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The Geopolitics of Energy

Energy Security in the 21st Century

Joris Verbeurgt

The existing world energy system was largely shaped by Anglo-American interests, which favoured market-driven competition over access to energy resources on a demand and supply basis. Global geopolitical shifts in the early 21st century have caused a profound transformation of this market-oriented system to which we need to adapt and react appropriately.

The geopolitics of energy comprises three dimensions: an economic dimension, an ecological dimension, and a security dimension.

The economic dimension of the geopolitics of energy is twofold: on the one hand, energy is indispensable for modern economies to produce and transport goods. There is a relatively straightforward relationship between energy and economic development, based mainly on the degree of energy self-sufficiency and on the composition of primary energy supply. On the other hand, energy resources are economic commodities themselves. The rise of the oil industry is interconnected with the rise of capitalism and international business, and fossil fuels are perceived as the driving forces behind technological advancement and economic power. In the twentieth century, the oil industry became the world's biggest business and the first globalised modern industry. The existing world energy system was largely shaped by Anglo-American oil companies that favoured market-driven competition over access to energy resources on a demand and supply basis, sensitive to price volatility. Due to internal and external dynamics, this market-driven system is undergoing profound changes in the early 21st century.

With regard to the ecological dimension, the use of fossil fuels by the industry, the transportation sector and households, is largely responsible for the environmental problems and the thereto related health issues of the past half-century: lead pollution, acid rain, fine dust pollution and, the most threatening of all, global warming and its consequences for the climate. As from the 1990s, more and more scientists claimed that fossil fuels were the principal cause of increases in atmospheric concentrations of greenhouse gases, driving up the mean temperatures of the planet and causing a worldwide melting of glaciers and of polar icepacks. Weather related disasters, like severe flooding or drought, gigantic hurricanes and tornados have rapidly risen since the 1990s. The possible consequences of the continued and increasing use of fossil fuels forces stakeholders in the fields of security and defence and policy makers to take these global disastrous effects into account when discussing energy related issues. Where traditional geopolitical thinking regarding energy focused on availability, reliability and affordability, modern geopolitics of energy involves sustainability as well.

Photo: U.S. Airforce

Conflicts over energy resources endanger the global balance of power.

Energy Security

Energy security is the third dimension of the geopolitics of energy. There are no uncontested or universally accepted definitions of 'energy security'; it is a broad, evolving concept, encompassing many elements and aspects the importance or significance of which can alter in relation to the viewpoints, backgrounds or scientific expertise of the person using the definition. Moreover, 'geopolitics of energy' is often narrowed-down to 'energy security' and both concepts are often used as if they were interchangeable.

The origins of energy security date back to the beginning of the industrial revolution. Energy was a vital source underpinning industrial growth, modern technological life and economic development. Energy was, and is, tremendously important in every field of life and is a primary concern, second only to national defence, for the survival and well-being of developed and developing nations and societies. It is no surprise, then, to see that the control over energy resources (oil, gas, coal, nuclear or renewable) is at the heart of great power politics.

The intertwining relations between oil, politics and international power first became evident during the First World War, when Great Britain, due to German submarine warfare, experienced severe shortages in oil supply which threatened

the entire war effort. With the beginning of the war, the combustion engine had gained prominence (in warships, airplanes, and mechanised transport) which increased the dependence on oil as a premier energy source. The Allies, under the impulse of First Lord of the Admiralty Winston Churchill, quickly realised the importance of a secure and uninterrupted supply of oil at a reasonable price. They figured out that the control over energy resources and their secure transportation to energy markets would also be vital to their post-war existence and influence. This gave rise to the concept of energy security, and energy resources gained a prominent place in the war and postwar strategy. During the First World War, the Allies altered their strategic objectives with regard to the Caucasus, the Middle East and the Ottoman Empire in the light of the presence (or absence) of oil reserves. Regions previously neglected by foreign policy (e.g. the Saudi Arabian peninsula) now attracted the attention of politicians, entrepreneurs and the military. In the Second World War, the control over vast energy reserves was an important determinant of the Axis strategy: Stalingrad was a result of Hitler's desire to gain access to the energy-rich areas on the Caspian Sea, while the American oil embargo against Japan was one of the main events that led directly to the attack on Pearl Harbor.

Ever since, securing energy resources is a key aspect of foreign policy making and of military strategy.

Energy Security in the Modern Era

While in the previous decades wars were fought over oil, the 1970s confronted the oil consuming countries in the West with a frightening new reality: oil used as a weapon When after the Yom Kippur war and its aftermath (1973/74) the Organization of Oil Exporting Countries (OPEC) decided to boycott the major energy consumers in the West, the crisis that followed brought the importance of energy security immediately to the attention of governments, businesses and ordinary citizens. The message was clear: energy security became a matter of international as well as national concern.

The collapse of the Soviet Union two decades later enabled a shift from a high dependency on petroleum to a more diversified energy package: natural gas and renewable energy became significant players in the energy picture, although petroleum keeps occupying a prominent place in the geopolitics of energy.

Photo: US State Department

To avoid conflicts over energy at an early stage the US set up the US-China Economic and Strategic Dialogue Joint Session on Energy Security. Pictured are former US Secretary of State John Kerry conducting talks with Chinese Vice Premier Wang at the US Department of State on 10 July 2013.

Shortly after the fall of the Berlin Wall, Anglo-American energy security policy strived at controlling most of the world's energy resources and at securing the lines of supply from producer to consumer. The free market model, based on demand and supply, favoured the Western energy consuming powers and became the blueprint for a global energy system, aimed at (relative) price stability. The oil producing countries in the Middle East were the cornerstone of that system and Western powers did not hesitate to use military force in order to consolidate their supremacy. The two Gulf wars against Iraq (1990-1991 and 2003) and the intervention in Somalia (1993-1995) to protect the Strait of Hormuz, vital to Western (and global) energy security, are just a few examples.

