Researchers from the Roya United Services Institute (RUSI), a thinktank based in London, who had visited Ukraine before and during the war observe that there were some Ukrainian units with command tents that most NA-TO officers would recognise, but that the majority of units were not far removed from their Soviet predecessors. In addition, both sides actually entered the war with a near numerical parity in artillery systems – it was the availability of munitions that separated them. Because of this, both sides represent fairly unique militaries that would have very little in common with the majority of armed forces around the world. This means that some aspects of



The images of Russian defensive lines showing tank obstacles reflective of WW2 are indicative of the prominent role played by armour in the Russo-Ukrainian war.

the war are likely of limited value for those writing doctrine and lessons learned, because they arise from unusual situations and would be very unlikely – perhaps even impossible – to replicate in any other war. Take for example, Russia's enormous expenditure of artillery ammunition, which reached 20,000 rounds per day at some points. This aspect of the war seems to highlight the need for lots of artillery ammunition and large mechanised formations capable of providing this level of fires whilst withstanding the attrition that comes with it. The reality is that there are few militaries that can produce this kind of battlefield effect, and even fewer that would actually choose to. It is a costly process requiring enormous reserves of ammunition and personnel. It works for the Russian forces because that is how they are trained to fight, and it compensates in no small way for a certain lack of tactical proficiency. If one is considering the possibility of war with Russia, then this is an important aspect of the war to consider, but its applicability to other conflicts is questionable.

So, with this warning in mind, are there any lessons for the employment of AFVs from the war in Ukraine that are sufficiently general to be applicable to a broader audience than those that must prepare to potentially face the Russian military? There are some aspects that can be drawn upon to arrive at potentially useful recommendations, however, it is equally difficult to assess whether these lessons are fundamentally new, or revisions of past conflicts. It is most probably more useful to fold observations from

Ukraine into a broader understanding of 20th and 21st century warfare, than resting solely on the outcomes of this specific war. Where possible, this article will try to do this, providing broader contextual analysis to assess whether these lessons are fundamentally new. It is fitting to start by assessing an age-old debate through the lens of Ukraine – has the tank had its day?

Tanks

A search for meaningful quotes to title this section returned nothing satisfying, this is because the end of the tank is not near and attempts to suggest as much tend to conflate the destruction of something with futility in using it. There is a tired old adage which goes: "A tank is like a dinner jacket you don't often need one, but when you do, nothing else will do." The reality is that tanks are like paper napkins, you don't always need one to protect your dinner jacket, but when you do use one it is very valuable and good at its job. Once you have used it, you might fold it up and put it in your pocket to use another day, or it might get ruined in the process and you will throw it away. Tanks have been used extensively by both sides in the Ukraine war, an impressive mix of T-62s, T-64s, T-72s, T-80s and T-90s in various states of modernisation have made battlefield appearances, some of them for the first time. They have been put to use in a number of ways that are worth exploring in an effort to understand where lessons might be drawn.

Tank on tank combat is relatively common, however, the dispersed nature of the battlefield means that at times when both sides are assuming defensive positions, it is often a single tank engaging one other. Engagements in this context can be observed to happen at very close ranges and it is interesting to note that the explosive reactive armour (ERA) arrays fitted to tanks on both sides frequently necessitate two shots for a successful engagement. The first with a high explosive round to remove the ERA, the second with a kinetic energy round to penetrate the tank and kill the crew. From here it is tempting to draw an ostensibly simple conclusion: Tanks will require two shots to kill an opposing tank. However, there are multiple aspects of this equation that are unknown. The first is the type of ammunition being used by Ukrainian and Russian tank crews.

Many early Soviet armour piercing fin stabilised discarding sabot (APFSDS) ammunition types (such as the ubiquitous 3VBM-9 'Zakolka') employ a steel projectile, carrying a tungsten slug behind an armour piercing cap. Monobloc depleted uranium



Whether used for direct or indirect fire, tanks provide a readily-available form of effective and accurate lethality. If they cannot be countered by infantry, they are likely to inflict a lot of harm.

penetrators like the 3VBM-13 'Vant', were introduced relatively late in the Soviet Union and solid tungsten carbide projectiles such as the 3VBM-17 'Mango' only in 1986. They were often confined to highpriority units operating tanks like the T-80. The older rounds produce a muzzle energy of around 6 MJ, while the newer varieties such as Mango can achieve similar levels of kinetic energy, but the greater hardness and density of their projectiles when compared with steel natures (7.8 g/cm3 vs 17g/cm3 for tungsten) makes them more effective at penetrating the complex armours found on tanks. However, if they are compared with modern western natures of ammunition – even in this simplistic fashion – there is an interesting disparity. According to the late Professor Ogorkiewicz, the L44 and L55 120 mm smoothbore guns that arm most NATO tanks are capable of producing

9.8 MJ and 12.5 MJ in muzzle energy respectively. Whilst this not the only deciding factor behind APFSDS lethality, it suggests that Western tanks are significantly more lethal in tank warfare than their Russian or Ukrainian counterparts.

ERA primarily defeats kinetic energy rounds by momentum transfer, it requires the use of thicker and heavier front flyer plates than is typical for high explosive anti-tank (HEAT) rounds as the projectiles they are countering are heavier and larger, according to Paul Hazell, Professor of Impact Dynamics in the School of Engineering and Information Technology (SEIT) at UNSW Canberra. Essentially, the weight and force of the flyer plate changes the course of the APFSDS penetrator and may even shatter the rod into smaller pieces. However, the armour behind the ERA must be considerable to absorb the impact of those fragments. As



The T-90A shown here is fitted with the Shtora-1 active protection system that defends against some types of guided missiles from the frontal arc of the tank. The tanks have been used both in Ukraine, Syria, and Iraq with varying degrees of success reflecting the importance of effective tactics and employment.

Photo: Ukrainian Mo



The end of a tank rarely indicates that violence it managed to inflict until that moment. Basing analysis solely on images of destroyed Russian tanks is therefore unlikely to produce reliable information regarding the vehicle's effectiveness, or its place within the totality of the battlefield.

most NATO guns fire ammunition natures that are generally longer, and capable of producing much higher muzzle energy as a result of their typically greater projectile weights (and in the case of L55 guns, higher projectile velocities as well), it stands to reason that the 'two shot' trend observed in Ukraine is not a general lesson that can be applied across the board. However, it is worth noting that tests of 1980s NATO ammunition natures showed that they were generally ineffective against Kontakt-5 ERA. So, perhaps it is worth delineating between older natures of ammunition, and the newer ones built upon the greater understanding of Soviet armour gleaned after the collapse of the Soviet Union.

In other contexts, tanks are used to provide both direct and indirect fire support against infantry formations. Ukrainian tanks are even fitted with a sight especially for this purpose and Russian tank crews have practiced this art with direction from Orlan-10s. It is not therefore new as far as a skillset is concerned, but its application in Ukraine is interesting – if only for the challenge it represents to infantry positions. A New York Times report on fighting near Izyum states the following:

"Tanks in particular have become a serious menace, fighters said, often coming within a mile of the battalion's positions and wreaking absolute havoc. Already this month, 13 soldiers with the battalion have been killed and more than 60 wounded." A RUSI report on the initial lessons of the war indicates that Ukraine was able to employ its tanks as a mobile reserve. In effect,

their indirect fire enabled them to act as artillery and armour simultaneously and engage Russian forces at opportune moments. They were reportedly accurate out to ranges of 10 km and required very little time for adjustment of their fire.

The absence of other tanks and paucity of anti-tank weapons – as well as the limited range of the latter – mean that tanks can be very destructive in the right circumstances. Indeed, Syrian tanks are known to have caused hundreds of casualties in a single afternoon of fighting because of the absence of any anti-tank weaponry. The absence of tanks has been felt in other conflicts,

too. Coalition troops fighting in Afghanistan would often be pinned down by the firepower of Taliban forces, leading them to rely upon attack helicopters and close air support to extract themselves from the firefight. The presence of a tank in this circumstance – as well as other AFVs with medium calibre cannons – would completely reverse this disparity in firepower. In Panzer Ace, the published memoirs of Richard von Rosen, a German tank commander in World War 2, Rosen retells occasions where Soviet anti-tank guns would be guickly silenced leaving their infantry at the mercy of the armoured formations and leading to heavy enemy losses.

Tanks are also a critical element of offensive operations, and it is abundantly clear that failing to support them with infantry and infantry fighting vehicles (IFVs) will lead to them being isolated and destroyed. However, as an element of an offensive operation they are absolutely critical because of the protection they offer. As mentioned above they are decisive in engagements against infantry formations in part because they require specialised tools to defeat them. This makes them central to effective offensive operations as they require effort and focus to kill, and in many cases will require more than one successful hit. They are, regardless of the images of tanks being destroyed, hard to stop, and they can be catastrophic for infantry without the right tools.

It follows that tank supremacy is a relatively constant aspect of warfare. If an infantry formation can be isolated from its supporting effectors and engaged by tanks, it will likely suffer heavy losses. So, whilst the use of tanks to provide indirect fire support



The Ukrainian Armed Forces entered the war with around 900 tanks to face an estimated Russian force of 2,300. Many T-64s in Ukrainian service have been modernised with night vision sights and more advanced communications systems. Some are also fitted with specialised sights enabling them to conduct indirect fire.

against positions in Ukraine may be somewhat novel, the superiority of tanks in the absence of anti-tank weapons is not. What, therefore, can be made of ATGMs and their use in Ukraine?

ATGMs

ATGMs have proliferated rapidly even within the Russian armed forces. They have moved from an extremely expensive asset assigned to commanders and a few others in the Soviet army, to something that is likely to be found in almost every section. The Ukrainians started the war with a healthy arsenal of domestically-developed ATGMs such as the Stugna-P from the Luch Design Bureau. The influx of western weapons like FGM-148 Javelin and NLAW served to distract much of the focus from Ukraine's own capabilities, but have nonetheless proven themselves to be valuable assets despite minimal training. The lethality of ATGMs against armoured vehicles is a well-understood aspect of the modern battlefield. The way in which the high explosive anti-tank (HEAT) warheads that arm most ATGMs work, means that they are very difficult to stop. The tip of a HEAT jet can reach speeds of 10 km/s, although it may only be 2-3 mm in diameter, and depending on the overall warhead diameter, many modern HEAT warheads can penetrate over 1,000 mm of solid steel. Despite such capabilities, even successful hits do not always lead to penetration or the vehicle's destruction. Israeli forces operating Merkava tanks were deployed to Lebanon in 2006, and were subject to multiple successful ATGM impacts, with more than 50 tanks being hit. Of the 50 hits, 21 tanks were penetrated leading to 10 vehicles suffering casualties. It is therefore possible for modern tanks to withstand high levels of ATGM attacks without the crew or vehicle becoming incapacitated, this is largely thanks to improvements in survivability such as trading flammable hydraulic fluid-based turret control systems for electric motors, safer ammunition storage and other modifications.

So, what can we learn about ATGMs from Ukraine? Combining Ukraine with other conflicts it is apparent that the healthy penetration characteristics of modern HEAT warheads do not neatly translate into definite kills – against heavily armoured vehicles at least. Ukraine mostly confirms that tanks remain survivable, and other conflicts confirm that some are more survivable than others. One element of the War in Ukraine that is perhaps unique, however, is the sheer mass of ATGMs. They are present in such numbers that units feel comfortable using them to engage bunkers, trucks,



The BMP-2 is used by both sides in the Russo-Ukraine war, and has been known since entering service in the 1980s for its ability to suppress and defeat infantry targets.



This image shows a disabled Israeli M48 Patton tank reportedly near a bunker of the Bar Lev Line in the Sinai Peninsula. Egypt's use of ATGMs in the Yom Kippur War drove a number of lessons within the US military.

light armoured vehicles, personnel, and any other target that can be justified. This free-spirited use of ATGMs is not new, it was common for forces deployed to Afghanistan to use Javelin as a form of long-range precision strike as opposed to close air support or artillery. It reflects a wider truism of militaries and war; troops will most likely use the most effective and safest tool they have to hand, not the cheapest or hardest. However, there is a lesson to be observed in the mass of ATGMs and how they impact armoured operations.

ATGMs were first used in a concerted and massed fashion during the 1973 Yom Kippur War, that oft-studied conflict has im-

pacted the US and other militaries guite considerably. The Egyptian and Syrian forces used 9M14 Malyutka 'AT-3 Sagger' missiles and attained penetration rates of 60% when the target was successfully hit. This led to an average of two deaths per vehicle. In response, Israeli vehicle survivability advanced considerably thereafter, leading to reduced casualties per successful penetration. Egypt had massed its Malyutkas, stripping them from reserve units and allocating them to frontline infantry in anticipation of an Israeli armoured counterattack in response to the crossing of the Sinai River. The Malyutka crews had also spent three years practicing with their weapons



The Merkava Mk IV is fitted with the Trophy Active Protection System (APS) to provide enhanced protection from against RPGs and ATGMs.

to ensure that they were as capable as possible. However, the Israeli forces obligingly deployed their armour in 'penny packets' (small groups) without infantry support, prompting the Egyptian chief of staff to remark in his diary that he had not expected the Israeli forces to be so cooperative. So, the Yom Kippur war served to illustrate that massed ATGM deployments could blunt a massed armour advance, but also reinforced the lesson already known from World War II (arguably even WWI), that armoured vehicles alone were vulnerable. So, is the massed use of ATGMs in Ukraine proving anything fundamentally different? Is there anything outside of the established understanding of combined arms doctrine that can be accounted for? US Army publications on combined arms manoeuvre note that "no single arm can be decisive," making combined arms operations essential to defeating the enemy. It stands to reason that any observations on the efficacy of ATGMs – or any combination of weapons and tactics for that matter - against formations consisting only of tanks are unhelpful, and do not meaningfully add to our understanding of modern warfare. However, the efficacy of ATGMs has arguably been maintained from 1973. It is apparent that advancing against an enemy with only one or two tanks and a small contingent of infantry, when ATGMs are present is unlikely to yield results, mostly because the large quantity of ATGMs makes the defenders well-placed to defeat the most threatening element of that force package. Yet and at the same time, we must consider the shape of the Ukrainian battlespace. It has been observed by many that neither side appears capable – or willing – of forming much

more than a company-sized battle group for offensive operations. In any other scenario this would amount to 'penny packet' deployments, but in Ukraine this might be a result of both attrition and the enormous size of the front line being fought over. It means that the defender may only have to destroy or disable a few vehicles in order to deter the attacker from proceeding, which in turn magnifies the effect of ATGMs. So, whilst the need for effective counter-ATGM tactics clearly remains and should be forefront in the minds of armoured forces, there is a question of scale. If the scale of attacking forces is greater, then the density of ATGMs required to exert an effect would have to increase commensurately. It cannot, therefore, be taken for granted that ATGMs represent the same level and type of threat across the spectrum of conflict.

Active Protection Systems (APSs) such as

Trophy and Iron Fist would likely return MB-Ts to a high level of survivability in sub-peer conflict scenarios. Such scenarios often involve urban warfare, which can make combined arms manoeuvre difficult because of a lack of space or scope to do so. However, ATGM uses in these conflicts tends to be restricted to one or two per engagement, alongside shoulder fired weapons like the RPG-7. In peer conflicts APSs will also help tanks to maintain survivability, but countering massed ATGMs will depend on the force's ability to suppress ATGM teams and supporting armour with infantry or vice versa.

In sum, Ukraine suggests that ATGMs remain lethal against armour, somewhat justifying the interest in APSs. Combined arms manoeuvre remains critical for survivability against these threats, and their massed use can make armoured formations risky to employ. Ukraine once more raises the question of how the scale of ATGM use impacts a formation. It is less about the lethality this is already well-understood – but rather a question of how ATGMs concentrated in a small area can impact a formation, and what adaptations are needed to counter them. One further consideration which should be factored into 'lessons learned' assessments, is how representative the fighting in Ukraine is of broader developments on the modern battlefield.

Cannons, Cannons, Everywhere

From these limited examples, it is possible to argue that the tank's status is not fundamentally changed by the war in Ukraine and ATGMs remain a problem, although not insurmountable. In many ways, these 'lessons' were well understood, Ukraine provides a convenient streetlight under which



A US Marine fires a Javelin ATGM from a HMMWV. The weapon has captured the limelight in Ukraine, despite operating alongside a large quantity of Ukrainian ATGMs.

analysts may look. There is, however, one aspect of the war that is worth labouring, if only for the fact that it has received less attention during past wars than things like air defence or the utility of airpower, and that is the role of the medium calibre cannon. Both sides have employed the 2A42 Shipunov 30 mm cannon that arms BMP-2s, BMD-2s, and the 2A72, a lighter derivative that can be found on BTR-82As and Russia's BMP-3 and BMD-4M vehicles. Ukraine also employs a locally manufactured version on its BTR-3 and BTR-4 wheeled IFVs. The cannons are prolific and have shaped combat for both sides, see for example this account from a Ukrainian fighter:

"Russian BTR vehicles I think are worse than tanks. The gun on them fires faster and they carry soldiers. If we see a BTR there are soldiers near it. If we see a tank sometimes it is alone and easier to destroy. Wounds from these are horrible. A whole leg can be removed. A shot to the body makes someone almost explode. They are easy to destroy but not good to fight directly."