New Geopolitical Challenges

The beginning of the 21st century is characterised by uncertainty and a changing energy landscape. The vulnerability of the whole energy sector can be described as the Achilles heel of the developed world and some predict yet another transition of the energy paradigm. Five trends can be identified as the driving forces behind this transition:

On the demand side, we see a diminishing role for the US in shaping oil markets due to the increasing oil demands of the rising Asian powers, notably China and India. It is argued that the Anglo-American market-based model is losing terrain to the petro-mercantilist approach of China and to the energy-hegemony approach of Russia. The Chinese petro-mercantilist model seeks to lock-up exclusive access to oil and gas reserves wherever it can obtain them. Chinese companies are also trying to buy Western energy companies in their hunt for energy resources and technology. Foreign policy and the search for energy needed to sustain economic growth, are intertwined through the (quasi-) state owned energy companies like SinoPec. The Chinese meddling in Sudanese internal affairs like in the Darfur region – a region rich in fossil fuels - is a classic example of that policy. The Russian energy-hegemony model suggests that Russia uses its enormous reserves of oil and natural gas and its geographical position to advance its foreign policy goals by bribing or bullying

Graphic: US EIA

Many EU member states are heavily dependent on Russian gas and oil supplies.

both suppliers (in Central and Southwest Asia) and users (the EU). At the same time, Russia uses its energy companies – of which energy giant Gazprom is the most notorious - to exploit the free market.
On the supply side, rising demands and supply constraints lead to price volatility. The world is running out of fossil fuels, although real shortages are not to be feared for in the near future. Largely due to the disclosure of new reserves (shale gas, for example) and to the use of new technologies that make the exploitation of these reserves profitable, scarcity is not as big as anticipated a decade ago. However, the days of energy abundance are definitely over. Assessment, production, conversion and delivery to where resources are needed in a cost-effective, secure and environmentally benign manner, have become a real challenge. The infrastructural needs to transport larger volumes over larger distances through already crowded and vulnerable choke points are another concern.
Political instability in and around countries that play a role – even a marginal one - in the worldwide energy system cause major price spikes on the market. Instability creates fear among oil importers and gives political power to oil exporters.
Terrorism is yet another factor increasing uncertainty with regard to energy security: the attacks of September 2001 have inspired different terrorist groups to new forms of terrorism. Since 2001, worldwide attacks on oil or gas pipelines and on other energy related infrastructure are increasing. This so-called 'economic jihad' threatens the safety and security of energy resources and has become another important security challenge for both industry and governments.

Photo: Joachim Kohler

The diversification of natural gas supplies, also with liquefied natural gas, can reduce energy dependencies.

However, climate change may be the biggest challenge to energy security; global warming poses by far the most important challenge to today's geopolitics of energy. Climate change will profoundly affect energy systems and the possible catastrophic consequences raise enormous macroeconomic security concerns in terms of disrupted methods of production, reduced household's purchasing power, drops in consumer confidence and, finally, reductions in economic activity. National security concerns, such as uncontrolled mass migration, as well as affordability of energy, will add to the problem.

NATO and Energy Security

NATO discovered energy security at the Bucharest Summit in 2008. Although energy security is largely non-military in nature and mostly a national responsibility, NATO understood that the energy developments mentioned above will have serious security implications. NATO could not turn a blind eye to the protection of critical energy infrastructure and should enhance energy efficiency in the military as well.
Energy security, with numerous implications for allied security, became a real strategic issue for NATO in the aftermath of the Russian annexation of the Crimea in 2014. For many NATO allies energy supply is a challenge. In March 2014, NATO Secretary General Anders Fogh Rasmussen declared that Europe's dependency on oil and gas imports was increasing at a time when the energy needs of rising powers such as China and India were rising as well. Political instability was haunting many energy-producing and transit states, while the quest for energy and other resources had sparked territorial disputes all around the world. Terrorist and cyber attacks against refineries, pipelines and power plants occurred in many countries, as well as piracy along critical maritime choke points.
NATO's energy security agenda is aimed at creating awareness of global and regional energy developments and supporting the political consultation process with shared intelligence. Although NATO's contribution to energy security is limited to analysis and consultation, it has become a permanent fixture in NATO's education and training programmes. NATO sees a role for itself in the three following areas:
1. Raising awareness by sharing intelligence on energy developments, by fostering political consultations among allies and partners and by exchanging information and insights with outside experts.
2. Supporting the protection of critical energy infrastructures by sharing best practices, by organising training courses and by inserting energy-related scenarios into exercises.
3. Enhancing energy efficiency in the military by the sharing of national best practices, by using energy-efficient equipment and by developing military energy efficiency standards.
In the near future, NATO will also focus on the energy resilience of the allies. Since resilient energy supplies are vital for collective defence, NATO support in this area is likely to increase. Cyber threats towards energy infrastructure will also gain in importance.
In order to take up these roles, NATO created several organisms: an Energy Security Section was established within NATO's Emerging Security Challenges Division. The Energy Security Section works together with outside experts and with the International Energy Agency (IEA) and with the Directorate-General for Energy of the European Commission. In 2012, a NATO Energy Security Centre of Excellence was established in Lithuania, providing analysis and training across the entire spectrum of NATO's energy security agenda and serving as a unique asset for supporting and promoting NATO's energy security agenda. In 2015, the first Energy Security Strategic Awareness Course took place in the NATO School in Oberammergau, covering a broad spectrum of energy challenges, ranging from the geopolitics of oil and gas to enhancing the energy efficiency of armed forces. And recently, in February 2018, NATO held its first energy security course at the newly created NATO-Istanbul Cooperation Initiative Regional Cooperation Centre in Kuwait. Several partner countries, notably Ukraine, attended the training course on the protection of critical energy infrastructure.

It is clear that NATO's role in energy security will remain modest, but that it is an essential part of the Alliance's toolkit and energy developments are too intertwined with other security issues to allow NATO to ignore them.