The power of the cannon is ferocious. The 2A72 is capable of firing 500 rds/min and in the BMP-3 is stabilised in both axes and connected to a fire control system that enables good accuracy at range. The high rate of fire is partially a result of the weapons being gas operated. In fact, the rate of fire can increase as the barrel heats up, as heat loss from the propellant gases is reduced, leading to higher pressures that in turn cycle the weapon's operating mechanisms faster.

The firepower of these cannons means that they can be used to dominate infantry formations from a distance, and they are also reasonably potent, which means they can – in a desperate situation – impart damage onto a tank. Both of these uses for the medium calibre cannon have been observed in Ukraine and it is apparent that infantry formations fare poorly against cannons if they are not supported. They also play an important role in urban warfare as they are capable of suppressing positions from ranges that are likely to be beyond the reach of the standard shoulder-fired anti-armour weapons carried by infantry formations.

This is not a completely novel trend either. US forces in Iraq in 1991 and again in 2003 used the 25 mm M242 that armed the M2/M3 Bradley IFV to great effect, even disabling dug-in T-62s with shots through the roof of the turret. They were invaluable in urban combat, providing rapid and demoralising direct fire against infantry in buildings and through walls if necessary. The UK similarly used its 30 mm RARDEN cannons



An M2A3 Bradley Fighting Vehicle from 5th Squadron, 4th Cavalry Regiment, 2nd Armored Brigade Combat Team, 1st Infantry Division, moves into position to conduct a firing systems check at the Presidenski Range, Trzebian, Poland, September 2017. The Bradley's medium-calibre cannon has proven itself in multiple conflicts for its rate of fire and lethality.

to good effect - albeit in a few limited examples – during the Falklands War in 1982. Cannons were also used as a form of precision direct fire in Afghanistan where they served to quickly suppress Taliban forces, and similar outcomes have been reported by French forces fighting in Mali. Ukraine does, however, show the absolutely critical utility of these weapons in a peer conflict. Many previous uses for these weapons have involved unequal fights with one side perhaps better equipped and trained than the other, or other complicating factors that suggest the benefits of the weapons might not be universal. Their use in Ukraine shows that they are an extremely lethal and useful weapon, which explains in part why most AFVs in NATO now carry them.

The important takeaway is the need to understand the risk generated by vehicles that do not carry cannons, encountering those that do. How, for example, will the UK's fleet of Boxers fare in a peer war if they are not equipped with medium calibre weapons? If nothing else, the medium calibre cannon is an eminently useful weapon. It can be used to engage a broad variety of targets and confers decisive lethality upon infantry formations. Arguably, this was already known — or at least suspected — but the Ukraine war has proven it to be true in a high intensity peer on peer environment.

Conclusion

Although at the time of writing and publication, the Ukraine war was approaching a year in duration, it is still not clear that there are any neatly defined lessons for AFV operators. At present, it is fair to argue that Ukraine is providing data, that in some cas-

es can be analysed to become knowledge. But it has not yet reached the point where the knowledge can be considered information or wisdom. The above indicates that careful consideration is required to ensure that 'new' lessons are not simply old lessons relearned. Perhaps a more considered approach would see the nature of combat in Ukraine assessed alongside previous analysis of other conflicts, to arrive at a set of combat truths around which militaries can build their doctrine and AFV requirements.

There are of course some lessons to be learned from Ukraine. For instance, the impact of drones upon the battlefield is farreaching. Although again, there is a need to discern that which is fundamentally new about the war in Ukraine, and that which has been seen before. There are lessons for cyber warriors around the effort and resources required to protect national data from determined and focused cyber-attacks. There are also lessons to be relearned about deterrence and the nature of interstate competition, and the role that armed forces ultimately play. For AFVs, it is not clear – in this author's opinion – that Ukraine has demonstrated any lessons that are fundamentally new to the world of armoured warfare. Novel and inventive tactics using legacy systems have proven fruitful, as is often the case in war, and unimaginative tactics have been punished, but it seems unwise to argue that every tactic employed by Ukraine, or every experience of a Russian armoured group is universally binding. Nevertheless, it should serve as a potent reminder of the scale of effort and commitment required to maintain armoured forces and send them to war, as well as the absolute central role that they will play.

Demand and Supply – The Complexities of Artillery and Ammunition Supply in the War in Ukraine

David Saw

The Russian invasion of Ukraine in February 2022 was supposed to be a campaign of rapid decision, operations were due to be concluded in a matter of days, with the end result being the collapse of the Ukrainian state, its government, and its military forces. At this point Russia would have established a client regime Kyiv, while absorbing Luhansk and Donetsk in the Donbas and changing the border situation in Eastern and Southern Ukraine to suit its purposes. However, things did not go according to plan.

As we now know, the assumptions that the Russian operational plan was based upon were totally incorrect. Clearly, the capabilities of the Russian military to successfully carry out the strategic mission and operational fundamentals as set out in their campaign plan were seriously overrated. Having misjudged their own capabilities, Russian commanders were equally deficient in their appreciation of the capabilities of the Ukrainian military, the resilience of the Ukrainian political leadership and the Ukrainian people's will to fight.

On paper, the combat power and materiel superiority of Russia in the land, sea and air domains were obvious. This should have translated into Russian forces being in possession of so many advantages that it appeared inconceivable, at the least to their commanders and planners, that they could fail to achieve their objectives rapidly. Yet not for the first time in military history, there was a massive difference between the 'perfect' world of the plan and the harsh reality of combat operations.

Now, many months later, there are a number of lessons to be drawn from combat in Ukraine across so many areas of military operations. In this article our intention is to look at tube artillery primarily in the context of the Ukrainian Land Forces, although limited reference will be made to the artillery situation of the Russian Army. Our starting point will be to look at the artillery systems available to Ukraine prior to the first Russo-Ukrainian conflict in the Donbas which commenced in 2014, before moving on to the current conflict and its transformation of Ukrainian artillery capabilities.



The 2S7 Pion self-propelled gun system mounts a 203 mm gun and is used by the Ukrainian Land Forces for long-range fires. Prior to the outbreak of the Donbas conflict in 2014, the majority of Ukrainian 2S7 systems were in store, since that time all these guns have been returned to service.

Lastly, we will examine operational lessons that can be drawn from the present conflict.

Artillery in Ukraine – The Beginning

With the collapse of the Soviet Union and the emergence of an independent Ukraine in 1991, one of the first steps taken by the Ukrainian government was the establishment of national military forces. What had become Ukrainian national territory was, in the Soviet era, one of the most significant centres of Soviet military power, meaning that an enormous amount of military equipment and stores had come under the control of the newly-independent Ukraine. Ukraine was to be the victim of political and economic instability all of the way through the 1990s, which saw the emergence of an oligarch class and increasing corruption problems. As far as the Ukrainian military was concerned, the main problem was a lack of funds. There was no shortage of equipment, but there was little point in having all of this equipment if you could not use it. Ukraine also had a significant de-

fence industrial capability, but there were problems here as well, they needed to reorganise to reflect the realities of the post-Soviet economic and political situation, and also needed funding to survive through a time where spending on domestic defence in Ukraine was minimal.

All in all, it was a difficult set of circumstances for the Ukrainian military and defence industry to operate within. Ukraine had complied with the force reductions mandated by the Treaty on Conventional Armed Forces in Europe (CFE), and as a part of this process a large volume of equipment was scrapped. Despite this, Ukrainian territory still held a vast quantities of equipment of all natures, including an immense amount of ammunition and large spares holdings for Soviet equipment. Inevitably, it was recognised that all of this could be monetised, and Ukraine became a major force in the sale of surplus equipment.

The Stockholm International Peace Research Institute (SIPRI) Arms Transfers Database provides a reasonable idea of the number of towed and self-propelled howitzers (SPHs) sold by Ukraine between 2000 and 2014:



The 2S1 Gvozdika 122 mm self-propelled gun is one of the major artillery systems for the Ukrainian Land Forces, both Poland and the Czech Republic have supplied 2S1 systems since the start of the conflict. Poland has been a major source of supply for Soviet calibre ammunition.

dent in the Ukrainian Land Forces' artillery inventory. In many respects Ukraine had more tube artillery than it could actually use, and consequently much of the equipment was left in storage, while other systems were left to rust.

port role, although it does have a secondary anti-armour mission. Also present, though not in significant numbers, was the 2B16 Nona-K, a 120 mm gun/mortar system, along with its self-propelled version, the 2S9. The D-30 122 mm howitzer was available in sig-

Year(s)	Importing Country	Equipment Type	Quantity
2000-2010	Democratic Republic of Congo	2S1 Gvozdika 122 mm SPH	18
2000-2010	Democratic Republic of Congo	2S3 Akatsiya 152 mm SPH	12
2000-2010	Democratic Republic of Congo	D-30 122 mm towed howitzer	36
2002	Azerbaijan	MT-12 100 mm towed anti-tank gun	72
2004	Georgia	2S3 Akatsiya 152 mm SPH	12
2007	Azerbaijan	D-30 122 mm towed howitzer	55
2007	Azerbaijan	2S1 Gvozdika 122 mm SPH	52
2007	Georgia	2S7 Pion 203 mm SPH	5
2008	Azerbaijan	2S7 Pion 203 mm SPH	3
2008	Azerbaijan	2S3 Akatsiya 152 mm SPH	16
2011	Sudan	2S1 Gvozdika 122 mm SPH	46
2011	Turkmenistan	2A36 Giatsint-B 152 mm towed howitzer	6
2011	Turkmenistan	2A65 Msta-B 152 mm towed howitzer	6
2011	Turkmenistan	M1954 (M-46) 130 mm towed field gun	6
2011	Yemen	D-30 122 mm towed howitzer	6
2013	Sudan	D-30 122 mm towed howitzer	5
2014	Nigeria	D-30 122 mm towed howitzer	18

Ukraine was also a major source of artillery ammunition for these countries and others, with Afghanistan and Iraq also thought to be major ammunition customers, with the US paying for the acquisition process. However, even the sale of 164 self-propelled howitzers (SPHs) and 210 towed artillery systems of various types outlined above, along with substantial quantities of ammunition, hardly made a

By 2014 and the start of the first Russian military aggression against Ukraine, which saw the seizure of Crimea and the start of what became the War in the Donbas, the Ukrainian Land Forces had a diverse range of towed and self-propelled artillery systems to call upon.

Towed systems included the T-12/MT-12 Rapira 100 mm smoothbore anti-tank gun, which is primarily used in the direct fire sup-

nificant numbers, despite the fact that many had been sold. The M-46 130 mm Field Gun was also in the Ukrainian inventory, but was not deployed in large numbers, as 152 mm artillery systems were preferred. These 152 mm systems provided the majority of Ukrainian towed artillery firepower, and the key systems in service were the D-20 152 mm gun, the 2A36 Giatsint-B 152 mm howitzer and the 2A65 Msta-B 152 mm howitzer.



Australian Army L119 gun systems were retired, subsequently purchased and ended up in Ukraine, courtesy of the British government, thus far some 80 guns have been supplied. The US has supplied their version of the system, the M119, with 36 guns and 180,000 rounds of ammunition being supplied.



The US Marine Corps decision to de-emphasise tube artillery meant that a substantial number of M777 155 mm howitzers were available for transfer to Ukraine, thus far some 157 guns have been delivered. In addition, Canada has supplied four M777 and Australia ten M777 to Ukraine.



The Polish AHS Krab 155/52 mm self-propelled gun system has been supplied in significant numbers to Ukraine, with an initial batch of 18 systems being followed by a second batch of 54 systems. Poland has been a major source of support for Ukraine.

Turning to self-propelled (SP) systems, the 2S1 Gvozdika 122 mm howitzer and the 2S3 Akatsiya 152 mm gun were the two most numerous SP artillery systems available to the Ukrainian Land Forces, with some 250 of each in service. There were a limited number of 2S5 Giatsint-S 152 mm gun systems in service, as well as a few 2S7 Pion 203 mm gun systems. In fact, there were over 80 2S7 systems in Ukraine, but the majority of these were in storage and had to be rapidly restored to operational condition once the conflict in the Donbas broke out. Also present were some 60 2S9 120 mm gun/mortar systems.

Lessons From the First Phase in the Donbas

The initial phase of operations in the 2014 Russian assault on Ukraine saw significant tactical and operational innovation on the Russian side, something that was seriously lacking in Russian operations during the 2022 invasion of Ukraine. Significantly, in the war in Donbas, UAV systems were used for target acquisition and real-time engagement, with targets acquired and engaged within 15 minutes, usually by Russian Multiple Launch Rocket Systems(MLRS).

As regards conventional artillery, the first phase in the Donbas showed that ammunition consumption was far higher than anticipated, running at 300 to 400 rounds per tube, per day. Fortunately, high-intensity combat was not sustained on a regular basis, there were peaks and troughs of combat activity. However, the longer the conflict went on, the more ammunition was being used and once the conflict went beyond 12 months, even the large ammunition stocks that the Ukrainians had started with were running low. Russian special operations forces also targeted major Ukrainian ammunition storage locations in the strategic depth of Ukraine and successfully destroyed large stocks of artillery ammunition, further worsening the ammunition supply situation.

Reports from the Donbas indicated that as much as 85% of the casualties suffered were caused by artillery fire. It is important to note that MLRS systems where particularly important in this first phase in the Donbas, especially when Russian forces used rockets with submunition payloads. However, conventional artillery also had a critical role to play. Both sides used the 2S1 Gvozdika SPH in direct fire missions, Russian forces used the system to suppress targets in support of advancing troops, like an old-fashioned assault gun. For the Ukrainians the 2S1 was used to bolster anti-tank defences, since its 122 mm ar-

mament could take out heavily-armoured targets. For the Ukrainians another critical area was counter-battery fire. Prior to the conflict, many of their longer-range tube artillery systems were in storage, but the need for counter-battery missions saw the rapid return of systems such as the 2A36 Giatsint-B, 2S5 Giatsint-S, and 2S7 Pion. Russian forces also started to place more emphasis on counter-battery missions as the conflict developed.

Other artillery trends seen were the dispersion of artillery systems, since traditional concentrated artillery positions were far too vulnerable. Related to this was the trend to attach artillery systems directly to lower-level formations, as this continued the policy of dispersion and also recognised the fact that battalion-sized units were operating across far greater areas than they would have traditionally. This was the foundation for the Russian Battalion Tactical Group (BTG), with its attached MLRS and tube artillery systems.

We have already mentioned the extensive Russian use of UAVs, to which Ukraine would respond by acquiring its own UAVs, but during the War in Donbas, they were less comprehensive than those of their opponent. Also widely used were artillery and mortar-locating radar systems, which, when used in conjunction with UAVs, greatly improved the responsiveness and accuracy of counter-battery fires. The im-

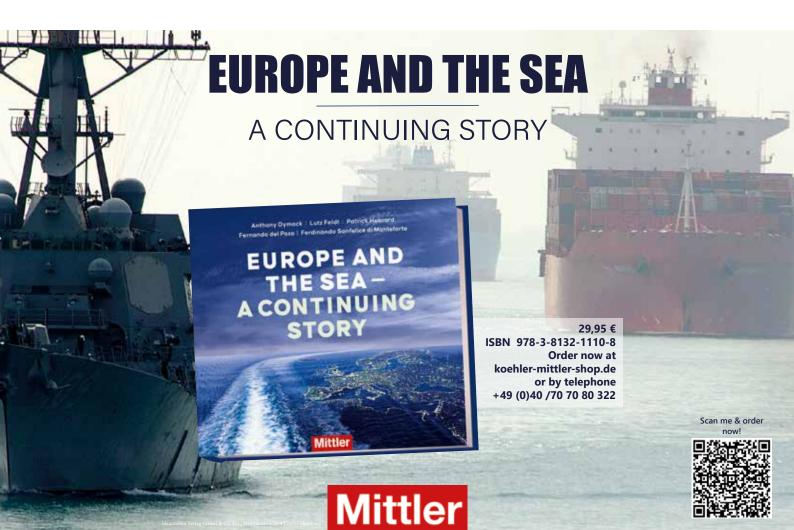


Lithuania donated a number of M101 105 mm howitzers from their reserve stocks to Ukraine and these were delivered in early September 2022 by truck, as shown here. This weapon uses the same basic ammunition as all of the other 105 mm howitzers supplied to Ukraine.

portance of counter-battery fires was not simply down to neutralising targets, since even forcing hostile artillery to suspend their activities and redeploy was also considered to be a good use of resources.

There were many lessons to be learned from the initial stages of the war in the

Donbas, one of the most significant was the importance of tube artillery. Unfortunately for Ukraine it was unable to add to its artillery capabilities in any significant manner, though under Ukraine Security Assistance Initiative, the US would supply 15 AN/TPQ-36 Firefinder artillery





France has transferred 18 French Army Nexter Caesar 155/52 mm gun systems to Ukraine. There have also been French media reports that between 6 and 12 Caesar systems based on the 8x8 Tatra 815 chassis from the Danish Army order could also be delivered to Ukraine.

locating radars, which improved their counter-battery capabilities. However, in terms of actual artillery, the only acquisition of note came in 2018 and 2019, when Ukraine was able to acquire 56 2S1 Gvozdika SPHs delivered in two batches from the Czech Republic.