The EU and Energy Security

For the EU, energy security is a matter of life and death. The EU imports more than half of the energy it needs and its import dependency amounts to 90% for crude oil and 69% for natural gas. A gas dispute between Russia and transit country Ukraine in 2009 threatened many EU countries with severe shortages and highlighted the vulnerability of the EU for supply disruptions and infrastructure failures. Even more, many EU countries rely on a single supplier – some countries rely solely on Russia for the import of natural gas. With a total energy import bill of more than €1Bn a day, it was necessary for the EU to draw up an energy strategy and in May 2014, the European Commission released its Energy Security Strategy. The aim of the strategy is to ensure a stable and abundant supply of energy for European citizens and the economy. The Strategy proposes actions in five key areas:

1. Increasing energy efficiency in order to reach the proposed 2030 energy and climate goals, with the focus on buildings and industry.
2. Increasing energy production in the EU and diversify supplier countries and routes. Negotiations are taking place with Russia, Norway, Saudi Arabia and countries in the Caspian Sea region. Another option for diversification is the increased import of US liquefied natural gas. Safe nuclear energy and renewable energy sources should also contribute to an increase in European energy production.
3. Completing the internal energy market and building missing infrastructure links that allow a quick reaction in case of supply disruptions. In July 2018, measures were taken to better integrate the Iberian Peninsula into the European energy market.
4. Building an external energy policy, including sharing information about national planned agreements with non-EU countries that may affect the EU's security of supply.
5. Strengthening emergency and solidarity mechanisms and protecting critical infrastructure by a more efficient use of storage facilities, by developing the possibility of reverse flows, conducting risk assessments and putting in place security of supply plans at regional and EU level.

The final aim of the EU energy strategy is to create a real energy union, making energy more secure, affordable and sustainable. To achieve that goal, the EU wants to facilitate the free flow of energy across borders and a secure supply in every EU country. New technologies and renewed infrastructure should contribute to the ideal of a sustainable, low carbon and environmentally friendly economy. Therefore, the European Energy Security Strategy was completed by the 2030 Framework for Climate and Energy.

Energy security is becoming an important issue for NATO and for the EU and plays an important role in the relations with Russia. However, it still largely remains a national responsibility, and nations are reluctant to give up their sovereignty in that vital field of interest. It remains to be seen how energy security will be managed in the future by the member states, NATO and the EU. ■

Land Combat System Support at the NATO Support and Procurement Agency (NSPA)

Jörn Brauer and Robert Elvish

This year NSPA is celebrating its 60-year anniversary! Today, NSPA is a key logistics enabler for the support of both NATO and nationally owned military equipment as well as managing contractor support to operations on behalf of the NATO Commands, multinational groups and individual nations.

The Agency is headquartered in Luxembourg and has programmes based in France, Hungary and Italy with outstations in Afghanistan, Kosovo and other locations. Today, NSPA's establishment encompasses more than 1,350 positions, with 60 of these personnel deployed on operations. NSPA business activity has grown nearly fivefold in the last decade and now includes the acquisition role. Business and workforce growth is predicted to continue, with customer nations directly funding more than 90 percent of these activities; less than 10 percent comes from NATO common funding.

The rapid growth of the Agency, political and operational developments and the need to develop the acquisition role led to a comprehensive review and refresh of the Agency's five-year Strategic Direction in 2017 and led to an optimised organisational structure that is now composed of four main business units:

- Life Cycle Management
- Support to Operations
- Central Europe Pipeline System
- NATO Airlift Management

These are underpinned by four key support functions: Procurement, Finance, Human Resources and Information Technology. These are essential to ensure the smooth running and management of the supporting processes.

NSPA's core business continues to be the life cycle management of equipment and weapon systems. Through the development of the acquisition role, the Agency now oversees activities in all phases (from concept phase through acquisition and in-service to disposal) of the system life cycle, providing customers with 'cradle-to-grave' support. NSPA currently manages 30 multinational Support Partnerships (SPs) covering over 90 major weapon systems.

The strength and attractiveness of the Agency is largely due to the wide range of experience and capability within the business units and the electronic logistics solutions available, which are developed and exploited to the fullest extent possible. The Agency has a proven record of timely and cost-effective delivery, high levels of transparency and customer satisfaction and creating economies of scale for customer nations, particularly in the very successful multinational SP mechanisms. The Agency also has the capability to access a broad supplier base of more than 10,000 companies using a range of innovative procurement mechanisms. It has a professional Agency workforce and attractive multinational legal frameworks, as well as an integrated suite of IT solutions and the ability to access transatlantic capability platforms through the NATO structure.

Authors

Jörn Brauer, Staff Officer Life Cycle Management Directorate, NSPA and **Robert Elvish**, Programme Manager Air and Land Combat System Programme Office, NSPA.

Photos/Graphic: NSPA

The mid-life upgrade of MLRS extended the capabilities and service life of the system.

Land Combat System Support

NSPA's support to Land Combat Systems is a perfect example illustrating the range and depth of support provided to NATO and Partner Nations. Most support in this domain is provided through the NSPA Air and Land Combat System Programme, it provides full life cycle support to a range of weapon systems with roughly 200 highly skilled engineers, technicians, logisticians and specialised procurement and finance staff.

The foundation of multinational cooperation and consolidation of requirements is the SP structure structure unique to NSPA. The SP concept brings together NATO and partner nations with common requirements, areas of mutual exchange interest in support of fleets, systems and services. Nations provide governance and guidance, whereas the Agency manages the support requested by the nations. This concept has proven its effectiveness for 60 years now.

Supported systems in the Land Combat System domain include missile systems such as TOW/ITAS, SPIKE, STINGER; artillery systems like the MLRS and PzH 2000; armoured vehicles including the LEOPARD, DINGO Light Armored Vehicle (LAV) and BOXER. The SPs are able to consolidate national requirements, resulting in economies of scale. NSPA provides competitive international bidding, ensuring the lowest cost, best value and a centralised point of contact for customer and industry engagement.

Scope of Support

The scope of life cycle management support for land combat systems includes acquisition, engineering, contract management, maintenance & overhaul and warehouse management. Support is provided primarily through contracts with industry, established through a streamlined international competitive bidding process. NSPA also maintains a highly capable workshop facility able to provide a range of direct services to nations including repair, maintenance and modification of mechanical and electro-optical systems. The United States' Foreign Military Sales (FMS) are another area in which NSPA has significant expertise and through which it is able to provide support to the partnerships and individual nations.

The latest major acquisition project is a fleet of Light Tactical Armoured Vehicles in multiple configurations. This fleet will consist of more than 100 vehicles. Deliveries are expected to begin in 2019 and to be complete within two years. The Agency has applied a rigorous project management approach to this undertaking ensuring that the customer nation is getting the best value while meeting their requirements on time.

Engineering changes, obsolescence management and mid-life upgrades are an essential part of the Land Combat Systems efforts. The rebuilding of the PzH 2000 Fire Control System is an example of the work undertaken in NSPA's own workshop facility. Likewise, the manufacture of TOW/ITAS Traversing Units demonstrates the broad range of capability available. Mid-life upgrades include improvements to the MLRS, such as the integration of a new fire control system and GPS as well as the vehicle drivetrain and turret motor upgrades. The Agency also runs a Service Life Extension Programme for the STINGER missile systems. This initiative will see the replacement of multiple time-expired components, such as the rocket motor and energetic material, leading to a substantial increase in the service life of this weapon system.

Examples

In the Land Combat System domain, the Agency is also providing Logistics and Engineering Support to Unmanned Aerial System (UAS) users. The UAS SP was established in 2014 and is currently providing logistic solutions for a variety of UAS systems such as RAVEN, ORBITER, WASP, FlyEye, BLACK HORNET, SEARCHER MK III, SCAN EAGLE and HUGINN.

Despite the differences in class and size of these systems, NSPA adopted a unique business model aiming to provide logistic support services integrated with configuration management to comply with the National Airworthiness regulatory frameworks. Under the existing logistic support contracts, NSPA is currently running several upgrade programmes triggered by new capability requirements and by the necessity to align the delivered systems on a unique supportable configuration.

The BOXER multi-role armoured vehicle is another example of support provided within the Land Combat Vehicle SP. It is being supported by NSPA in cooperation with the procurement agency OCCAR (Organisation Conjointe de Coopération en matière d'ARmement/Organisation for Joint Armament Cooperation) ensuring an efficient cooperation from production to in-service support. Support services for the BOXER include Configuration Management, Interactive Electronic Technical Documentation, Logistics Support Analysis, Technical Data Package management, common stock management and provision of spare parts. In addition, NSPA has contracts and outline agreements in place for industry support services. SP nations are currently Germany and the Netherlands, while future BOXER nations may join the Support Partnership to take advantage of the many benefits provided through NSPA.

Outlook

The Agency's recent exponential business growth is a clear indicator of its success, building on the outstanding levels of services delivered and high rates of customer satisfaction. ■

Left: Manufacturing the TOW/ITAS traversing units demonstrates NSPA's broad range of capabilities. Right: Comprehensive support is granted for the increasingly internationally used MRAV BOXER.

"High Range of Capabilities to Support NATO and the EU"

Interview with Brigadier General Rudolf Maus, Director of Life Cycle Management of the NATO Support and Procurement Agency (NSPA)

Foto: NSPA

ESD: What led to the recent restructuring of NSPA by building two new directorates out of your previous area of responsibility, one for Support to Operations and one for Life Cycle Management?
Maus: Until the end of 2017, I was responsible for all operational capabilities of the NSPA in both domains, the support for operations as well as the Life Cycle Management, which represents a very wide spectrum of different capability portfolios. The Agency is facing a continuous rapid business growth in all areas, including an increase in the new acquisition role.
To give you an indication, NSPA business activity has grown nearly fivefold in the last 10 years and reached more than four billion Euros in 2017. Within the growing business portfolio, we also had to focus on the further development of the systems acquisition capability and the management of the exponentially expanding Life Cycle Management activities.
Beside this, it was necessary to concentrate all resources to support NATO and the nation's missions. Due to the changing geopolitical situation, the Agency has to be ready to support NATO's current and future missions, which also cover European areas of interest.
Mainly this growth in portfolio, scope and variety led to the restructuring to maintain a manageable span of control and a focused customer engagement at senior management level as a vital element to achieve customer satisfaction.

ESD: Focusing on the continuous growth of the NSPA, what do you see as major success factors from the customers' point of view?
Maus: The Agency's recent exponential business growth is a clear indicator of its success to achieve a high degree of customer satisfaction in delivering projects and services in a responsive and transparent way within scope, time, budget and at high quality.
The Agency is offering a proven platform for multinational cooperation and with that the ability to consolidate national requirements, to contribute to interoperability, to provide the know-how and experience exchange amongst nations. This often leads to new initiatives and to achieving collective solutions with the advantage of building capabilities together, which one nation alone could not achieve. Economies of scale – but also a high degree of efficiency – come with it. In particular, in areas where resources are scarce, a collective approach also avoids unnecessary competition between allies, an effect we all know, for example, in the operational environment where reacting markets often create extra burdens.
A further advantage represents the very successful mechanism of a very direct and effective governance model exercised by the nations in currently 30 established multinational Support Partnerships. Member nations who decide to follow common goals and achieve defined products and services build the legal framework in which they decide on – amongst other characteristics – the required goal, scope, budget and work force and approve the desired outcome. This mechanism keeps our governance fully committed to the programme and focused on a successful outcome.
Finally, making use of NSPA's capabilities means using a highly skilled and very experienced work force in a very wide capability spectrum; this can help to avoid "reinventing the wheel", closing national expertise or resource gaps or freeing up national resources, which then can be reallocated to other national priorities.
Therefore, from this perspective, we see ourselves not only as an executing agent for collective solutions, but also as an alternative to national initiatives under national responsibility.