Certainly, Ukraine could have benefitted from the provision of substantial amounts of defence equipment from friendly nations during the War in the Donbas, but in reality it received very little. On the other hand, the training assistance that it received has helped stimulate cultural change in the

Ukrainian military, helping it to transition from its Soviet roots to become a much more modern and flexible instrument. Its ability to adapt to changing circumstances presents a stark contrast to the relatively inflexible nature of Russian military operations in the current conflict.

It should also be remembered that Ukraine did not have the financial resources to significantly add to its military capabilities, what defence funding it could allocate had to be spent very carefully. There were some domestic artillery development efforts though, most notably the 2S22 Bogdana, which is

Photo: Ukrainian Land Forces

Both Estonia and Italy have donated FH70 155/39 mm howitzers to Ukraine, with Italy also providing 155 mm projectiles and charges. Other European countries such as Spain and Finland have also supplied 155 mm ammunition to Ukraine.

a NATO-compliant 155 mm artillery system mounted on a Ukrainian AutoKrAZ KrAZ-63221 6×6 truck platform. The system was first displayed in 2018 and the single prototype reportedly successfully completed firing trials in January 2022. The single Bogdana system has apparently seen combat in the current conflict, but given the devastation suffered by Ukraine's manufacturing sector, there seems little possibility that further such systems could be built.

The Current Conflict

The Russian invasion of Ukraine that commenced on 24 February 2022 was to be the final act in Russia's effort to dismember the country and turn what remained into a client state. This was a process that started on 21 February 2014 with the annexation of the Crimea by Russia, and in March was followed by a separatist movement bursting into life in the Luhansk and Donetsk regions of the Donbas. By April 2014, separatists in both regions had declared themselves as 'People's Republics' and, with Russian military support including troops and weapons, commenced military operations against the Ukrainian state.

When the current conflict broke out there were very few who expected Ukraine to survive, from Moscow's perspective the February invasion was supposed to resolve Russia's Ukraine problem in a matter of days. The fact that many months later Ukraine is still resisting, has recaptured much territory lost in the initial invasion and has inflicted humiliating reverses on Russian ground forces is a substantial achievement. Ukraine's willingness and capability to provide sustained resistance was obviously not a factor that had been correctly calculated in Russian planning.

A crucial factor behind Ukraine's ability to sustain resistance was that unlike in 2014, its plight was not ignored by the international community. This time Ukraine had international support, resulting in the supply of weapons, equipment, ammunition, training, finance and other means of support, allowing Ukraine to continue fighting and enhancing its ability to successfully conduct combat operations. Unlike during the War in the Donbas, where Ukraine was suffering from qualitative inferiority, all of this foreign assistance has given Ukraine qualitative equality in a few critical areas, and even superiority in some.

Foreign Artillery Assistance

Ukraine has received a host of different artillery systems from friendly nations, covering the whole tube artillery spectrum from obsolete, to obsolescent, to state-of-the-



The 2A65 Msta-B 152 mm howitzer came into service in the late 1980s and Ukraine ended up with some 100 of these systems, during the current conflict they are credited with capturing at least 20 more of these guns from Russian forces.

art. Equipment supplied includes artillery in old Soviet calibres already in service with Ukraine. Also received were towed and self-propelled systems in standard NATO 105 mm and 155 mm calibres, with new production self-propelled systems to be shipped in due course.

Dealing with Soviet calibre equipment first, the following have been notable transfers to the Ukrainian armed forces, but do not represent all received/obtained equipment: securing other sources of supply has become necessary. For instance, Greece was able to supply 2,100 122 mm rounds. By mid-2022 though, Ukrainian government officials were stating that in the Donbas alone they were firing more than 6,000 artillery rounds per day and were in desperate need of more ammunition.

Meeting Ukrainian needs for Soviet calibre ammunition saw some unusual sources of supply enter the fray. In July, the British

Equipment	Quantity	Supplier
D-30 122 mm towed howitzer	Not Known	Czech Republic (ex-Bulgaria)
D-30 122 mm towed howitzer	9	Estonia
M1954 (M-46) 130 mm towed field gun	15+	Croatia
2S1 Gvozdika 122 mm SPH	Not Known	Czech Republic
2S1 Gvozdika 122 mm SPH	20+	Poland
ShKH vz.77 DANA 152 mm SPH	20+	Czech Republic
2S19 Msta-S 152 mm SPH	30+	Russia (Captured)
2S33 Msta-SM2 152 mm SPH	12+	Russia (Captured)

Acquiring ammunition for these Soviet Calibre systems would normally not be that much of a challenge, obvious suppliers include Poland (Polish ammunition of this type is widely used in Ukraine), The Czech Republic and Slovakia amongst others, and the capture of Russian ammunition stocks. However, ammunition usage rates have exceeded expectations, meaning that

government declared that it would acquire 50,000 rounds of Soviet calibre ammunition for Ukraine, and it would appear that Pakistan was the source. In early August reports surfaced of RAF C-17 transport aircraft flying missions to Nur Khan airbase at Chaklala, near Rawalpindi in Pakistan. C-17 missions were conducted via either Cluj in Romania or RAF Akrotiri in Cyprus, in total

there were 12 flights were over a 15 day period. The purpose was to transport Pakistan Ordnance Factories (POF) 122 mm HE natures with LIU-4 fuzes, and by the end of August, photo confirmation of Pakistani ammunition in Ukrainian service became available. Supplying this ammunition made great sense for Pakistan, it improved relations with Britain and the US, which was important as Pakistan was looking for a loan from the International Monetary Fund (IMF) and military equipment from the US, and POF itself, which was paid for the ammunition.

A more unexpected source of Soviet calibre ammunition was Iran. Bearing in mind that Iran has supplied Russia with UAVs (Mohajer-6; Shahed-129) and loitering munitions (Shahed-131; Shahed-136), the fact that Iranian artillery ammunition is being used against Russia came as something of a surprise. Supplying both sides in a conflict is not unknown, but initially there were suggestions that the OF-462 122 mm projectiles and their accompanying B-429E fuzes had originally been sent by Iran to their Houthi clients in Yemen before being intercepted on the way, with the seized ammunition sent to Ukraine. More recently this explanation has become doubtful, with images of Iranian OF-462 packing crates in Ukraine and associated documentation indicating that the Iranian ammunition was manufactured in 2022, as well as the appearance of Iranian 152 mm rounds in Ukraine. It would therefore appear that Iran is seeing the conflict in Ukraine as a commercial opportunity, with both sides as customers.

Towards the end of November 2022, images surfaced on social media purporting to show Ukrainian domestically-produced 152 mm rounds. At present, it is unclear whether the rates of production are sufficient to meet Ukraine's rates of ammunition expenditure, or how long Ukraine will be able to sustain production amid attacks on its energy infrastructure. However, this source should not be discounted as a possible means for Ukraine to sustain its own artillery.

One unexpected artillery ammunition story concerns Russia. Although they were credited with having vast ammunition stocks, the intensity of ammunition consumption nonetheless became a problem. This was compounded by the reported large amount of dud rounds being fired by Russian artillery, indicating improper storage and/or quality control problems in manufacturing. These problems should be resolved by newly manufactured ammunition, but this brought another set of problems to confront – that rates of use exceed manu-

facturing rates. The resulted in the Russia being in the unexpected position of having to acquire Soviet calibre ammunition on the international market.

According to the US, Russia has been successful in finding an artillery ammunition supplier in the form of North Korea, which has produced immense quantities of weapons and ammunition for the Korean People's Army (KPA). Tube artillery forms a critical part of KPA capabilities and ammunition stocks are substantial. These deals are made easier by the fact there is a railway line running from Pyongyang to Vladivostok. Once it arrives in Vladivostok, ammunition can be placed on the Trans-Siberian Railway and shipped westwards or air freighted. It is unclear whether Russia is paying cash for the ammunition or a mixture of weapons, food and fuel.

There is of course one major supplier of both Soviet and Western calibre artillery ammunition that could rapidly respond to large requirements and that is China. It is very significant that Beijing has decided not to actively involve itself in Ukraine conflict. In fact, China is benefitting from the situation via deeply discounted Russia oil and increased Russian dependence on trade with China and access to Chinese finance.

Western Artillery Systems

The supply of artillery systems to Ukraine by the US and other Western nations has made a decisive contribution to Ukrainian firepower, in many cases offering performance advantages over Russian artillery systems. However, not all of the equipment supplied to Ukraine delivers qualitative advantages, and some system donations can be considered as no more than a gesture. Despite that, the range of tube artillery which has been made available to Ukraine is impressive, both in terms of size and diversity. Looking first to towed artillery systems, the following have been delivered to Ukraine or are in the process of being delivered:

Notably, some of the systems listed are fairly obsolete by modern standards, with the most notable example being the M101 105 mm towed Howitzers, a model which was produced between 1941 and 1953. These would have little real battlefield utility, but may be useful for training purposes. In a similar vein, Portugal offered to supply five M114 155 mm towed howitzers, which also date back to WWII. however this latter offer was declined by Ukraine. More modern offerings include the FH70, TRF1, and the M777. These M777 guns have mostly been taken from US Marine Corps stocks as they move towards new operational concepts that reduce the need for armour and artillery.

These towed artillery systems have also been supplemented by large quantities of self-propelled artillery, with Ukraine having received or is in the process of receiving the following 155 mm SPHs:

zana 2, and PzH 2000. Notably, several of the losses can be attributed to the Lancet loitering munition, suggesting Russia is adapting its counter-artillery operations. Additionally, Ukrainian PzH 2000 crews tended to fire a large number of rounds on a continuous basis, leading to serviceability problems with the system, according to German media reports. Spare parts also seem to have not been available in sufficient quantities, reports from Ukraine suggesting that one PzH 2000 might have been cannibalised for spares. On the positive side, these harsh lessons have led towards the establishment of a support infrastructure for Ukrainian PzH 2000 systems. To this end, Krauss-Maffei Wegmann (KMW) are establishing a centre in Slovakia to provide repair and maintenance services, plus logistic support, for systems such as the PzH 2000. Another potential self-propelled artillery system arrival in Ukraine is the BAE Sys-

Equipment	Quantity	Supplier
M109A3GN	22	Norway
M109A4BE	20	UK (ex-Belgium)
M109A5Ö	6	Latvia
M109L	20-30 (in progress)	Italy
CAESAR 6×6	18	France
CAESAR 8×8	6	France
Zuzana 2	24	Slovakia
AHS Krab	72 (18 delivered; 54 in progress)	Poland
PzH 2000	114 (14 delivered; 100 in progress)	Germany
PzH 2000	8	The Netherlands
PzH 2000	6	Italy
RCH 155	18 (in progress)	Germany

While these have augmented Ukraine's indirect fire capabilities, they have also faced challenges. A number of AHS Krab and M109 SPHs have been destroyed or heavily damaged already, along with smaller quantities of CAESAR 6×6, Zu-

Equipment	Quantity	Supplier
M101 (105 mm)	Not Known	Lithuania
M119 (105 mm)	36	USA
L119 (105 mm)	86	UK (ex-Australia)
Model 56 (105 mm)	6	Spain
FH70 (155 mm)	Not Known	Estonia
FH70 (155 mm)	Not Known	Italy
TRF1 (155 mm)	15	France
M777 (155 mm)	142	USA
M777 (155 mm)	4 (plus 10 spare barrels)	Canada
M777 (155 mm)	6	Australia

tems Archer 155/52 mm 6×6 wheeled artillery system. The Swedish Army was asked to conduct a study to determine how many Archer systems could be transferred to Ukraine, without degrading Swedish artillery capabilities, and it concluded that 12 systems could be spared. It is now up to the recently elected Swedish government to decide if they will supply these Archer systems, in the meantime Sweden is providing military assistance to Ukraine, including ammunition.

These artillery transfers have been accompanied by large quantities of ammunition, however, the only clear data on artillery ammunition supplies to Ukraine come from the US, along with some limited information from Canada, Germany, and the UK. The following table summarises known quantity artillery ammunition transfers either completed or in progress as of late 2022:

Equipment	Quantity	Supplier
105 mm artillery ammunition	180,000	USA
155 mm artillery ammunition	924,000	USA
155 mm M982 Excalibur Guided Rounds	4,200	USA
155 mm Remote Anti-Armour System (RAAMS) rounds	9,000	USA
155 mm artillery ammunition	20,000	Canada
155 mm artillery ammunition (est.)	26,000	UK
155 mm artillery ammunition	13,500	Germany

Outside of these known quantities, various others have contributed ammunition. In terms of 105 mm ammunition, Lithuania, Spain, and the UK are understood to have contributed, while in terms of 155 mm ammunition, Canada (including M928 Excalibur rounds), Finland (TKR 88 rounds), Germany (including Vulcano 155 mm Extended Range and 'SMart' sensor-fuzed natures), Italy, Norway, Spain, and Sweden have all provided ammunition.

As such, 155 mm systems have grown in importance to become the key element of the Ukrainian Land Forces tube artillery capability. However, ammunition usage rates have been prodigious in Ukraine, causing alarm in the US as 155 mm ammunition stocks have been run down and current production is not enough to replenish expended stocks. According to the Center for Strategic and International Studies (CSIS): "In FY 2023, the United States only planned to buy 29,000 of the basic high explosive projectiles (M795). Surge capacity was 288,000 projectiles per year, though with a 48-month lead time." Now it appears that plans are under consideration that would see monthly 155 mm production increase to 36,000 rounds, although reaching this production rate will take three years!

Once again artillery ammunition expenditure has been much higher than expected in a conventional conflict. It would therefore appear that either our ability to accurately predict rates of expenditure remains an inexact science, or that maintaining sufficient ammunition stocks has been institutionally deprioritised. It is obvious that without the US transfer of immense quantities of 155 mm ammunition, the course of this conflict could have been totally different. Obviously NATO members are going to have to do some serious thinking about the size of their artillery ammunition stockpiles once the lessons of the current conflict are analysed.

Lessons to Learn

There are many lessons that can be taken from the current conflict in Ukraine, in terms of sustaining the defence industrial base and in terms of actual combat operations. When the US starts worrying about the ability of its defence industrial base to restore stocks that have been depleted by transfers to Ukraine, there is a real problem. We have noted the issue of 155 mm ammunition stocks, but the problem is widespread, including FGM-148 Javelin missiles amongst other examples.

The US has traditionally been able to rely upon immense stocks of materiel in its possession, the fact that is apparently no longer the case is a major concern. Materiel shortages limit operational possibilities, which in turn reduces strategic options available to the US. It has taken Ukraine conflict to start the US thinking about sustaining production capabilities and having the ability to rapidly increase production capabilities. That is a positive development, however, the major negative is that it will take years to restore production capabilities in many critical areas. If the US is suddenly becoming aware of critical equipment shortages that should be a warning for Europe, where many nations have been less than diligent in having appropriate ammunition and spare parts stockpiles. The rate of artillery ammunition usage in Ukraine should be a real lesson to European militaries and force them to seriously consider if their ammunition war stock numbers are truly adequate for combat operations. The same logic applies to more expensive, but more capable, guided rounds that are already only available in small numbers. As regards artillery ammunition, some US studies lamenting the decline of US 155 mm ammunition stockpiles and the timescales required to increase ammunition production, have pointed to the fact that their European allies also manufacture 155 mm and that this could become another source of supply if required. Unfortunately, this fails to take into account

that European militaries will also need to replenish their 155 mm stocks after transfers to Ukraine. Added to this, European industry has generally not been producing artillery ammunition in large quantities due to a lack of domestic demand. Like the US, Europe must look towards strategies to sustain its defence industrial base and create a surge capability to meet increases in demand.

In the current conflict in Ukraine there has been plenty of coverage of how important rocket systems such as HIMARS and MLRS have been. This tends to diminish the significance of tube artillery systems. However, any operational analysis will clearly demonstrate the key role that these systems are playing in the conflict. The key finding as far as tube artillery is concerned is the fact that ammunition consumption is far higher than previously expected. In turn this brings another issue to the fore, sustained high utilisation rates over months will reduce artillery performance, meaning that the availability of spare barrels, as well as repair and overhaul services must be assured.

Operationally, the reality is that artillery systems must be dispersed and be able to quickly get into and out of action to survive on the battlefield. This seems to indicate that self-propelled systems are the choice solution for artillery on the modern battlefield. Increasingly, the future of artillery systems appears to be working towards mobile solutions, with reduced crew numbers in a protected environment and an automatic loading system, eventually evolving towards a system offering completely autonomous operation.

On the other hand, both Ukraine and Russia continue to use significant quantities of towed artillery, indicating, that if employed properly, towed artillery can still play a role on the modern battlefield. The tactics of dispersed operation, selecting an appropriate firing position, rapidly into and out of action and moving to a new location rapidly can also work for towed artillery to an extent. The downside is that towed artillery crews have to do without the speed or protection provided by many self-propelled howitzers. What the conflict in Ukraine has demonstrated is that in terms of artillery, rocket systems and tube artillery are complementary. It has also demonstrated that the West has caught up with Soviet and successor Russian doctrine in terms of the utilisation of rocket systems and in the performance of tube artillery, where the advantages of range and accuracy often rest with Western systems. Accurate engagements out to extended ranges, in conjunction with



One unexpected source of additional artillery systems for Ukraine has been captures from the Russian Army, such as this Msta-S 152 mm self-propelled gun system. As Russian forces have been forced back, significant quantities of self-propelled and tube artillery, as well as ammunition have been captured.

advanced surveillance and targeting systems will be the future direction of tube artillery systems. Inevitably, there will be a need to use guided projectiles, and the challenge comes in making these affordable to acquire in credible numbers. On top of that, regaining the ability of artillery to engage armoured formations with top attack sensor-fuzed munitions will also be a requirement.

After so many years of Western militaries focussing primarily on asymmetric conflicts, what is happening in Ukraine must force a rethink in terms of conventional conflicts and whether the correct force structures and equipment are in place to fight conventional conflicts if so required. There has been much talk in Europe of increasing defence expenditure in recent times, certainly more funding will be required to regain conventional capabilities. Unfortunately, the current economic crisis in Europe accompanied by frequently high levels of public spending mean that defence spending increases are vulnerable to being severely limited. This would be a serious obstacle for European forces attempting to restore their capabilities to fight conventional wars.

Protecting Armoured Vehicles from CBRN Threats

Dan Kaszeta

Rumours of the demise of the tank are, in fact, premature. Mechanised warfare is occurring on the Russian-Ukrainian front at the time of writing and will likely continue for some time. Given that one of the combatants, Russia, is a nuclear power and historically had stockpiles of chemical and biological weapons, we cannot truthfully say with assurance that the era of chemical, biological, radiological, and nuclear (CBRN) threats is over for good. A natural confluence of CBRN threats and mechanised warfare is the desire to seek protection of combat vehicles from such threats.

odern armoured fighting vehicles (AFVs) - tanks, reconnaissance vehicles, armoured personnel vehicles, and

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a panoply of related types of wheeled and tracked combat vehicles, evolved for several reasons. But one of the main historical motivations was to provide not just mobility but protection to modern military forces. Layers of armour protect soldiers from various types of direct and indirect fire. Many, but certainly not all, modern AFVs, have features that protect their crew and/or passengers from chemical, biological, radiological, and nuclear threats. The overall aim of CBRN survivability on the battlefield is to keep the AFVs in the fight, and that usually means keeping the crew safe from harm.

Within the CBRN threat spectrum, only the direct effects of nuclear detonations physically damage the AFV itself. Most of the time, CBRN threats harm the crew or passengers, or contaminate the vehicle so that

its utility might be constrained, but do not physically damage the vehicle. Operational constraints might take the form of forcing crew to wear personnel protective equipment, thus degrading operational capability. Alternatively, contamination of an AFV might mean that using it outside a contaminated area would spread the contamination. Imagine a company of tanks driving through contaminated mud and then tracking that mud through a critical road junction or onto a bridge. Or worse, into the back of an aircraft or onto an airfield. In addition, contamination can reduce some specialty capabilities. A recce vehicle, combat engineer vehicle, field ambulance, or armoured recovery vehicle that is contaminated with radiological or chemical hazards might be useless for its specialty role until decontaminated.

There are many approaches to protecting AFV crews and passengers. The passengers are often as important as the crew, as one of the key roles of infantry fighting vehicles (IFVs) and armoured personnel carriers (APCs) are to transport infantry sections and squads, as well as other combatants like sappers or cavalry scouts. While mechanised warfare has gone a long way from considering APCs to merely be taxis for dismounted infantry, part of the raison d'être of such vehicles is to protect the passengers, so we must consider CBRN protection to be part of that purpose.

AFV Masks and Suits

At the most basic level, one can achieve a high degree of protection simply by providing the same CBRN personal protective equipment (PPE) to the crew and passengers that the rest of the army uses. For the most part, this is the broad approach to protecting passengers. A mechanised infantry squad in most armies generally has the same CBRN PPE as non-mechanised infantry. It has long been conventional wisdom in many armies that the general-purpose protective masks/respirators (nomenclature varies) are designed primarily around infantry soldiers and their specific requirements. These may not necessarily be optimally designed for use by armoured vehicle crew. For example, a tank crew needs to communicate with each other. This is typically done by headphones and microphones as part of a headset or helmet. Will any of that work if the driver and commander of the tank have to put on an infantryman's protective mask? In addition, the field of view afforded by an infantryman's mask may not be ideal for driving. Likewise, aircraft crews face similar issues.

For such reasons, major PPE manufacturers have, for decades, produced product lines of respiratory protection aimed at vehicle crews. These products typically have the requisite communications capability wired into them and are designed to integrate with military optical systems commonly found on AFVs. One example of many is Avon Protection's FM51 mask. Another was the US Army's M42 mask, made by ILC Dover, which is still found in service. Numerous comparable masks exist around the world. Compatibility of connections is a problem, however. This might be an issue in a situation like Ukraine, where numerous donors are providing a wide range of equipment.

It should also be noted that protective clothing – suits, boots, and gloves – for AFV crew will have different requirements. The tradi-

developments is chemical protective undergarments that are designed to fit under existing flame resistant AFV crew uniforms.

Collective Protection

By definition, a tank or other AFV is a confined environment. It is possible to provide CBRN protection to an entire vehicle rather than just give individual protection to the occupants. Traditionally, there have been two major approaches to this - ventilated facepieces and overpressure systems. Ventilated facepieces are the next step up from individual protective masks/respirators. They provide pressurised filtered air through a hose to the crew's protective masks. As a result, most specialty AFV protective masks are designed with such a hose or to connect to such a system, while



The US military's M50-series includes masks specifically adapted for combat vehicle

tional NATO Cold War-era activated charcoal suit may not actually be the safest thing to give to a combat vehicle crew. One of the great killers of AFV crews is fire, and generations of CBRN protective equipment designed for other uses were (and some still are) made of things that will either catch on fire or melt. Needless to say, CBRN protective gear that makes conventional hazards worse than they need to be is not the ideal approach to crew or vehicle survivability. Improvement is clearly evident in this segment of the market. All around, newer designs and technologies have meant that most military CBRN kit is less flammable than the past. In addition, there have been generations of CBRN protective clothing for AFV crews that incorporate flame resistance and fire-retardant capacities. Another useful approach that shows some prospect for future

retaining a filter in case the crew needs to evacuate or dismount. Such systems have a higher protective factor in most cases, because of the supplied air. On the other hand, there are maintenance and filterlifespan considerations for the installed hardware.

Combat Vehicle Variant

Many AFVs now operate a more fulsome method of protection, known as variously as collective protection and/or overpressure systems. These systems operate by providing filtered air, at higher pressure than ambient atmospheric pressure, to the interior of the vehicle. These systems entail considerable engineering effort as they have to move a lot of air and need sizeable filters. Furthermore, the whole vehicle design needs to be considered as every gap, port, and hatch needs to be airtight. Overpressure systems are usually maintenance-





The US military's M51 mask is designed for combat vehicle crews.

intensive and, anecdotally, sometimes get neglected as part of ongoing maintenance. It is important to design such systems properly. If not correctly designed and constructed, collective protection systems can be damaged by blast overpressure from explosions.

Readers interested in a more thorough discussion of the hardware and manufacturers within the AFV collective protection segment can find a thorough discussion that this correspondent wrote in issue 4/2018 of this magazine. There are relevant NATO standards in this space to guide manufacturers and procurers, such as NATO Triptych AC/225 and Allied Engineering Publication 54. These standards get much consideration even in non-NATO states. The general market situation has changed only slightly since that was written. Honeywell (USA), Dräger (DE), HDT Global (USA), Nexter (FR), Bioquell (UK), Temet (Finland), and Beth-El (Israel) are only some of the main players in this market space.

Collective protection generates operational challenges as well, as vehicles need to be in "buttoned up" mode to use it. So much as a single open hatch sacrifices all of the effort. Masks, whether connected to a ventilation system on their own or not, and overpressure systems are excellent defences, but they need to be actually used in order to have useful protective benefit. Few tank crews like to drive all wearing masks or train very often to do so. Likewise, if you observe actual mechanised or armoured operations, you will see that AFVs spend much of their operating life operating with hatches open, the driver's head exposed, and the torso of the vehicle commander emerging from his/her hatch. These are

vulnerabilities that all of the available hardware will not mitigate. The biggest issue of collective protection is expense, however. These systems are expensive, and the filters need to be changed regularly, creating recurring costs. Some work has gone into regenerative filters, which will have more initial expense, but far less downstream expense as their service lifetime and associated labour will be much lower.

Another aspect of protecting the vehicle as a whole instead of merely protecting the occupants is paint. Some types of CBRN threats, principally the blister agent mustard gas and persistent nerve agents like VX, have an insidious ability to seep into paint and desorb slowly over time, making decontamination more difficult. A persistent hazard can, on some painted surfaces, become MORE persistent, which is troublesome. Decades ago, the US military addressed this by developing CARC - chemical agent resistant coating. Such coatings are expensive, but are now in widespread use. Historically, the US experienced throughput issues when combat vehicles needed to be repainted, as only a handful of facilities were able to apply CARC paint. Finally, yet another aspect of CBRN protection of AFVs is situational awareness. Chemical and radiological detection now work in real time or near to real time. Military detector systems are getting smaller and cheaper in real terms. Armies that once procured tens of detectors are now procuring hundreds or thousands. At the beginning of this correspondent's career, CBRN detection on a vehicle was limited to a handful of specialty reconnaissance vehicles. The paradigm was shifted on this by the mass procurement of many thousands

of M4-series Joint Chemical Agent Detectors (JCAD – made by Smiths Detection) by the US military. Part of the JCAD programme has been the fielding of power and communications adaptors to mount it on many kinds of vehicles. Some other countries have followed suit and there are now chemical agent detectors on AFVs in a number of countries. Similarly, radiation detection systems hard-wired into AFVs are now widespread around the world.

Nuclear Considerations

At the beginning of this correspondent's defence career, the prospect of tactical nuclear weapons used on the battlefield was shrinking. Unfortunately, the Russian-Ukrainian conflict has some people talking once again about battlefield nuclear weapons. This current trend makes a brief discussion of AFV survivability in a tactical nuclear environment worthy of discussion. AFVs, and in particular main battle tanks (MBTs) provide a reasonable degree of protection in a tactical nuclear environment. Nuclear weapons provide hazard through a lot of mechanisms, such as blast, heat, prompt radiation, and residual radiation. Of course, a near hit or near miss with even the smallest nuclear weapon provides blast and heat that will shred, tear, flip, or melt any AFV. But the radii of these effects, especially against buttoned-up MBTs is surprisingly modest, particularly when considering smaller tactical nuclear weapons. A nuclear artillery shell fired against a well-dispersed tank battalion may only take out a dozen tanks. With smaller nuclear detonations, the largest radius of casualty-producing effects is made by gamma and neutron radiation, not blast or heat.



HDT's M48A1 filter is widely used to provide CBRN protection in vehicle applications.

Of everything on a modern battlefield, MBTs are the most robust in a tactical nuclear environment, because of their 'transmission factor' - the degree of shielding that they provide against gamma and neutron radiation. The thick armour on AFVs greatly increases this transmission factor. Tank armour was once strictly a matter of armoured steel, which is not bad at attenuating gamma rays but not particularly great at blocking neutrons. However, tanks now have composite armour, some of the components of which may serve to attenuate neutrons. For example, Russian MBT composite armour is believed to contain boron, which has useful shielding properties. AFV hardening against nuclear threats is classified in the USA but the paper trail clearly references classified specifications for nuclear hardness being circulated as part of major procurements. Several QSTAGs -Quadripartite (US, Canada, Australia, UK) Standardisation Agreements – are known to exist in the nuclear hardening field.

A Systemic Approach

AFV survivability on the CBRN battlefield also has aspects broader than the physical hardening of the vehicle and the provision of



Austrian Army tank crew in CBRN protective gear.

PPE to the crew and passengers. The underlying objective in CBRN defence in army operations is to preserve the ability to continue military operations. How an army deals with the CBRN threat at a broader level, from the top-down, is also relevant to the CBRN survivability of AFVs, their crews, their passengers, and preservation of fighting ability. Two broader approaches are contamination avoidance and decontamination.

So-called "contamination avoidance" developed out of Cold War era NATO doctrine and procedures. It is, broadly, a large toolbox of tactics, techniques, and procedures (TTPs) to calculate and estimate where contamination might be found on the modern battlefield. By developing and implementing an army-wide network of reporting of CBRN attacks, augmented by detection and CBRN reconnaissance,





Decontamination is part of AFV CBRN survivability.

CBRN specialists in battalion, brigade, or divisional headquarters can use field reports and weather data to make educated estimates as to where CBRN hazards are likely to impact upon military operations. The idea, in principle, is that defending forces can take action to reduce their exposure and offensive forces can avoid areas of known, likely, or suspected contamination. The end result, in an ideal situation, would be that many forces, including AFVs would not be sent in to contaminated areas unless there was a compelling need to do so. My own experience, learning how to practice contamination from bottom-up, is that an awful lot of things need be done correctly, and a lot of information needs to be collected and processed for contamination avoidance to work at all. Whether it will work on a modern battlefield in a CBRN environment or not is anyone's guess, as it has never been tested. In theory, NATO-standard contamination avoidance doctrine can reduce the need for AFVs to have protection.

However, in practice, this is a weak branch to hang a heavy coat upon.

Contamination avoidance represents the 'glass half-full' approach in modern CBRN defence, by hoping that rather a lot of the force is going to be able to avoid CBRN hazards by means of sophisticated situational awareness. The 'glass half-empty' counterpart is decontamination. Military decontamination doctrine assumes that some soldiers and systems are going to get dirty. Troops, equipment, and systems will need varying levels of decontamination in order to stop being a hazard to life and health, to stop the spread of contamination, and to allow fighting capability to get back into the battle.

This means that an important part of CBRN survivability of AFVs is the existence of robust decontamination capability and capacity. CBRN decontamination has been discussed at length in several previous articles in this magazine, but it needs to be viewed as an integral component of protecting AFVs and their crews from CBRN

threats. The sooner and more effectively a tank or APC can be decontaminated after an attack, then more the threats to its crew and occupants are reduced and the risk of spread of contamination is reduced. Decontamination of military vehicles is serious business, and a large subsector of military CBRN defence. It was discussed in detail in this magazine in issue 1/2020, for those interested in a deeper dive.

In sum, there are a number of valid AFV CBRN protection approaches, all of which come with their own strengths and weaknesses. These have been summarised in the table at the bottom of the page.

The Way Forward?

Looking to the future, is there an end to the need for CBRN protection of AFV crews? There are several ways of seeing how that may come about. One is continued efforts to make sure that the use of CBRN weapons is a thing of the past. Diplomacy, arms control, and non-proliferation efforts have actually done a lot of hard work to see that the peril of CBRN warfare is only of historic interest. However, we must be realists and see that such an objective, while worthy, may be forever just beyond our reach. A more pragmatic approach may be in unmanned systems. Are we getting to the level of sophistication when a tank needs no human crew? AFVs with the humans engineered out of the interior would be far more robust and survivable in CBRN environments. This is food for thought for future discussions. It will be interesting to see where the AFV market is in ten years.

CBRN Protective Feature	Advantages	Disadvantages
Specialty masks	 Broadly similar to the masks regularly used in the army 	Integration into electronics and optics
Special suits / undergarments	Flame resistance	• Expense
Ventilated facepieces	 Improved respiratory protection and comfort 	Needs central filter and blower units.Maintenance
Filtered overpressure systems	High level of protection	Easily compromised by open hatches or leaksExpensive operations and maintenance
Special paint/coatings (CARC)	Improves decontaminationReduces persistence	Expense vs conventional paintSpecialty facilities
CBRN detection systems	Improves situational awareness	Sometimes an afterthoughtNeeds integration
Composite armour	Improves radiation protection	ExpensiveNot often used on lighter vehicles
Contamination awareness	Helps avoid the problem to begin with	 Has many components and elements that need to be done correctly Nobody knows if it will work
Decontamination	Reduces hazards to personnelReduces spread of contamination	Labour and resource intensive



Viewpoint from Paris



France Adopts New National Strategic Review

Denys Kolesnyk

Russia's full-scale invasion of Ukraine on 24 February 2022 became a turning point

for European security priorities and became a source of discomfort for many in the West who had tried to downplay the Russian threat. Some even paid for their incorrect assessments of the situation with their posts. For instance, General Éric Vidaud - Head of the French Military Intelligence (Direction du Renseignement Militaire - DRM) – was discharged from his position due to "shortcomings in the assessment of the war in Ukraine", only seven months after being appointed.

The invasion also brought more uncertainty to the defence climate in Europe. The French national intelligence capabilities as well as approaches towards the region have run contrary to the US' assessment prior to the Russian invasion of Ukraine, and afterwards it became necessary for France to adapt to the new reality.

The Strategic Update (Actualisation Stratégique), published in January 2021, is one of the key French doctrinal documents that had to be urgently reviewed. Already on 9 November 2022, France's President Emmanuel Macron unveiled the new National Strategic Review (NSR) while traveling to Toulon – a southern city hosting a French Naval base.

The new document replaced the Strategic Update of 2021, which had been an attempt to amend the initial Strategic Review of Defence and National Security (SRDNS), published in 2017 - some five months after Macron acceded to the Élysée Palace.

Contrary to its predecessors, the new document was drafted in haste and despite the pressing need to review France's approach towards European security, and especially the Russian threat, the result seems to be quite modest.