ESD: Acquisition of military systems has become a new area of responsibility for NSPA – what has changed or will change?
Maus: The NATO Council allocated the Acquisition role to NSPA in 2015. Although this task was not new to NSPA (we ran acquisition projects already in the Armoured Vehicles, Helicopter, Unmanned Aerial Systems, Deployable Camps and Ground Based Defence domains), the Agency took further initiatives to strengthen this capability.
As I mentioned before, we optimised our organisational structure by establishing a new Directorate responsible for "cradle to grave" Life Cycle Management. The Directorate of Life Cycle Management is covering all Acquisition activities from concept phase to the fielding as well as In-Service Support and – later in the life cycle – upgrading of systems, as well as Disposal, Dismantling and Demilitarisation, which in our view is also a growing domain. Currently, we do support more than 90 weapon systems in different phases of their life cycle.
This includes responsibility allocated to us in 2017 of the project management for the concept phase of the "Alliance Future Surveillance and Control (AFSC)", which can be seen as a first example in the major acquisition domain.
This new organisation has been operational since 1 January this year.
Next to this, we introduced an Acquisition Planning & Development Office in my staff, which provides us with the very important capability to cover the very early pre-project acquisition phase. As NSPA's point of contact for future acquisition initiatives, this team of acquisition experts will, in a close dialogue with the customer nations, ensure the development of an initial business case including project plan, life cycle cost and risk

analysis. It is designed to ensure a professional project and Integrated Project Team set-up, following the vital principle: "Get it right from the beginning!" This team will also help to continuously improve the acquisition processes and execution in the Agency.
From this perspective, NSPA also took initiatives to further enhance our fully integrated Project Management tool, which also allows us to build up IPTs by embedding national representatives as IPT members with real-time direct access into our Project Management system. This opens a completely new way of interacting with our customers remotely and across borders. One example is a series of projects, which we are conducting for a nation, in which the Project Manager function is filled in by an MOD member and executed from the home base in that country. This is just one example of further innovation we are looking at, and there will be many more possibilities in the future.

ESD: The last question is about your view regarding NSPA's support opportunities in capability development and sustainment towards European Union member nations. Is this an area that NSPA can manage?
Maus: In July 2016, the joint NATO-EU declaration was signed with the intent to increase the cooperation between the two entities, to avoid duplication and to spend money wisely to gain a maximum of capabilities.
We see today a strong drive in the community of the European nations, based on EU investment funds, PESCO and capability requirements like described in the initiative on military mobility as well as in operational environments. I do see many cooperation opportunities with the EU nations in the armaments, procurement and logistics capability domains, but I also see a risk of duplicating already existing, established, proven and well-performing capabilities. From my perspective, this should be avoided to the benefit of the nations, as it will reduce inefficient money spending.
Building on existing complementarity, synergy and strengths should be the way forward. NSPA would like to be seen as an option in this domain. As I explained earlier, the customer base of the Agency, including our partner nations, already encompasses all EU nations. We are very experienced in the set-up, execution and implementation of collective solutions.
There are already several successful examples of support provided to and cooperation with EU nations. For instance the NATO-owned MRTT programme, which is based on a European initiative and executed in cooperation with OCCAR, the build-up/operation and maintenance of a fully equipped hospital for the deployed troops in Kosovo, the logistics support to sustain EU Battle Group deployments, the naval fleet support in Mediterranean Sea operations, logistics support in operational theatres like Iraq and Mali, as well as a variety of support to nearly all individual nations.
From this perspective, I also would like to highlight the very good and successful cooperation established with OCCAR in programmes like the MRTT, BOXER, A400M, TIGER Helicopter and Cobra.

The interview was conducted by Gerhard Heiming.

Amphibious Warfare

Current Programmes on a Global Scale

Jack Richardson

In the last century there have been several large-scale amphibious landings around the world, from D-Day and the Pacific campaign in World War II to the Inchon landings and the Falklands War. More recently, the US and UK forces invaded Iraq from the sea across the Al Faw Peninsula in 2003, and there have been amphibious elements to the ongoing Saudi-led intervention in Yemen. That is why the British Ministry of Defence sees amphibious capabilities as being important in the future.

The importance of amphibious operations continues to endure, with the UK MoD's "Future Operating Environment 2035" document singling out the littoral (particularly where urban areas are concerned) as a key operating environment going forward.

United States

Currently, the force offering the most advanced and comprehensive range of amphibious capabilities is the US Marine Corps (USMC), which deploys seven Marine Expeditionary Units (MEUs, three on each seaboard and one in Japan) to meet contingencies. They can be scaled up in size if necessary, but each consists of a battalion-sized unit of Marines as standard, augmented by artillery, reconnaissance and armoured elements in addition to logistics and aviation units. Respectively, these are termed Ground Combat Element (GCE), Logistics Combat Element (LCE) and Aviation Combat Element (ACE). Each MEU of 2,200 personnel is overseen by a Command Element.

The MEU is integrated with an Amphibious Ready Group (ARG). The ACE (centred on the MV-22 OSPREY tiltrotor, supported by helicopters and AV8B HARRIER IIs, which are being replaced by the F-35B) is embarked in either a WASP class Landing Helicopter Dock (LHD) or an AMERICA class Landing Helicopter Assault (LHA). They also carry part of the GCE with capacity for 1,687 Marines, who can be transported ashore using either three Landing Craft Air Cushion (LCAC) or two Landing Craft Utility (LCU) held in a well dock at the stern. This facility will feature in the AMERICA class from LHA8, it was omitted from LHAs 6 & 7 to prioritise aviation). These play a significant role in transporting the GCE and LCE to and from shore, able to carry 75 and 125 tonnes of equipment respectively. Within the ARG, the Landing Ship Docks (LSDs) of the HARPERS FERRY, WHIDBEY ISLAND and ANCHORAGE classes provide logistical support. The other core component of the ARG and MEU is a Landing Platform Dock (LPD) of the SAN ANTONIO class. These were designed to replace various legacy classes and carry up to 800 Marines and their equipment, who can be ferried ashore with either two LCAC or a single LCU. Additionally, the SAN ANTONIO class can carry up to fourteen Assault Amphibious Vehicles (AAVs). Despite being able to carry up to 25 Marines from ship to shore, the vehicle is now reaching obsolescence and is due to be replaced by the Amphibious Combat Vehicle (ACV). The winner of the competition was announced in June 2018 as the Iveco SUPERAV 8x8, after many years of evaluation following the cancellation of the Expeditionary Fighting Vehicle. With an initial contract for 30 vehicles with an option for up to 204 more to fully replace the AAV in incrementally upgraded variants by 2035, the SUPERAV will have a crew of three and up to thirteen Marines with the capacity for various weapon payloads. This baseline vehicle, and a dedicated Command and Control (C2) variant, will have greatly improved mobility and protection over the AAV and will be able to keep up with the M1 ABRAMS Main Battle Tank (MBT) and the Light Armoured Vehicle 25 operated by the USMC.