The 60-page document is divided into three parts, with the last one proposing 10 strategic objectives. It acknowledges the "major shift in strategy", provoked by the Russian invasion of Ukraine, and takes note of "moving from a latent competition to an open confrontation, on the part of Russia and, increasingly, to greater competition with the People Republic of China", thus highlighting the importance of the Russian threat. The general thread of the document, however, is the confirmation of assumptions and trends identified in the 2017 and 2021 editions. Among France's security priorities it is unsurprising to find the "strategic autonomy" that is defined as a "prerequisite for pro-

tecting our fundamental interests". Alongside this, the document notes that the freedom to act and protection of France's fundamental interests should be ensured, above all, by the "credibility of nuclear deterrence". Even though this statement only follows the general logic of Paris, nuclear issues are getting higher on the agenda, especially given that the NSR 2022 notes "Russia's use of nuclear rhetoric as an offensive (not defensive) device in support of the invasion of Ukraine has the potential to undermine strategic equilibrium and, in the longer term, to intensify proliferation".

The document also notes that the "hybrid strategies" have shown their impact. Yet again, it is unsurprising to see that the NSR 2022 mentions Africa, where France continues to suffer from the Russian hostile actions in cyber and information spheres, instigating anti-French sentiment among the local populations, especially in Mali and the Central African Republic. Therefore, the document goes further and acknowledges something new - the "strategic function of influence" that "aims to promote and defend the interests and values of France" and is considered, by the document, to be "an essential part of the expression of power". It is worth noting that France has made some progress in terms of addressing the foreign malign influence on French soil, among other things by creating the Viginum anti-disinformation agency, which aims to protect the country from foreign cyber and influence operations. In order to act abroad, the Military Doctrine for Information Warfare (Doctrine militaire de lutte informatique d'influence – L2I) was unveiled last year.

The manipulation of information (the preferred term in France for 'disinformation') is mentioned several times in the document, and reflects France's increased awareness of the problem since 2017. The fight against disinformation became an important issue for Paris, especially given the vulnerabilities of French society. Thus, the NSR 2022 advances the idea that the French Republic has to have a "wide range of response options, beyond public denunciation of perpetrators, as happens with cyber attacks".

However, in general terms, the document seems a bit less solid than its 2017 predecessor and doesn't provide much compared to the 2021 Strategic Update. Yet, given the rapidly changing security environment on the European continent, and the rest of the world, we may come to expect the publication of such documents every year or two to keep pace with evolving threats.

Russia's Weaponisation of Winter

Juan Manuel Chomón Pérez and Craig Hymel

Over the coming months, the bloodiest battles in Ukraine may not feature dramatic scenes starring American MQ-9 Reapers striking Russian T-90M tanks in Mariupol, nor a swarm of Iranian Shahed 136 drones (known as Geran-2 in Russian service) destroying a HIMARS battery positioned on the West bank of the Dnipro River. Instead, the battles with the greatest number of casualties may well consist of everyday Ukrainians with deteriorated immune systems fighting disease and exposure brought on by an ancient threat, which has often been a Russian ally: General Frost.

e're already seeing signs of a potential alliance between Russia and the Winter season. Russia is engaging in a form of scorched earth tactics, using hundreds of cruise missiles to disrupt and destroy Ukrainian energy and fuel storage infrastructure, while recently withdrawn Russian forces wait in trenches on the eastern side of the Dnipro River. The potential future scenario created by these strikes is easy to imagine – with Ukrainian energy infrastructure out of commission, the temperature drops, and Winter steps in to finish the job for Russia. Cold, disease, and unsanitary living conditions caused by lack of power leads to increased attrition in the Ukrainian ranks, lowering the population's morale and forcing either a mass exodus or a spike in civilian deaths. Russia, meanwhile, uses the lull to finish training and equipping conscripts, fortify its positions, and to fix their dysfunctional logistics system. Come the March thaw, Russia finds itself facing off against an exhausted Ukraine populace instead of a well-prepared defender.

Authors

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'General Winter', from a 1916 front page illustration of the French periodical Le Petit Journal

Western Weapons Versus Russian Weaponisation of Winter

It is true that Ukrainian long-range and heavy artillery positioned on the West bank of the river will also exact a toll on the Russians, who will be within range of GM-LRS rockets used by the M142 HIMARS, M270 and MARS II weapons systems, as well as precision guided munitions such as the US 155mm Excalibur system or the German M2005 projectiles. Ukraine continues to threaten all ground lines of communication (GLOC) from Zaporizhzhya to Crimea, but the reality is that Ukraine's lack of air and maritime superiority prevents them from decisively disrupting Russian interior lines. Likewise, partisan action has not proven decisive in interdicting these GLOCs; while Ukraine's interdiction campaign in Kherson was successful, the geographical factors contributing to the campaign's success are not applicable to the war as a whole. Even Crimea, disrupted as it was by the bombing attack against the Kerch bridge, cannot be appreciably isolated so long as Russia continues to hold its current gains.

It is important to remember that Russia's logistical problems to date are largely self-inflicted. While it may amuse some to see pictures of Russian conscripts armed with museum relics and rusted-out AK-47s, the reality is Russian GLOCs remain intact and western sanctions have largely failed to produce decisive short-term effects. Ukraine cannot repeat its interdiction campaign at an operational level outside of Kherson, and remains far more dependent on western economic aid to continue fighting than Vladimir Putin and Russia are

As the world's COVID pandemic crisis has proven, fighting diseases can be as complicated as fighting Russian troops, and casualties can be even higher, as consistently demonstrated throughout military history. Ukraine needs not just air defence systems and extended-range artillery but also tons of coal, diesel and other petroleum-based fuels for new boilers and electricity generators, an organised network of campaign Role 2 and Role 3 military hospitals, food provisioning points, snowploughs, and a myriad of other basics. On 22 November 2022, Zelensky announced that 4,000 'Points of Invincibility' – shelters which include heating, water, first aid and an internet connection - had already been established, and more were planned for Ukraine's embattled civilians. The initiative is a good start, but such numbers are likely insufficient in the current scenario of an almost complete breakdown of the national energy system.



Red Army soldiers defending their position during WWII in Stalingrad, today Volgograd. The battle was a turning point of WWII.



President Volodymyr Zelensky and UK Prime Minister Rishi Sunak inspected snow-covered Russian military equipment captured by Ukraine, on display at Mykhailivska Square on 19 November 2022.



Snow is evident on the ground in Kyiv, as President Volodymyr Zelensky took part in a ceremony honouring the victims of the Holodomor in November 2022.

With the destruction of major crossing points over the Dnipro, the Ukrainian Army faces tremendous, perhaps insurmountable, challenges with establishing a bridgehead on the Eastern bank, especially given the lack of significant airborne transport capabilities. The river's width near Kherson is between 600 m to 900 m. and further north it reaches 3 km wide. Moving Ukraine's troops to a crossing northeast would take time and logistical effort during a traditionally difficult season to conduct military operations. Meanwhile on the eastern front, offensives on both sides continue to make marginal gains at a grinding pace. The growing reality of a prolonged positional war has highlighted the importance of even basic logistics and reminds us of one of the most important lessons learned in the two World Wars - the importance of resilient supply chains. Logistics is of such strategic relevance in the face of 'general winter' that neglecting supply chains for the most basic supplies could result in disaster and change the course of the war.

Strategic Supply Chains

The recent information campaign about a possible dirty bomb or use of tactical nuclear weapons may become an inadvertent cognitive smokescreen that prevents us from focusing on a much more probable and traditional enemy of countries that have militarily confronted Russia – winter. The latest Russian attacks on thermal and hydroelectrical power plants, along with the regime's block on nuclear power plants seized by Russian forces providing electricity to Ukraine are just the beginning. When we add increasing power cuts (or the total absence of electricity) due to Russian attacks, to the historical difficulties in transportation resulting from winter weather conditions, a significant portion of the troops and the general population could find themselves deprived not only of heating but also of basic necessities, especially drinking water, food preparation and some perishable goods. The Kremlin is accustomed to including winter in its war calculations; it's a staple of a military strategy which is deeply ingrained in Russia as a whole. Russia has already used winter in its 'art of war' to defend itself in the past against the Swedish troops of Charles XII, Napoleon's army, and Hitler's Wehrmacht. Granted, winter is a mercurial mistress, and has not always been faithful to Russia, such as in the Winter War with Finland in 1939. Then, an unprepared and overconfident Red Army lost

some 125,000 soldiers due to causes attrib-

utable to winter vice only 25,000 casualties on the Finnish side. Despite such losses, the end result was that the USSR ultimately succeeded in exacting territorial concessions from Finland

What is unquestionable, however, is that winter is not a benign player in the War in Ukraine, and it will put supply lines at all echelons to the test. Theatre supply depots, warming centres, and strategic reserves of fuel and food are basic concepts of long-term military logistical planning, but both the knowledge and the capabilities to implement these concepts at scale within Europe have atrophied due to a lack of large-scale conflict. NATO members became comfortable with their own technological superiority and were convinced of the improbability of a future European conflict. Thanks to Western military and NGO support, Ukraine receives partial support for some of its logistical functions, military or otherwise. On the Russian side, military logistics functions are relatively free and unrestricted, with the main limitations being those imposed by its own mismanagement.

Ceasefire or Humanitarian Catastrophe

From a tactical point of view the most recent events show Ukraine to be tipping the balance in its favour, however, winter could still freeze any possibility of another short-term operational victory such as those resulting in the withdrawal of Russian troops from around Kiev, Kharkiv, or more recently Kherson. A fully mobilised and motivated population together with support from NATO countries that have provided modern weaponry, military intelligence and advice may not be enough in the face of winter if basic supply lines are not secured

In a Russia where Putin's loss of popularity is increasing at the same rate as his recruitment of young men for war, Putin needs a strategic turn to the conflict. In the short-term, few options can deliver the desired results. Nuclear weapons are often discussed, and are largely considered an improbable albeit game-changing option. Winter, too, is a risk that Putin hopes to exacerbate through his current missile strikes. Yet Russia could potentially employ more exotic methods to augment these strikes. Cyberattacks against infrastructure remain a threat, and as seen with the 2021 Colonial Pipeline ransomware attack, need not target hardened government or military networks, but rather vulnerable commercial entities.



A residential building in Vyshgorod, Northern Kyiv, heavily damaged by a Russian missile strike.

There is an additional potential threat which is as dangerous as it is little-known (both due to its lack of use to date, and the secrecy of its technology): non-nuclear electromagnetic pulse (NNEMP) weapons. To be clear, the effects of such weapons would look nothing like their Hollywood portrayals, nor have their dramatic effects. However, as discussed for decades and even observed with natural EMP phenomena, the smaller effects which can be feasibly produced by NNEMP weapons can cause outsized damage to electrical grids, especially in hard-to-replace items such as transformers. The effects of their use in any major city are easy to imagine: gridlocked traffic, transformer stations disabled, military and civilian communication systems disrupted, hospitals with non-functioning electrical devices, the list goes on. When combined with worldwide oil supply issues, survivability measures such as backup generators will be hardpressed to maintain essential services until cities can effect repairs.

Putin, born in St. Petersburg (formerly Leningrad), is keenly aware of the role winter can play in warfare, and has likely been counting on the arrival of General Frost. The effects of winter conditions on vehicular movement and manoeuvre can be severe, as any soldier who has operated on icy roads, or in blinding snow and fog could tell you. The effect on a population perhaps even more so – for instance, the Wehrmacht's Siege of Leningrad lasted for 900 days, during which 1.5 million people died, 97% of them from cold and hunger. It is not an exaggeration to say that Russia is engaging in a loose siege of sorts, exacerbating the damages caused by winter by deliberately targeting energy



A burned-out apartment building in Borodyanka, Kyiv Oblast stands empty following a strike which set fire to the building. As well as power and food shortages, portions of the Ukrainian population have lost their homes, and thus their permanent shelter to the fighting.



A group of Ukrainian soldiers travels down a dark road in the back of a truck. Lack of power will make operating in urban areas more challenging, since effective defence will be partially reliant on effective utilisation of existing civilian infrastructure.

and sanitation infrastructure, whether by its cruise missile barrages or by more exotic means. All this can tip the balance in Russia's favour without provoking a NATO or nuclear response.

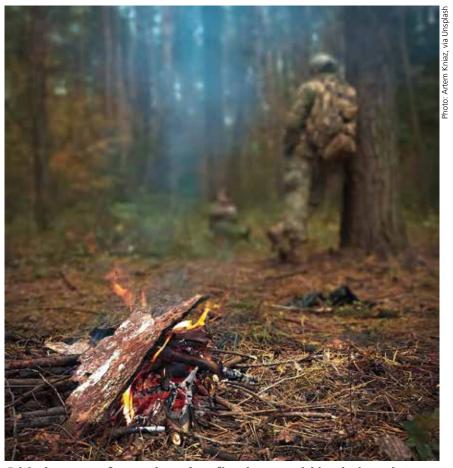
In this war, the two sides are not fighting by the same rules. Western support for Ukraine would likely diminish or cease if the Ukrainian army commonly committed war crimes. However, Russia's strategy is to eliminate, through the effects of winter, as much of the civilian population as possible and to break their will. If Ukraine's civilian sector is unable to make a meaningful contribution to the war or the remaining economy because they are preoccupied with trying to stay warm, dry, and fed, Ukraine's military in turn will likely suffer a loss of capacity.

For all these reasons, Ukraine, despite scoring tactical victories, may be close to suffering a strategic setback. Winter has arrived in a Ukraine that is dependent on its European and American allies, who face their own spectres of elections, populism, debt crisis, inflation, and the energy crisis, among others. The EU, with a population accustomed to decades of prosperity and peace within its borders, currently faces serious energy problems and high inflation. Consequently, it is beginning to raise its voice in favour of a diplomatic solution to the war. Germany is taking the initiative by visiting Xi Jinping and asking him to mediate with Russia. A few weeks later this was followed up by Charles Michel, the Head of the European Council, visiting China with the same intentions. There are also sources of internal friction, for instance Hungary previously refused to approve a major EU economic aid package for Ukraine. This EUR 18 Bn aid package was finally approved by EU member states, but they were unable to use the EU budget due to Hungary's veto.

Support in the USA is also becoming less certain. The Chairman of the Joint Chiefs of Staff, General Milley, has already made public allusions to Ukraine needing to find a diplomatic solution to an intractable conflict. Support for Ukraine remains a strong bipartisan issue, but growing discontent regarding inflation and supply chain shortages will provide inroads for isolationist movements within both the Republican and Democratic parties to re-

duce or block further aid to Ukraine. This aid represents more than half of the total received by Kiev and the largest aid package deployed since the Cold War. In the event of this support drying up, the EU is unlikely to pick up the slack. Rumours have been growing in recent days that the US government is advising Zelensky to sit down and negotiate with the Kremlin. In the absence of mutual recognition of territories by both sides, the only hope is a cease-fire, in the eyes of many influential political and military figures.

With the arrival of winter, the stones in the shoes of Western citizens could make them forget that many people in Ukraine are walking barefoot, and thus fail to provide logistical support that will be more necessary than ever. Kherson is an easy target from the eastern bank of the Dnieper and without water, electricity, or even fuel it becomes part of an expanding Ukrainian scorched earth where winter survival is not feasible. During the months of December, January and February, average temperatures do not exceed -2 °C on average. Urban residential structures often lack the old basements with provisions and the wood or coal-burning



Critical sources of warmth, such as fires become riskier during winter, when reduced foliage cover makes even small fires more discoverable by enemy reconnaissance.



A HIMARS system is offloaded from a C-17 Globemaster III, on 27 January 2022, at Marine Corps Air Station Camp Pendleton, California.



USMC M777 towed 155 mm howitzers are staged on the flight line prior to being loaded onto a USAF C-17 Globemaster III aircraft at March Air Reserve Base, California, on 22 April 2022. The howitzers are part of the United States' efforts alongside allies and partners to identify and provide Ukraine with additional capabilities.



US Humanitarian Assistance Programme Team from the Logistics Readiness Centre in Italy sent sleeping cots and generators to assist Moldova's government with aiding displaced Ukrainians.

stoves and braziers that provide older rural houses with a low-tech alternative to central heating. Without gas and electricity, flats turn cold, and cities become breeding grounds for germs, with their denser populations and greater dependence on functioning sanitation systems.

Weighing the Options

What are Ukraine and the West to do in this situation? The best solution would be to shore up the EU and NATO's resolve and continue, if not strengthen, economic and military support to Ukraine. Unfortunately, the West has likely irretrievably lost the domestic messaging initiative to populists. Major governments have failed to build a compelling narrative and underlying internal economic assistance to steel their citizens against the economic hardships such support causes. In contrast with the efforts governments made in World War II (who similarly had to deal with economic hardship due to the Great Depression), today's administrations have been reluctant to take measures that would cause significant economic disruption. The result has been an anaemic messaging campaign that fails to convince the average citizen of the importance of this conflict, leaving the information domain ripe for exploitation by populist movements on both sides of the political spectrum. We are already seeing governments losing momentum and enthusiasm, regaining it will be a daunting task.

Further exacerbating the situation, many NATO governments, such as Britain and Germany, have depleted their existing stockpiles of ammunition and weapon systems. Worryingly, the replenishment rates needed to continue supplying these NATO weapons and ammunition greatly outstrip the required manufacturing rates. Moreover, the supply chains for many of the raw materials needed to produce them are dominated by China. The rate at which European or American arsenals are being emptied could jeopardise NATO's own ability to react and its strategic autonomy.

All of this puts Ukraine at a crossroads. Faced with the risk of not being able to ensure adequate supply lines due to insufficient military logistics, the growing uncertainty of Western support and Russia's growing attacks on energy infrastructure, President Zelensky may have no choice but to sit down and negotiate with Russia. Otherwise, General Frost may once again take centre-stage in the war, taking down a large part of the Ukrainian troops and civilian population with him, resulting in tragedy on a scale not seen in Europe in the last 80 years.

The Georgian Perspective on Shifting Security Dynamics in the Caucasus

Eugene Kogan

Despite the ongoing Russian war against Ukraine and the continuing reassurances coming from NATO that Georgia's interests are being taken into consideration, Georgia's NATO accession process has come to an impasse. Instead of reaching a national consensus and keeping society united, the population remains divided and polarised. The only progress that can be highlighted is the forthcoming manufacturing of unmanned aerial vehicles and the establishment of a Cyber Security Command.

Introduction: Difficult Realities

Despite deceptive external calm vis-à-vis ongoing skirmishes between Armenia and Azerbaijan, Iran's military exercises on the border with Azerbaijan and Turkey's ongoing operations against the PKK in Syria, Georgia remains vulnerable to any potential conflict with Russia. What is more, Georgia has no allies or partners that will come to its rescue in case of military conflict with Russia. Georgia is in a 'grey area' with respect to Russia, and will therefore need to rely on its own strengths and resourcefulness.

Lacking a potent air force, or sufficient air-defence and unmanned aerial vehicles (UAVs), Georgia's Defence Forces remain at the risk of being defeated by Russia. Furthermore, when compared to Ukraine, Georgia lacks strategic depth and a strong and united Home Front that would bring the country's population to support military efforts. As long as the country remains politically divided and the society is polarised, the chances for creating a strong and united Home Front remain elusive.

Economic ties further complicate these matters – according to a report by Transparency International Georgia published in November 2022, Georgia's economic dependency on Russia has "significantly

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Georgian soldiers with the 12th Georgian Infantry Battalion run to assist after a simulated vehicle-borne improvised explosives device attack during the Georgian Mission Rehearsal Exercise at the Hohenfels Training Area in Germany, 9 October 2019.

increased" compared to the previous year but has not [yet] reached the stage where Georgia would find itself in "deep crisis" if relations were suspended. For instance, Georgia received about USD 2.2 Bn from Russian remittances, tourism, and goods exported, between January and September 2022 which is 2.6x more than the income received from the same Russian sources in 2021. This is problematic for Georgia, as Russia can use its economic leverage to punish target countries with these dependencies. Thus far, it appears that the Georgian Dream (GD) government has not drawn the right conclusions regarding dependence on Russia.

What exactly can Georgia do to change the current difficult situation? Play an ambiguous NATO accession card that has so far failed to materialise into anything concrete? Try to overcome internal polarisation which hampers the country's political consolidation, or procure the necessary weapon systems to ensure the country's security?

Georgia's NATO Accession: A Process Without Progress

With regards to Georgia's NATO accession process, not much has changed since the NATO Bucharest Summit in

April 2008. In other words, NATO maintains an open-door policy for Georgia and recognises Georgia's independence, sovereignty and territorial integrity but no Membership Action Plan (MAP) has been offered to Georgia thus far. Without a MAP, Georgia is effectively stuck in accession limbo, a situation which is likely to continue for the next five to ten years with no guarantee of success. There is one additional factor that concerns Georgia. Prior to the Madrid NATO Summit in June 2022, Georgia and Ukraine were both treated as aspirant members of the Alliance. After the summit, Georgia's bid was decoupled from Ukraine's, its status was downgraded and likened to that of Bosnia and Herzegovina, and Moldova two countries that have a long way to go before they will be able to join NATO. Although NATO established and enhanced several result-oriented programmes with and for Georgia, such as the NATO-Georgia Commission (NGC), the Annual National Programme (ANP) and the Substantial NATO-Georgia Package (SNGP), these programmes are no substitute for a MAP even though they have an added value for Georgia. These programmes have at least created possibilities for the country to prepare itself for membership, even if joining the Alli-



Georgian soldiers with the 12th Georgian Infantry Battalion prepare to manoeuvre in Mine-Resistant, Ambush Protected (MRAP) vehicles during the Georgian Mission Rehearsal Exercise at the Hohenfels Training Area in Germany, 9 October 2019.

ance presently remains beyond the horizon. However, there remain some mismatches between Georgia's aspirations and its capabilities in the security sphere. Georgia, as a Black Sea littoral state, aspires to contribute to the security of the entire Black Sea region, however, the fundamental problem is that Georgia lacks a

Navy, possessing only a Coast Guard. This service is firstly not equipped for military conflicts, and secondly, is under the command of the Ministry of the Interior rather than the Ministry of Defence (MoD), and lastly, it does not participate in joint exercises with the Alliance. As such, major questions of capability, coordination, as



A Georgian Army soldier acting as opposition forces pauses for a photo during Combined Resolve XV at Hohenfels Training Area, Germany, 1 March 2021.

well as cooperation and interoperability remain unsolved.

The Alliance's problems with Georgia primarily revolve around several hard realities – Georgia is located too far away from its centre, plays a rather marginal role in the Black Sea Region despite bordering Turkey, and is extremely difficult to defend in the face of Russian aggression. As a result, NATO has so far left Georgia in the position of partner but not a member. Georgia's accession efforts are encouraged, but the possibility that Georgia may remain a partner rather than becoming a member requires acknowledgement by the Georgian government

Internal Political Polarisation

Political polarisation is one of the most crucial problems of Georgian society, which is broadly divided into supporters of the current GD government, and the supporters of the opposition. There are many countries around the world with polarised societies, but in Georgia's case, the country also wishes to become a member of the European Union (EU), and the present political polarisation makes it harder for Georgia to achieve this goal. While the GD government strives toward EU candidate status, its chances of attaining this goal are slim, since it is not implementing the 12-point recommendations made by the EU despite saying otherwise. What is more, there is a lack of national consensus regarding the implementation of these recommendations.

Complicating things further, the Georgian government maintains cordial relations with Russia due to its economic dependency on the latter. According to the aforementioned report by Transparency International Georgia, a total of USD 1.135 Bn were sent from Russia to Georgia in the first nine months of 2022. The share of remittances from Russia in relation to Georgia's total increased to 40% in 2022, compared to 17.5% in 2021. The last time similarly high rates were achieved was 2015. Therefore, the balancing act policy is becoming very difficult to maintain because of contradictory demands from the EU and Russia. While the former stands for good governance, an independent judiciary, as well as critical and transparent parliamentary debate, the latter offers its sizeable market for Georgian goods, which could be closed at any moment, and remittances from Georgians working in Russia are no less important.

Procuring Weapon Systems

A lesson learnt by the Georgian MoD from the 2020 Nagorno-Karabakh conflict between Armenia and Azerbaijan is that the country needs to be militarily prepared for any potential conflict. Georgia has proposed establishing a new Cyber Command, with assistance from the UK, but still needs to improve the Georgian Defence Forces. This would require not just acquiring modern equipment, but also continuous training, and joint military exercises with NATO partners. Otherwise, Georgia would have no chance to survive in a military confrontation with Russia. Therefore, procuring UAVs and loitering munitions, as well as improving their cyber security capabilities are core priorities for Georgia.

With regards to the procurement of UAVs, there are some signs of progress. Polish company WB Group and Georgian company Delta signed a contract for the production of UAVs through their joint venture (JV), Delta-WB, which was established in May

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2022. The first systems are expected to be delivered to the Georgian Defence Forces in 2023. In addition, a training facility under the control of Delta-WB is expected to be established, to conduct training and enhance the skills of Georgia's UAV operators.

On the other hand, progress in other areas has been slower. In August 2021, Georgia was reported to have requested 46 Javelin Command Launch Units (CLUs) and 82 FGM-148 Javelin missiles from the US, however despite approval from the US State Department, the deal has not so far not progressed.

Conclusion

The Georgian MoD realises that the extensive use of UAVs and loitering munitions in the 2020 Nagorno-Karabakh war represented a turning point in modern warfare. Similarly, the Russia's early use cyber-attacks against Ukraine underscored the importance of well-prepared cyber security forces. Georgia's proposal to establish the Cyber Security Command in 2023 would therefore seem to be relatively timely.

As for Georgia's NATO membership, the Alliance remains divided and, therefore, indecisive about granting Georgia membership. It is of utmost importance to emphasise that a MAP for Georgia and eventual membership of NATO is not decided by the military commanders, who have praised Georgia's military reforms, but by the political leadership, which presently lacks consensus on Georgia's membership. Therefore, the Alliance should strive to achieve an internal consensus on this issue. Until NATO can agree, Georgia will not get a MAP and accede – and Russia will be the only winner of the NATO stalemate. Russia knows this and remains vigilant when it comes to Georgia's current and future status, as it continues to monitor Georgia's cooperation with NATO. Lastly, Georgia's internal political polarisation continues to hinder the country from making progress toward EU and NATO membership. Here, there may be no real solution until the next parliamentary elections in 2024.

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The Rise of Hanwha – Becoming a Global Player

David Saw

The story begins with a small company formed in the midst of a war in the Republic of Korea (ROK) in 1952 and continues to the present day with the company having grown to become one of the most important ROK companies and a global conglomerate in the form of Hanwha. Now Hanwha is poised to add a new capability to its portfolio that could see it acquire a shipbuilding group, making it the owner of one of the major producers of naval and commercial vessels in the ROK.

Before going into an in depth discussion of the evolution of a major ROK defence company, its necessary to delve into the history of the ROK to provide some context of the political, economic and defence/defence industrial challenges that the country has faced. The starting point comes in 1910, when Korea became a colony of Japan. The Japanese colonial administration put most of their focus on industrial and infrastructure development into the north of the country. This was also a response to the fact that there were natural resources in the North of Korea, such as coal, iron ore, magnesite, zinc and gold. In turn this led to the development of cement and chemical factories, electricity generation, industrial enterprises, steel mills, synthetic fibre and textile production and even shipbuilding and ship repair facilities. In contrast, the South of the country, effectively the ROK of today, was primarily an agricultural economy.

After the Japanese surrender in August 1945, Korea was partitioned along the 38th parallel, with the Soviet zone of occupation in the North and the US zone in the South. At this time, it was estimated that 65% of heavy industry was in the North, while the bulk of the population was in the South. The partition of Korea was not supposed to be permanent, however the inability of the Soviet Union, the US and even the UN to agree a path forward towards an independent and reunified Korea, inevitably led to a continuation of the partition. In the North, the Democratic People's Republic of Korea (DPRK) was formed, with Kim Il-sung as its leader, backed by the Soviet Union, while in the South, the ROK emerged with Syngman Rhee as its leader, backed by the US.

The end result of all of this was conflict, on 25 June 1950, the DPRK's Korean People's Army (KPA) invaded the ROK and the Ko-



A ground-level view of Hanwha's Seoul Headquarters. The company has steadily risen to become a major global player in the defence sector.

rean War began. The KPA was on the verge of victory until ROK Army (ROKA) resistance and US and international intervention, under the auspices of the UN, turned the tide. This then led to UN forces advancing into the DPRK and heading towards the DPRK northern border with China. The plan was that the UN forces would bring the conflict to a conclusion by the end of 1950, instead the northern advance by UN forces led to Chinese intervention, in the form of the Chinese People's Volunteers (CPV). The CPV pushed the UN Forces back and a little over a year after the Korean War had started, the conflict was in stalemate in the vicinity of the original border between the DPRK and the ROK. However, the conflict continued until the signing of an armistice on 27 July 1953.

Rebuilding Korea

In the aftermath, the ROK was devastated. Seoul, the ROK capital, had been lost twice and recaptured twice, it does not take much to imagine the level of destruction inflicted on that city. All across the ROK were ruins and destroyed infrastructure, but in the midst of all of this some saw opportunity as the ROK would inevitably have to be rebuilt. Among these was a man by the name of Chong-Hee Kim, who at that time was the manager of Joseon Gunpowder Joint Market, Inc. In 1952 Chong-Hee Kim purchased the Joseon Gunpowder company and renamed it 'Korea Explosives'. Reconstruction in the ROK created a demand for industrial explosives, and by the end of the 1950s Korea Explosives was in a position to meet domestic demand. Previously, significant quantities of industrial explosives had been imported from Japan.

During the 1960s the Korean government embarked on a policy of state-sponsored industrial development to grow the ROK economy. Tariff barriers were put into place limiting foreign imports, while at the same time creating a situation where ROK companies could use their dominance of the domestic market to allow them to expand

into international markets. The ROK government dominated the financial sector, allowing favoured companies to receive financing for expansion, and also provided tax breaks for companies as they grew into new sectors, particularly sectors that the government saw as strategically critical to future economic development.

These were the circumstances the led to the rise of the 'Chaebol', a phenomenon particular to the ROK economy. A Chaebol is a family-run conglomerate, consisting of large numbers of diversified affiliates or subsidiaries. The ROK government economic strategy used the Chaebol as the means to drive the growth of the ROK economy. Growth was certainly delivered - from the early 1960s until the late 1980s, the ROK Gross Domestic product grew at a rate of 8% year-on-year! Who were/are the Chaebol? Well-known names such as Samsung, Hyundai, Lotte Group, LG, Doosan, Hanjin and Hanwha are all Chaebol. All have multiple affiliates, Samsung is said to have 60, LG has 73, Lotte Group has 75 and some Chaebol have over 100 affiliates. Hanwha presents an excellent example of how Chaebol diversified (the company only adopted the name 'Hanwha' in 1992, up until that point it had remained 'Korea Explosives'). The first expansionary programme in the 1960s saw the company move into construction, then petrochemicals and then the energy sector. In the 1970s, this was followed by further investments in petrochemical concerns, machinery manufacture, hotels and resorts and financial services. Investment and expansion into these business areas continued in the 1980s and there was also investment into the automotive sector.

Years of continuing economic growth for the ROK and seemingly endless expansion for the Chaebol came to a grinding halt due to the Asian Financial Crisis of 1997. The collapse of the Thai baht against the US dollar set off a wave of financial contagion across Asia and this eventually battered the ROK economy. Korean banks had recklessly lent large sums to the Chaebol and other ROK companies, who became heavily indebted. As the ROK currency started to depreciate, the banks became vulnerable, stopped lending and started calling in loans. To halt the crisis the ROK government acted, with the assistance of the IMF, to avoid financial collapse and were successful.

Recovery from the financial crisis forced many Korean companies to restructure to reduce their debt burden and to sell off or otherwise dispose of unprofitable or underperforming subsidiaries. A notable major corporate casualty of the financial crisis and was Daewoo, then the second largest



The K136 Kooryong 130 mm MRL was designed by the ROK Agency for Defence Development (ADD) as a counter to North Korean artillery rocket systems, Hanwha supplied the rockets for the Kooryong system. Hanwha is now responsible for the latest generation ROK MRL, the Chunmoo.

conglomerate in the ROK. Daewoo went bankrupt in 1999 with debts of USD 50 Bn! The ROK government and financial institutions worked to preserve the 20 companies that made up Daewoo, setting some up as independent companies and selling others. The Daewoo companies were active in construction, telecoms, electronics, cars, trucks and buses, as well as other areas. Most significantly they were also a major defence company and shipbuilder in the ROK, these ex-Daewoo assets would eventually come to play a part in the story of Hanwha's rise as a defence company.

Defence Beginnings

Like many other Chaebol, Hanwha had to reduce debt and restructure after the financial crisis, a task which it managed successfully. By this point the company was starting to be a player in the ROK defence industry. This most visible part of this process was in the form of the K136/K136A1 Kooryong 130 mm Multiple Rocket Launcher (MRL). The Kooryong was designed by the ROK Agency for Defense Development (ADD) in the 1970s, in response to an ROK military requirement for a counter to the large number of MRL systems fielded by North Korea. Hanwha was tasked by ADD with the manufacture of rockets for the Kooryong system, producing HE, HE-FRAG and extended-range rockets for the original K136 system, and later the improved K136A1 variant. In parallel, Hanwha's defence involvement grew, ushering in the production of pyrotechnics and propellant charges for conventional artillery.

Hanwha was part of the ROK defence ecosystem, but at this point it was not a major player. The leading positions were occupied by Chaebol such as Hyundai, Samsung and Daewoo. However, as previously noted, the Asian Financial Crisis of the late 1990s led to the collapse of Daewoo and substantial reorganisation at the other Chaebol. It also saw new players enter the defence sector through corporate acquisition.

Doosan, a Chaebol that was founded in 1896, had interests in construction equipment and industrial vehicles. They saw synergy with Daewoo Heavy Industries (DHI) and officially acquired the company from the ROK government entity charged with managing the post-bankruptcy assets of Daewoo in early 2005. Post-acquisition, the enlarged Doosan became a major player in the ROK armoured vehicles sector.

In the early 1980s the ROK Army developed a requirement for what they called the "Korean Infantry Fighting Vehicle (KIFV)." The ADD was charged with developing a system to meet the requirement and DHI was selected as the manufacturer. A decision was taken to buy a foreign armoured vehicle design and the resulted in the selection of the Food Machinery Company (FMC) Armoured Infantry Fighting Vehicle (AIFV) design, itself a further development of the M113A1. The AIFV had been purchased by Belgium, the Netherlands and the Philippines and so was a proven design. For the ROK application, modifications were made to the AIFV baseline design to meet local requirements. It should be noted that the AIFV design also provided the basis for the FNSS ACV vehicle family in Turkey.