Graphics: U.S. National Archives

An artist's concept of LHD-1, similar to the LHA-1 amphibious assault ships. LHD-1's primary mission is to embark, deploy and support all elements of a Marines landing force, using amphibious vehicles, helicopters and HARRIER aircraft. The electronic and communication systems of the 844-foot ship allow it to serve as a command post.

Author

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The other shortlisted vehicle for the ACV requirement was the TERREX 2 APC from Singapore Technology (ST) Kinetics who had partnered with US contractor SAIC to produce this 8x8, V-hulled vehicle. Able to carry eleven passengers in addition to a three-member crew, the TERREX 2 evolved over the original TERREX to operate at up to SEA STATE 3 and, like many other vehicles, can be equipped for different roles. At the same Expo, ST Kinetics showcased the latest member of its BRONCO family. Composed of two tracked cabs, this amphibious vehicle is marketed as being able to operate in different terrains from mountain ranges to desert environments in a variety of roles from troop-carrying to C2 and ambulance.

The UK

A similar vehicle called the VIKING (built by BAE Systems, Land Systems Hägglunds of Sweden) was operated by the Royal Marines (RM) in Afghanistan to great effect. The RM is built around 3 Commando Brigade, which trains for a variety of amphibious contingencies. It comprises three battalion-sized formations (one of which is optimised for maritime security operations) alongside supporting artillery, logistics, engineer and intelligence elements (some of which are detached from the British Army). The brigade also features 43 Commando Fleet Protection Group, responsible for guarding the UK's nuclear deterrent at Her Majesty's Naval Base Clyde in Scotland. For its traditional role of amphibious warfare, 3 Commando Brigade relies upon the two ALBION class LPDs. These 19,000-ton vessels can routinely carry 256 troops and their equipment (with a surge capacity of 405) in addition to up to 30 armoured vehicles or six CHALLENGER II MBTs. These are ferried ashore from the Landing Craft Vehicle and Personnel (LCVP) Mk 5, which can transport a company of fully equipped Marines (or an armoured vehicle similar to the VIKING) over 210 NM. A larger type is the LCVP Mk 10, which can carry up to 120 Marines at 10 knots. Both of these types can also be operated from the BAY class LSD, which can carry up to 400 troops and up to 24 CHALLENGER IIs. These versatile ships, crewed by the civilian Royal Fleet Auxiliary (RFA) are also suitable for a wider variety of roles including humanitarian relief in the Caribbean and maritime security in the Gulf. The primary task in the latter is supporting the RN Mine Countermeasures Vessels in the region, but the ships have played host to US Riverine Command Boats. Furthermore, in 2012, it was reported the RFA CARDIGAN BAY acted as the base for RM VIKINGs conducting raids into Somaliland. Also, the 1998 Strategic Defence Review (SDR) made clear a requirement for six Strategic Transport Ships of the POINT class. Operated under a private contract, these ships play a key role transporting equipment around the world to support UK expeditionary operations, an example being the buildup to the 2003 invasion of Iraq.

Despite being highly capable, and also receiving an upgraded, twelve passenger, LCAC capability in 2010, the UK's amphibious forces have been through significant upheaval in recent years. In 2018, the RN's only Landing Platform Helicopter (LPH) HMS OCEAN was decommissioned and sold to Brazil. In addition to their carrier strike role, one of the QUEEN ELIZABETH class aircraft carriers will use helicopters to conduct littoral manoeuvres to fill this gap. However, given their size and potential vulnerability, this is a controversial prospect. Under the 2010 SDSR, the number of POINT class ships went from six down to four and one of the ALBION class was placed in extended readiness. Indeed, as the UK MoD battles continuing budget shortfalls, there is speculation in the UK press that these ships could be withdrawn from service altogether, leaving a significant capability gap even though amphibious capabilities remain important across Europe with a number of states renewing their fleets.

The Netherlands

One force with which the RM retains a close relationship is the Royal Netherlands Marines. Ever since they forged close links in the Cold War to guard NATO's Northern

Photo: IVECO

An Iveco 8x8 SUPERAV launched from an LHD-1. The SUPERAV is capable of supporting littoral operations in open ocean beyond sea state 3. The vehicle can carry a 10 t mission load, including an overhead weapon station mounting up to a 40mm cannon. The SUPERAV platform is equipped with a new 700 hp powerpack and driven in water by two propellers.

Flank, the two forces have coordinated training for a variety of contingencies. The extent of this is such that the BAY class LSDs are derived from the Dutch/Spanish ENFORCER LPD design. The Royal Netherlands Navy retains two of these ships in service. HMNLS ROTTERDAM is able to support up to 611 troops and has a hangar that can accommodate six medium-sized helicopters in addition to a well-dock from which LCVPs can be deployed. Her sister ship is HMNLS JOHAN DE WITT which has the same aviation, C2 and hospital facilities but benefits from a double lane well-dock, from which both LCVPs and LCACs (with the parting removed) can be deployed. There is also the Joint Support Ship HNLMS KAREL DOORMAN which not only supplies fuel and solid supplies to Dutch warships around the world but contains amphibious shipping to support the Dutch Marines. The versatility of these ships is underlined by the fact that all three have operated off Somalia as motherships in the anti-piracy role. This forms part of a trend whereby roles of amphibious and other naval ships are becoming blurred. The ABSALON class support ships operated by the Royal Danish Navy are used to carry LEOPARD II MBTs, as their mission decks were designed for a broad spectrum of operations.

Photo: UK MoD

Royal Marines Landing Craft Vehicle Personnel (LCVP) Mk 5

France

Also bolstering its amphibious capabilities is the French Marine National (MN), which over the last decade has taken delivery of three MISTRAL class LPDs. These advanced vessels enjoy extensive C2 capabilities, accommodation for 450 to 700 troops and fully equipped medical facilities. They have the ability to transport a large number of helicopters (either 16 in the medium category or up to 35 lighter types) and have greater on-board space due to azimuth thruster propulsion. From the large floodable well-dock facility in the stern, each ship can deploy two Engins de Débarquement Amphibie Rapides (EDA-R) catamarans. These large craft can achieve 30 knots and travel 400 NM with up to 80 tons on board. Images from the recent Catamaran 2018 exercise with the RN show these vessels discharging a wide range of vehicles from the French Army's 9th Brigade (its specialised, all arms, marine formation). Vehicles shown ranged from the VBCI 8x8 Infantry Fighting Vehicle to the AMX-10RC 6x6 reconnaissance vehicle.