By 1984, DHI's infrastructure for the manufacture of the KIFV was ready and first deliveries of the K200 KIFV followed thereafter. The K200 then provided the basis for a complete family of vehicles: two types of mortar carrier, recovery vehicle, NBC reconnaissance, command post and an anti-aircraft variant mounting an M167A1 20 mm Vulcan cannon. Then an upgraded version of the vehicle, the K200A1, featuring improved automotive systems, entered production. In turn this spawned variants such as mortar carriers, recovery vehicles and air defence vehicles.

The K200 platform also provided the basis for a far more impressive mobile air defence capability in the form of the K30 Biho system. This was equipped with twin 30 mm KKCB automatic cannons from S&T Dynamics, a surveillance and tracking radar and an optoelectronic sight. The capabilities of the system were enhanced by the installation of the indigenous Shingung very short range air defence (VS-HORAD) system, developed under the KP-SAM programme. Biho developments include a variant mounted on a wheeled platform and more recently Hanwha developed the Biho II, offered on either an 8×8 wheeled or tracked platform. The K200 also provided the basis for the K-SAM Chunma mobile short range air defence (SHORAD) system based on the Thales Crotale NG, which was further developed by the Samsung Thales joint venture to meet ROK requirements.



K200/K200A1 Korean Infantry Fighting Vehicles (KIFV) of the 11th Mechanised Division, ROK Army on a river crossing exercise. The KIFV was the entry point for Daewoo into the armoured vehicle sector, this armour design and manufacturing capability is now part of Hanwha.

At the end of the 1990s the ROK started work on a next-generation IFV programme, with Doosan being awarded a contract to deliver a prototype Korea Next-Generation Infantry Fighting Vehicle (KNIFV) in 2003. After successful prototype testing, Doosan were awarded a production contract in 2009, for a first tranche of K21 vehicles for the ROK Army. DHI and later Doosan also worked on wheeled 4×4 and 6×6 armoured vehicle

solutions, with some limited success. The main prize in the wheeled armoured vehicle sector for ROK industry was an ROK military requirement for a large number of 6×6 and 8×8 vehicles. Three companies proposed solutions for the requirement, Doosan, Samsung Techwin and Hyundai Rotem, with the latter eventually selected to meet the requirement for some 600 vehicles. Despite this, the Doosan armoured vehicle business was a very credible capability and had a solid position in the ROK defence ecosystem.

The Growth Path

Over the years Hanwha has grown through substantial Mergers and Acquisition (M&A) activity and where required has spun off subsidiary companies that no longer meet its strategic vision. In 2014 Hanwha embarked on a wave of M&A activity that strengthened existing core areas in the company and also made plain that they had defined a new strategic area of interest for the company.

What made this particular M&A activity work was that Hanwha was looking to acquire capability, while Samsung was looking to divest capability in order to concentrate on its core electronics business and financial sector holdings. Petrochemicals have been a core business area of Hanwha for years, hence the attraction of acquiring Samsung General Chemicals and the Samsung stake in the Samsung-Total joint venture with Total of France. The other aspect of this M&A was that Hanwha had obviously decided that they wanted to be-



The K30 Biho was developed to provide the ROK Army with a mobile air defence gun system and is equipped with two 30 mm KKCB automatic cannons. More recently, the system's capability has been enhanced with the installation of launchers for the indigenous Shingung (also known as 'Charon') VSHORAD missile, with four missiles being carried.



The Norwegian Army replaced its M109A3GN/GNM self-propelled gun systems with the Hanwha K9 Thunder, acquiring 24 K9 howitzers and six K10 ammunition resupply vehicles. In November 2022 they purchased four more K9 and eight more K10 systems.

come a major player in the defence sector and the means to achieve this goal was the acquisition of the defence, aerospace and security interests of Samsung.

This saw the Samsung interest in the Samsung-Thales joint venture acquired by Hanwha, providing radar, optronics, communications, command system and weapons capabilities. Then in 2016 Hanwha would acquire the Thales stake in the joint venture, making it a wholly-owned subsidiary. In the aerospace sector Hanwha gained aircraft and helicopter engine manufacturing, related component manufacturing capabilities, marine gas turbine manufacturing capabilities and missile motor technologies from Samsung. One of the most high-profile aspects of the M&A was the acquisition of Samsung Techwin, which amongst other things provided security and surveillance systems, as well as robotics technologies. Most importantly, it also gave Hanwha the selfpropelled artillery capability developed by Samsung Techwin, which had obvious synergy with Hanwha's existing artillery rocket business.

At the start of the 1980s in response to the continuing growth of the DPRK artillery threat, the ROK embarked on a programme to procure new self-propelled artillery. The aim was to produce the system locally and the M109A2 was selected to meet the requirement in late 1983, but in the end the turret and the ordnance were supplied from the US. Samsung Techwin were charged with producing the ROK M109A2 variant, as the K55, with over 1,000 systems being produced from 1985 until the late 1990s.

As the K55 entered production, the ADD started work on a programme to design

and develop an indigenous advanced selfpropelled artillery system. The objective was to field a 155 mm 52-calibre system, that had major growth potential to take into account advances in technology and changes in operational requirements. This resulted in the K9 Thunder system and in the development of supporting units in the form of the K10 ammunition resupply vehicle and the K77 fire direction centre vehicle. Subsequently, K9 technologies were applied to the upgrade of the K55 gun system, resulting in the K55A1, which is due to supplement the K9 in the ROK military until the K55A1 out-of-service date is reached. The growth potential of the K9 was demonstrated by the fielding of the K9A1 variant in 2018, the next evolution is the K9A2, featuring reduced crew numbers and automatic loading, this will enter service in

the near future. In the 2030s the K9A3 is due, set to be available in either manned or remote controlled configurations, and featuring a new L58 gun and extended range ammunition. Following this, in the 2040s another K9 system evolution is due to enter service.

Hanwha then added to its defence capabilities with another M&A programme in 2016 that saw the acquisition of Doosan's armoured vehicle and related defence activities, which were formerly those of Daewoo. This put Hanwha into the top tier of ROK defence companies and helped it become a global defence company, principally via the sale of K9 systems in recent years to Australia, Egypt, Estonia, Finland and India. In August 2022 Hanwha signed a major contract with Poland, under which up to 672 K9 systems will be acquired, with some to be directly acquired from the ROK and some produced in Poland. October 2022 saw the signing of a contract under which Hanwha will supply Poland with 288 Chunmoo MRL systems, with the first 18 to be delivered in 2023. Hanwha will also supply a full range of rockets, with rocket production planned to eventually take place in Poland.

Elsewhere in Europe, Norway, which had previously acquired 24 K9 guns and six K10 ammunition resupply vehicles, added to its fleet with the purchase of four more K9 and eight more K10 systems in November 2022. Future prospects for the K9 in Europe include the Romanian self-propelled gun requirement and the British Army Mobile Fires Programme (MFP). Another important Hanwha programme is the AS21 Redback IFV, based upon the K21 IFV, it is one of the final two contenders selected for the Land 400 Phase 3 programme in



ROKNS Yulgok Yi-I is a KDX-III class destroyer of the Republic of Korea Navy (ROKN) built at Daewoo Shipbuilding & Marine Engineering (DSME). Hanwha is in the process of acquiring DSME, a major supplier of destroyers, frigates and submarines to the ROKN, further strengthening Hanwha's defence business.

Australia. It is also being offered by one of the groups competing for the US Army's OMFV programme, and has been evaluated in Poland in connection with a 'Heavy' IFV requirement, ostensibly to supplement Polish Borsuk IFVs which are due to enter service by around 2024.

The Next Phase

The next phase in the future growth trajectory of Hanwha became clear in September 2022, when Hanwha signed a conditional purchase agreement with the Korea Development Bank (KDB) under which they would acquire a 49.3% share and management control of Daewoo Shipbuilding & Marine Engineering (DSME) in an arrangement valued at USD 1.53 Bn. Hyundai Heavy Industries (HHI), the main competitor of DSME, had attempted to buy the company earlier in 2022, but that effort failed in the face of competition concerns from the EU.

With DSME, Hanwha is gaining the third largest shipyard by value in the world, the downside is the current state of the operation. This is why Hanwha only signed a conditional purchase agreement, which enabled them to conduct proper due diligence of DSME in order to obtain a full idea of its assets and liabilities. According to media reports out of the ROK, Hanwha are now satisfied with what they have found at DSME and are set to proceed with the acquisition. However, they will have to seek regulatory approval from competition authorities in the ROK and internationally. Assuming that these approvals are received, Hanwha hopes to complete the acquisition and take full control in the first half of 2023.

DSME is a major commercial shipbuilder and has benefitted from increased demand for LNG tankers in recent times, it is also a major player in offshore platforms and rigs. Presumably more important for Hanwha is the naval business of DSME, responsible for the construction of submarines, destroyers and frigates. The primary customer is the ROK Navy, but there have been exports to Thailand, a submarine contract with Indonesia, which they hope to expand, and potential business in the Philippines. In addition, four replenishment tankers have been sold to the British Royal Fleet Auxiliary, Norway purchased a logistic support ship and Malaysia has purchased training vessels from DSME.

Hanwha will have to inject management resources and capital investment into DSME, which is currently a lossmaking business. On the other hand, if they can restore DSME to financial health they will have a very useful asset in their hands. For the future, it is clear that Hanwha intend to be a major international player in the defence sector, and have the resources to compete internationally.

Powering Armour into the Future

Tim Guest

The battlefield has become increasingly complex, hybrid and power hungry, and armoured fighting vehicles (AFVs) have followed suit. Their growing wealth of new sensors and advanced weapon systems are placing higher operational demands for reliable, readily-available electrical energy supplies on those vehicle platforms than ever. Available power must be delivered to the right system at the right time to give commanders confidence that a mission can be completed without those supplies letting them down. This article looks at some of the latest thinking and developments in electrical power and power storage for combat vehicles.

Power from Power

Power resource on AFVs is already under enormous pressure with demands for electrical power from the likes of command and control (C2) systems, sensors and the data connections that support them, that is now reaching the limits of what a conventional vehicle platform and power plant can generate and supply. Yet as more and more sensors and tech advances are added to a platform, and we look to a future when the likes of directed energy weapons are commonplace, armoured vehicles will need a reliable mix of continuous and pulsed power supplies

to ensure their battlefield competence. To solve this power supply challenge, hybrid electric power/drive systems have been researched for at least a couple of decades as the likely best way to meet these demands, not just for the vehicle's own propulsion, but also to deliver a continuous auxiliary power supply for all the new mission systems and weapons.

In addition, next-generation armoured vehicles also need power sources that will enable longer mission endurance, with a reduced carbon footprint, but without compromising space, weight or safety. This is where electric drive systems on land could deliver significant operational advantages.

For example, as new larger vehicles such as wheeled or tracked self-propelled (SP) artillery are developed with more complex missions and new tactics, their power needs will have to reflect both traditional operational performance as well as meet new requirements. As has been seen in Ukraine, for any vehicle to stay in position for too long lessens it chances of survival. SP artillery tactics are some that have changed considerably, with shootand-scoot pressures that will demand any drive system be able to provide high peak power on a potentially regular basis for such systems to deliver their mission, with burst of energy required to acceler-



Image shows the Rafael Samson 30 mm Remote Turret with Spike and Trophy APS. The array of sensors and new weapon systems onboard latest armoured vehicles place huge demands for power on the vehicle systems.

ate the guns away from a gun position immediately after a fire mission has been completed.

Reassuringly, the development of various electric drive systems for armoured vehicle platforms is underway across the defence industry and various research establishments; their implementation would enable the creation of new design options enabling improved mobility, durability and adaptability on the battlefield, although any success also relies on novel energy storage solutions being developed, such as the possibility of structural and conformable batteries, which potentially offer the chance of bespoke power storage for almost any armoured vehicle, no matter shape and size and real estate available for that power storage; if innovative batteries and supercapacitors can be produced in a flexible form factor, it's possible that these could be incorporated into elements of a core vehicle design, or its internal 'furnishings', perhaps as a structural element,

thereby saving internal space and enabling advantageous weight-distribution options.

Electrical Drive Progress and Moves

At Qinetiq, the company's engineers and scientists have been working on the challenges described above for some years and have made headway for both wheeled and tracked armoured vehicle propulsion and power requirements. The company considers electric drive systems to offer excellent automotive performance in the first instance, and while different types of hybrid technologies exist, it is a 'series-hybrid architecture' the company believes is the best for military applications, as shown in both modelling and "real-world testing in military electric drive programmes".

The company's in-wheel, electric Hub Drive technology work, for instance, combines electric propulsion with me-

chanical and regenerative braking in a compact package, to overcome past challenges where efficiency and size have been the weaknesses of previous attempts at electric propulsion for wheeled military vehicles. The company actually entered into a strategic partnership with Texelis in 2021 to deliver inwheel electric Hub Drive technology to the military armoured vehicle market, in which Texelis took on responsibility to manufacture Hub Drive technology at scale to meet market demands, while QinetiQ has contributed core electrification technology and expertise to the team. The aim was to deliver a Hub Drive transmission where "electrical machines are small-sized for the high-speed propulsion, with all the advantages in terms of acceleration and agility, with the high torque demands for hill climb and obstacle crossing handled by the range-changing gearbox". Jean Vandel, MD for Defence, Texelis, said at the time that it was an important area of development for the military vehicle market worldwide, with the electric Hub Drive enabling enhanced power, system efficiency, the ability to operate silently using the battery as a source of power. This would enable vehicle power architecture to be completely rethought, discarding conventional axle and driveshaft design constraints. CTO at QinetiQ, Mike Sewart, added that the company's electric drive capability has been in research and development for "many years". In Q1 2022, after less than a year of the partnership, the two companies announced that they had actually delivered the first in-wheel Electric Hub Drive and suspension prototype for installation on an 8×8 armoured vehicle for test and evaluation.





For tracked vehicle electrical propulsion, Qinetig have developed the E-X-Drive, which according to the company, is a lighter, more compact and efficient solution, compared to conventional mechanical transmission systems. It combines electrical and mechanical components in a configuration that incorporates mechanical regenerative transfer of steering power, range-shift mechanisms, and permanent magnet motor technology, all as part of an electric propulsion system that offers the opportunity for manufacturers to develop increasingly innovative tracked vehicle configurations, with such key performance and electrical power advantages as energy storage that allows load-levelling, regenerative braking, and silent watch capabilities.

Storing Power on Board

Whether an electric propulsion system or not, on the subject of stored power on board future armoured vehicles, Ori Kost, Large Format Battery Programme Manager at Epsilor, considers that modern AFVs not only need to meet the higher power and energy requirements of the vehicle itself, but also need the capability to support the energy needs of local, dismounted infantry troops who carry a wide variety of electronic systems, all of which require charging. He says that with the likes of "multi-weapon turrets, situational awareness and driving support, active protection", and other systems, which consume substantial amounts of energy, the latest armoured vehicles must have more efficient and powerful energy sources for both the vehicle and its crew, as well as nearby units.

As to latest armoured vehicles, Kost believes that today's armoured vehicles 'need to be much smaller and lighter' in some cases. And smaller and lighter means smaller internal combustion engines requiring more frequent fuelling than larger vehicles. That said, Kost stresses that despite their smaller size the engines will be required to supply energy to a growing number of systems and dismounted units. They will also likely be equipped with active protection systems

(APSs), which, unlike passive armour, will, he reminds us, consume energy.

Li-ion on the Rise

Kost says that most armoured vehicles on the battlefield today still rely on the old NATO-standard 6T lead-acid 1 kWh batteries, though these are beginning to be replaced in many forces with Lithium ion (Li-ion) batteries, which have up to four times higher energy density and better performance characteristics in extreme conditions. This step to Li-ion alone is important, for now, as the AFVs even on today's battlefield require substantially more energy than lead-acid batteries can provide and there simply is not the vehicular real estate available to realistically add more lead-acid units. As mentioned above in relation to electric drives, silent watch must be enabled by the electrical power systems on board, and vehicles must not have to turn on their engines for several hours to recharge batteries, as is the case with the older battery types. A Li-ion onboard battery, however, with its much higher energy density than the incumbent leadacid, will, according to Epsilor's Kost, substantially extend the duration of a silent watch operation. He says that new Li-ion rechargeable technology, standardised for armoured and military vehicles, is now mature enough to transition from the early adopter phase to the growth phase, adding that demand for such



Epsilor's COMBATT line of Li-lon vehicle batteries provide high energy density using two chemistries: Li-lon NCA and Li-lon LFP.

technology is growing, partly as a result of several armoured vehicle acquisition programmes with a premium-energy requirement. In addition, Li-ion's superior energy density by a factor of 2 to 4 over lead-acid, and being maintenance-free with a typical a 10-year lifespan, means that the expense of field logistics will be significantly reduced compared to current vehicle batteries.

Silent watch is a crucial, frequent aspect of soldiering often involving long periods of waiting, anticipating, during which absolute quiet must be observed. Many militaries have adopted diesel auxiliary power units (APUs) to extend their silent watch capabilities, but, according to Ori Kost, these will soon be replaced by Li-Ion-based central energy banks, which will be able to provide the required energy for all on-board electronic systems. He says the new energy banks will replace the "noisy generators, which provide limited power and will enable missions to be executed in full silence for a full night".



Linking Towards The Future – Generic Vehicle Architecture

David Saw

Superficially, armoured vehicles used to be a less complicated proposition, it was not that long ago that a tank would have had a voice-only radio, there would have been an intercom system for crew communication, the main gun would have been stabilised, with the sight being a relatively simplistic optic. Realistically a tank of this era would have only been effective in daylight engagements and even then, situational awareness around the vehicle would have been limited, depending on the placement of periscopes and vision blocks.

Then came the remorseless march of technology, sometimes delivering evolutionary developments and sometimes revolutionary developments. In the context of our relatively uncomplicated tank, technology came to add new capabilities. Image intensification, and later thermal imaging systems came into play, gradually growing in capability and allowing combat operations across a full battlefield day. Communications systems became more reliable and basic fire control systems came into service, growing in performance year-on-year.

One of the most significant developments was the opportunities offered by the microprocessor revolution of the 1970s which led to the transformational possibilities delivered by the increasing power of computers. This transformation made its way into the military sphere, in the context of an armoured vehicle it offered a massive expansion in the performance envelope of the communications system, fire control systems now offered unprecedented accuracy, while optronics offered a new paradigm in situational awareness.

All of a sudden the talk was of C4 systems standing for Command, Control, Communications and Computers. More was to come though as C4 expanded to become C4ISR, adding Intelligence, Surveillance and Reconnaissance to the overall capability package. The tank and other armoured vehicles due to their sophisticated sensors and systems, became more than just combat systems.

The tank could act as a command and control (C2) unit, as a communications hub and as a surveillance platform using its sighting systems. It can act as a targeting system for external effectors, such as aircraft or helicopters, other vehicles and artillery for example. This ability to acquire and designate of the command of the comman



Prime Minister Rishi Sunak and the Secretary of State for Defence, The Rt Hon Ben Wallace MP, on top of the turret of an Ajax armoured vehicle at Catterick Garrison. British interest in Generic Vehicle Architecture (GVA) is designed to aid the integration of complex systems and sub-systems in vehicle design.

nate targets for other systems will became increasingly important for tanks. The advantages of the tank in terms of protected mobility added to its integral capabilities mean that it can play a multitude of roles in both high intensity and asymmetric conflict environments, a feature that is all too often ignored. For example, the British did not take tanks to Afghanistan, while Canada and Denmark did, to the benefit of those who worked with them on operations.

In the Beginning

The reason that we have been discussing tanks thus far is simple, it was a tank programme that started the British on the

path to the development of a Generic Vehicle Architecture (GVA). During the 1970s there was perception in Britain that, with the arrival of the T-64 and the T-72, Soviet armour had undergone a qualitative shift upwards. As a result, NATO armour was rapidly becoming inferior and while the British Chieftain tank was still viable and could be improved, the British Army would need a new generation main battle tank (MBT) to counter current and future threat developments. The failure of the Anglo-German Future Main Battle Tank (FMBT)/ KPz3 programme opened the way for a new British tank programme, and this was the MBT-80, with the programme getting underway in September 1978.



On the path to the Challenger 3 upgrade, the Rheinmetall Challenger turret demonstrator on trial at Unterlüß, Germany in 2018. The growing sophistication of electronic systems and sensors in armoured vehicles, has acted as the catalyst for British work on Generic Vehicle Architecture (GVA).

Where the MBT-80 was different was it was going to be one of the first armoured vehicles to take advantage of the microprocessor revolution. An example of this was the fire control system elements being linked by a digital data bus, indeed the MBT-80 is often credited with being one of the first armoured vehicles to have a vetronics (vehicle electronics system). Like many British defence developments, the MBT-80 was a victim of the collapse of the Iranian Revolution and the fall of the Shah, leading to the effective cancellation of a host of major defence contracts between Iran and Britain. This put key elements of the British land defence industry into crisis, forcing the British government to take emergency measures to sustain the industry, part of the cost of those measures was the cancellation of MBT-80.

Even though MBT-80 was cancelled, it provided the basis for the further development of GVA. Equipment installed in a tank has to operate in a very challenging environment, considerations such as power requirements, power distribution and fit, format and function of electronic systems had to be established so that a set of standards could be defined. Once standards had been established it was then possible to further define what was necessary and could be delivered through the evolution of GVA.

Unfortunately, Britain did not have much in the way of new armoured vehicle programmes to refine their GVA ideas, but there were research programmes that helped to progress the capability. One of the most important programmes was the Vehicle Electronics Research Defence Initiative (VERDI). VERDI used a standard Warrior Infantry Section Vehicle (FV510) as a demonstrator vehicle for GVA technologies starting in the late 1980s. Issues were data bus development, integration of sensors and displays, integration of navigation systems and developing methodologies to allow the crew to be presented with this data in a usable manner. The next stage of this effort came in 1993 with the VERDI-2 pro-

gramme which investigated how technology could allow for effective vehicle operation with reduced crew numbers.

Setting Standards

All of these GVA efforts would be fundamental as the British Army embarked on a new armoured reconnaissance vehicle programme in the mid-1990s known as Tactical Reconnaissance Armoured Combat Equipment Requirement (TRACER). This was a joint programme with the US, their equivalent vehicle was the Future Scout and Cavalry System (FSCS). The FSCS/TRACER programme officially got underway in October 1996. Changing requirements and cost escalation led to the cancellation of FSCS/TRACER in October 2001.

The end of TRACER was yet another failure in terms of British Army armoured vehicle programmes, to which could be added the failure of the Family of Light Armoured Vehicles (FLAV) and the Future Family of Light Armoured Vehicles (FFLAV) programmes that sought to find a replacement for the FV432, Warrior and CVR(T). Then later on you would have Britain joining and then departing from the Multi-Role Armoured Vehicle (MRAV) programme, what we would now call Boxer, in 2003.

There was another programme in prospect in the form of the Future Rapid Effect System (FRES), this would see large numbers of armoured vehicles produced in two variants: the Utility Variant (UV), a



The seemingly immortal FV432 on exercise at Warminster, this vehicle has been in British Army service for more than 60 years! Modern armour and proposed next generation armour are a vast leap in capability and complexity over the FV432, hence the need for a Generic Vehicle Architecture (GVA).

wheeled vehicle, and the Scout Variant (SV), a tracked vehicle. The UV requirement would eventually develop into the Mechanised Infantry Vehicle (MIV) requirement that was won by Boxer, while the SV requirement would evolve into Scout SV, with various development contracts awarded to General Dynamics UK (GD-UK) from 2010 onwards, leading to the 2014 Ajax contract award.

In the midst of all of these failed programmes, the Ministry of Defence (MOD) continued to support research into GVA and this led to the release of Def Stan 23-09 covering GVA, in August 2010. The document introduction states: "The purpose of this Def Stan 23-09 is to enable the MOD to realise the benefits of an open architecture approach to Land platform design and integration, especially in regard to platform infrastructure and the associated Human Machine Interface (HMI) in order to improve operational effectiveness across all Defence Lines of Development (DLOD), reduce integration risks and reduce the cost of ownership across the fleet. This is achieved by mandating and applying the appropriate interface standards." The scope of the document is to specify: "mandatory standards to be used in the design and implementation of land platform electronic and power infrastructures, mechanical interfaces, HMI and Health and Usage Monitoring Systems (HUMS) together with requirements for Interface Control Documents (ICDs) and Verification and Validation (V&V)."

Def Stan 23-09 defines GVA as follows: "The term Generic Vehicle Architecture refers to the open, modular and scalable architectural approach applied to the design of platforms to deliver the MOD's desired operational, technical and cost benefits." Beyond that, GVA is a part of the MOD's overall Land Open System Architecture, which also include generic 'base' and 'soldier' architectures.

British GVA evolution continued within the Warrior Capability Sustainment Programme (WCSP), unfortunately cancelled in March 2021, despite this it is clear that future vehicles and upgrades of existing platforms will follow the path set by GVA. Elsewhere the British GVA standards provided the basis for NATO STANAG 4754, which sets the NATO GVA standards, although additional elements have been added to the baseline British GVA standards. In turn STANAG 4754 and Def Stan 23-09 provide the basis upon which a broader set of European land vehicle GVA standards are being developed.

Mission requirements for armoured vehicles continue to grow in complexity, the integration of multiple systems and sensors demanded an effective structure for implementation and operation, hence the development of GVA standards. That Britain has played a central role in this GVA process is extraordinary, especially when the number of cancelled British armoured vehicle programmes is taken into account. One wonders how much more they could have achieved if one of the cancelled programmes had continued and resulted in a vehicle that had been taken into operational service. Imagine how much data could have been generated, further speeding GVA definition and development.

Good Connections

Tim Guest

MIL-STD cables and connectors are ubiquitous on the battlefield in their use for the widest range of applications on land, at sea or in the air. They ensure all kinds of military equipment operates reliably at all times and in the harshest of environments. From the connectors and cables on radios and communications equipment, to those supporting radar systems, vehicle-mounted and soldier-worn sensors and devices, as well as field medical equipment; the list of platforms and military systems involving and relying on connectors and cabling is seemingly endless. This article takes a general look at connecters and cabling in terms of some of the technology involved, as well as referencing applications on land, sea and in the air.

Evolving Tech for Changing Operational Demands

The production and supply of military cables and connectors in recent years has seen significant developments and advances with latest materials, enabling not only the introduction of more reliable and efficient systems, but also products that are much more resistant to environmental factors, extreme climates and

shock damage. Not only does this make their use in the most arduous of military applications much more reliable, but new materials have also enabled the production of cabling and connector solutions that are lighter and more flexible, so their installation and maintenance in what can often be difficult and extremely confined spaces aboard military vehicles, aircraft and vessels, is made much easier. The use of fibre-optics, too, has delivered other

cable and connector advances and advantages for the military user, including the ability for faster transmission rates of larger amounts of data on the increasingly connected and networked battlefield. That's a good thing, because new and emerging technologies and approaches to warfare are all hungry for more data to be transmitted, as well as more power to support increasing demands, than ever before. Digital transformation initiatives

across the board, from soldier modernisation programmes connecting soldierworn sensors and optical devices with personal power supplies, to command, control, communications, computers, cyber, intelligence, surveillance and reconnaissance (C5ISR), the proverbial explosion of ubiquitous, persistent sensors on vehicles, aircraft, and ships, to highspeed, high-bandwidth tactical networks and AI-driven applications; all these have placed huge demands for new levels of connectivity on the humble connector and cabling, which, together, make these wider programmes, technologies and architectures all possible.

The Humble Connector

MIL-STD or MIL-SPEC electrical connectors are specifically designed to protect a connection from damage and contamination from dust, dirt, water and any other contaminants likely to be encountered under rugged conditions. What ference, as well as others with filters to prevent radio frequency (RF) interference. Whatever the application, however, many standard military connectors have a typical construct, which consists of a mating pair, with a plug half and a receptacle half - the 'male' plug with pins, fits into the 'female' contact channels. The contact pins are often composed of beryllium copper alloy, or a phosphor bronze alloy, then plated with a highly conductive, non-corrosive metal coating, often gold. Depending on the connector maker - of the likes of Fischer, ODU, SMI, TT Electronics and others – and the product series, the pins are housed in a dielectric polymer or glass insulator, all encased in an aluminium shell, which is anodised to protect the aluminium from corrosion.

Contact pins are either fixed or removable from their insert, which itself is often sealed hermetically in its shell/casing to make it waterproof. To ensure the male

discharge and/or electromagnetic inter-

Several female receptacles on a vehicle intercom/communications unit await connection with their male counterparts.

kind of connector is used for a particular application is largely determined by the application itself. A saltwater, marine environment will require water-proof, sealed and corrosion-resistant systems, unnecessary for installations aboard an armoured vehicle, for example. Underwater use connectors have appropriate sealing for their environment, and hermetically-sealed connectors prevent the ingress of moisture. Some connectors are integrated-filter connectors, which incorporate a filter that protects them from magnetic interference or unwanted signals. For example, there are filter connectors shielded against electrostatic

and female halves mate correctly (incorrect orientation might damage the pins and affect the contact) there is an alignment, or keying feature, which ensures precise mating and locks the connection in place, essential in rugged and highvibration scenarios to prevent the connector halves from disconnecting from one another.

When it comes to fibre-optic cable connectors, these join two ends of a cable in a mechanical coupling that precisely aligns the cable's fibres to ensure as little light loss as possible takes place once the two ends of the fibre are pressed together, typically with a spring-loaded mechanism. Any gaps between the two fibre-optic faces, or the slightest misalignment, will cause a loss of signal, referred to as called insertion loss. Loss of signal is actually something that occurs along the length of a fibre-optic link and is expressed in decibels (dB).

This is a natural occurrence with all types of transmission, whether data or electrical power and, as with pretty much all physical transmission lines or conductive paths, the longer the path the higher the loss. These losses are compounded by insertion loss at each connection point along the line, whether a splice or a connector, meaning the more connection points the greater the insertion loss.

With innumerable MIL-SPEC standard pinned, fibre-optic and hybrid connectors available, (some of which also find use in commercial applications), mention of a few is worthwhile before a brief, final look at some aspects and applications of

Possibly the most popular and widely used types of circular connectors in general military use are those which adhere to the MIL-C-5015 standard. These connectors, from a wide range of suppliers, are available in several classes and rated for operations in temperature ranges of between -55°C to +125°C, 175°C or 200°C. Next, two environmentally-resistant, miniature circular connectors with hermetic receptacles and associated accessories, adhering to MIL-C-26482 standard specifications include a quick disconnect mechanism; compact Series I connectors of this spec have excellent mechanical, electrical and environmental properties and are widely used in military comms. Finally, in military aviation and aerospace applications, MIL-DTL-5015 standard specified connectors are widely used for ground support and airframe systems, where their rear-release mechanism and other proven features, adopted into this latest standard from older model connectors, have made this an extremely reliable and widely used connector for aerospace applications.

Cables in the Sky

In military aerospace applications, such as fast jets, electrical wiring interconnect systems (EWIS) must be capable of handling some of the highest and fastest data rates imaginable. However, they must also have a reduced weight profile and be flexible and abrasion resistant, so they can be routed, without risk of failure, through complex paths in an airframe,

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around corners or through holes. Flame resistant, shock, vibration, corrosion and extreme-temperature resistant, the typically pressure-moulded cabling routed around a military aircraft must show all these attributes, as well as display such high-tech parameters as strong electromagnetic (EM) protection.

One specialist in this field is SMI, whose military aviation cabling expertise enables EWIS to be deployed throughout an airframe, even to those areas such as the undercarriage and the fuel tanks, which experience some of the harshest conditions. An effective EWIS also enables a move away from hydraulic actuation to electrical harnesses, which creates considerable weight savings. That's not to say aircraft cabling will not come into contact with some of the aggressive fluids typical in the aviation space, so it must be resistant to chemicals, fuels, or hydraulic fluids. That said, when routing cables through some parts of an airframe, through a bulkhead, for example, penetrators, such as those from SMI's penetrator family, will be required. Penetrators guide and protect cabling as it passes from one space to another, whether a simple partition or a critical bulkhead barrier, such as a fuel tank, and must transition the cable through the bulkhead while preventing leakage from one side to the other.

Aspects of Deep Sea Cabling

From the air to the maritime environment, where combat, sonar or propulsion systems are only as good as the infrastructure connecting them and cabling, penetrators and connectors all have to be robust, reliable and effective for such naval systems to deliver, particularly on submarines. Maintaining the integrity of a submarine's pressure hull, for example, is critical to protecting the life of the crew, as well as maintaining its operational capacity.

The vessel's cabling delivers data and power to and from the command centre to the ship's extremities and wherever that cable system passes through the pressure hull, a potential weakness is created. As a result, high-spec penetrators are used on the pressure hulls of submarines. These can be glands, which help transit cables that are permanently installed as part of the penetrator; they can also be connectorised versions, where receptacles on both sides of a bulkhead can be mated or de-mated. Pressure hull glands (PHGs) provide the most reliable hull transitions available and enable multiple cables to be amalgamated in a complex thermoplastic moulding; individual cables are sealed and water-blocked to prevent leaks. PHGs from maker SMI are able to manage electrical, coaxial and optical conductors from single cables, or up to 19 cables through a single small aperture in a boat's hull. In addition, the company's TelemetriX pressure hull penetrator solution for both surface and submarine fleets, is designed and manufactured to merge external features of Def-Stan 02-524 Part 2 with MIL-C24231 submarine penetrator features, using internal componentry that is also extensively qualified in accordance with Def-Stan 08-171 and PTS 14299, including underwater explosive shock testing. Indeed, SMI's glands are continuously tested in production, with final visual, radiographical and pressure testing to ensure decades of reliable operations in extreme, deepwater ocean and combat conditions.

As more and more nations prioritise control of their territorial waters, investment in submarine fleets is on the increase and while older platforms can undergo life-extension programmes, future vessels are being designed with increasingly complex combat systems and operational capabilities.

Inboard and outboard cabling is today recognised as the central nervous system of a submarine, delivering power and data to critical systems. However, as operational requirements become ever more complex, OEMs and naval forces alike are having to ensure the performance and reliability of their cabling architectures, so they are both cost-effective and also perform optimally, without failure, throughout the operational life of a submarine.



Hybrid connectors have both FO termini and signal pins.



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