Spain

As amphibious capabilities become more prominent in Europe, there is another design which stands out. The Spanish Armada's JUAN CARLOS I strategic projection ship was commissioned in 2010 and has a large well-dock (that can take up to four LCVPs), in addition to a fully equipped hospital and dental surgery. The ship supports the Spanish Marine Corps (who also benefit from the support of two GALICIA class LPDs, similar to HNLMS ROTTERDAM) which consists of two infantry battalions, a mechanised one (containing the AAV-7) and supporting elements. Up to 913 troops can be accommodated on the JUAN CARLOS in addition to a broad range of helicopters (twelve in the hangar and another six on deck). There is also a ski-ramp which can launch the Spanish Armada's AV-8B HARRIER II, but it is currently unclear whether funding will permit these to be replaced by the F-35B. Such are the capabilities of this ship, the Turkish Navy is procuring a similar one named ANADOLU, from which the F-35Bs may be operated.

Italy

Also in the Mediterranean, the Italian Marina Militare operates the San Marco brigade with three regiments, the first a composite, expeditionary force, the second orientated towards maritime security operations and the third towards training. The force, over-

seen by command and support elements, is looking to recapitalise with a new LHA/LPH type of vessel. Currently, the brigade is operated from the three small SAN GIORGIO class LPDs, from which a battalion of marines, various landing craft and three helicopters can be deployed (though they lack a hanger). As the need for amphibious capabilities has spread to the Middle East and North Africa (MENA) region, two similar ships have been procured, one for Algeria and another forthcoming for Qatar. Though they have the core features of medical and C2 facilities, these have greater offensive weaponry than traditional amphibious ships. These include an Oto Melara Rapid 76mm gun for countering surface and aerial targets in addition to a silo aft of the superstructure capable of launching MBDA ASTER air-to-air missiles which are supported by a powerful Active Electronically Scanned Array.

Russia and Egypt

One of the more significant amphibious warfare developments in the region however lies on the Suez Canal. France had originally been contracted in 2011 to build two MISTRAL class LHDs for the Russian Navy. However, this purchase was cancelled in August 2015 following a backlash from the US and Eastern European states, in the context of Russian aggression in Crimea. The following year, however, France succeeded in selling the two ships to Egypt, where they were renamed GAMAL ABDEL NASSER and ANWAR EL-SADAT. These vessels provide Egypt with a valuable expeditionary capability from which aforementioned quantities of troops and armoured vehicles can be deployed. It is, however, unclear what types of aircraft the Egyptian vessels will operate, with suggestions Egypt may deploy Russian types including the KAMOV 52 coaxial rotor attack helicopter from the ships. Despite the setback of failing to purchase to MISTRAL class ships, Russia is planning a new LPH by 2022 and is procuring smaller support ships.

China

In East Asia, however, progress has been more rapid. Perhaps the most significant efforts are those of China, which has established two all-arms marine brigades with a third in the process of being stood up. To support this 20,000-strong (and growing) force, China's People's Liberation Army Navy (PLAN) has built six Type 071 LPDs. Similar to the SAN ANTONIO class, these can transport a battalion of 800 Marines and land them using LCVPs, LCACs and helicopters. China also plans to build an uncertain number of Type 075 LHAs. Displacing 40,000 tonnes, these ships will be able to carry up to 30 helicopters, offering increased power projection in the disputed South China Sea region.

Japan

This has sparked a response from Japan, which is in the process of raising significant amphibious forces in the added context of the controversial moves by Shinzo Abe's government to establish a more assertive defence policy. In 2018, the Japanese Ground Self-Defence Force (JGSDF) activated the Amphibious Rapid Deployment Brigade (ARDB). Composed of approximately 2,100 personnel, parallels have been drawn between this new unit and USMC MEUs because Japan has purchased V22 OSPREYs and AAV-7 APCs. This is in addition to considering the purchase of new Landing Craft and, controversially, F-35Bs to operate from Japan's existing IZUMO class helicopter carriers.

Photo: Crown

A Royal Marines Landing Craft Utility (LCU) Mk10 B2 conducting cross decking drills with the French Marines with a French EDA-R catamaran landing craft in the background

Photo: U.S. Navy

A Landing Craft Air Cushion (LCAC) launches from the deck of amphibious assault ship USS BONHOMME RICHARD (LHD 6).

South Korea

Similarly, South Korea is studying the possibility of deploying the F-35B from its DOKDO class LPHs. With one of these vessels in commission and another under construction, they possess the C2 capabilities and medical facilities to form a key part of the ROKN's vision to become a blue water navy. This is through carrying 700 Marines (South Korea has 29,000 in total over two divisions and a brigade), six tanks and AAVs in addition to LCACs.

Australia

As part of this trend of proliferating amphibious capabilities in the Asia-Pacific region, Australia has been at pains to enhance its amphibious capabilities with the commissioning of the LHDs CANBERRA and ADELAIDE in 2014 and 2015 respectively. These are derived from the JUAN CARLOS LPH operated by the Spanish Navy and are able to carry four LCM 1E Landing Craft to move up to 1,000 personnel ashore. This has meant significant changes for the Australian Defence Force, including the re-role of the 2nd Battalion, Royal Australian Regiment to provide specialist capabilities to secure the beachhead before the main force in brought ashore. These ships, which operate alongside the LSD HMAS CHOULES (procured from the RFA in 2011) have already been proven in exercises with the US and in their secondary role of providing humanitarian assistance after Cyclone Winston devastated Fiji in 2016. Amidst regional geopolitical concerns, this is also a key priority for states in the region. India purchased the former AUSTIN class LPD USS TRENTON in 2007 (there is an ongoing competition to procure four multi-role support vessels), whilst a specialist marine brigade is being raised by the Indian Army.

Singapore

One state which, as previously mentioned, has pedigree in producing amphibious vehicles is Singapore. The Republic of Singapore Navy operates four ENDURANCE class LPDs and is seeking a more capable replacement class. Alongside the TERREX 2 at Eurosatory 2018 was a private venture by Krauss-Maffei Wegmann and NEXTER which has resulted in the Amphibious Protected Vehicle Tracked (APVT). This is an amphibious APC which on land is controlled by a driver and commander sitting side by side but upon entering the water (a protective screen is erected at both ends), is propelled in the opposite direction using pump jets. Driven by a diesel engine on rubber tracks, APVT has a remote weapons station and a payload of up to five tons. To date, it has been tested over multiple types of terrain and is marketed for riverine or open water operations.

The large number of amphibious warfare projects around the world, from these next-generation vehicles to large scale amphibious shipping, underlines the increasing value of these highly specialist capabilities. ■

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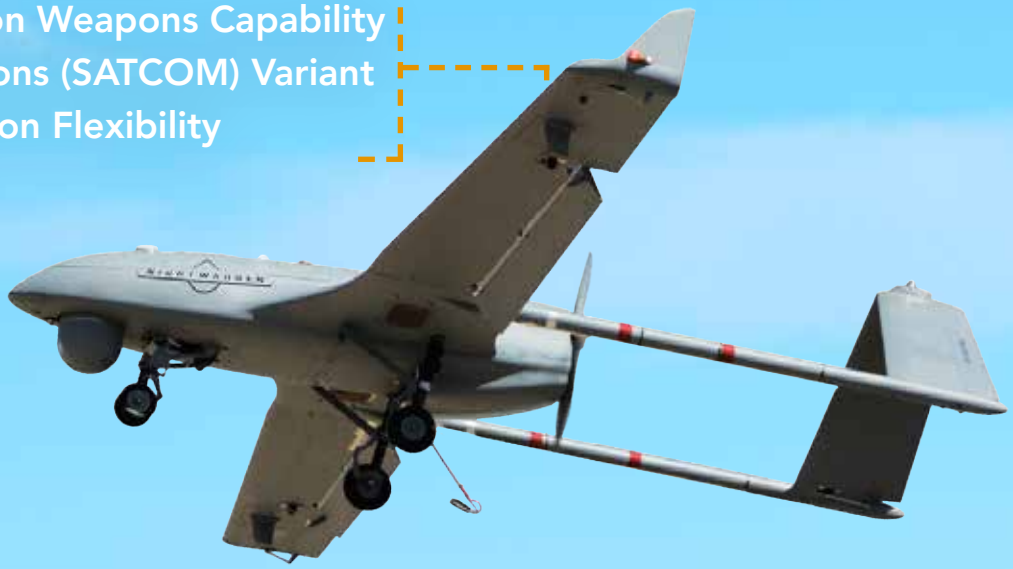

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UK Armoured Vehicle Programmes

David Saw

For almost 44 years the primary mission of the British Army was to be prepared to fight a high-intensity mechanised conflict on the North German Plain. For some 40 of those years, that mission would be conducted under the auspices of NATO. Then the world changed.

The end of the Cold War and German reunification marked the end of the primacy of the British Army of the Rhine (BAOR) in British Army operational thought. The consequences of this massive change were that the British Army would need to reinvent itself to remain relevant in the face of new security realities.

Photos: UK MoD

The CHALLENGER 2 LEP aims to modernise the tank to provide a precision direct fire manoeuvre capability, but doubts exist that all tanks will go through the LEP.

Although the Cold War might have ended, the British Army that was built to fight the Cold War found itself deploying to the Middle East in 1990/91 in what was known to the British as Operation Granby. This meant the deployment of two armoured brigades and the HQ of the 1st (UK) Armoured Division; 221 CHALLENGER 1 tanks and thousands of other vehicles were employed. Apart from the CHALLENGER 1, which entered service in 1983, in terms of armour there was the WARRIOR IFV in multiple variants, this had entered service in 1987, the CVR(T) family of vehicles, which entered service in 1973, and the FV432 family of vehicles that entered service in 1963.

In many respects, the British Army was in a good position as far as armour was concerned. At the start of the 1990s, the CHALLENGER 1 had proven itself to be a very effective tank in combat in the Middle East. Furthermore, as it had only been in service for some eight years by the early 1990s, it had plenty of potential for upgrade and service life extension. Yet, the CHALLENGER 1 began to be withdrawn from service in 1996, with its replacement being the CHALLENGER 2. The first batch order consisted of 127 tanks and 13 Driver Training Tanks DTT. A second batch order in June 1994, covered 259 tanks and nine DTT. The first CHALLENGER 2 tanks were delivered in 1998, with deliveries completed in 2002.

The WARRIOR had also performed extremely well in Granby and would remain in production until 1995, with the British Army acquiring 789 vehicles, although the original requirement actually called for 1,053 vehicles. The CVR(T) vehicle family had continued to demonstrate how useful it was, while the FV432, although old, had demonstrated that, whilst it might not be the greatest armoured vehicle in the world, there were plenty of missions it could perform for the British Army.

The evolution of British armour after the end of Operation Granby in February 1991 has proven to be a saga of complexity, immense frustration and failure. Indeed, some 27 years after Granby, the British Army still operates the WARRIOR, the CVR(T) family and the FV432 along with its numerous variants. It must be noted that, as of 2018, the WARRIOR has been in service for 31 years, the CVR(T) first entered service 45 years ago and FV432 entered service 55 years ago.

There are numerous factors that have contributed to the British failure to effectively modernise their armoured vehicle fleet. Obviously one of the primary factors was politics in the post-Cold War world; the British Government, like many other European governments, looked to reduce defence spending to obtain a 'peace dividend' that could be spent on more politically useful purposes. Consequently both military budgets and the size of the military shrank. With no clear national defence strategy having emerged to reflect conditions in the post-Cold War world, defence matters were left to drift.

Events in the Balkans in the 1990s would find the British Army involved. Operation Grapple saw major British deployments to Bosnia initially as part of the United Nations Protection Force (UNPROFOR) and later as part of the NATO Intervention Force (IFOR). Deployments to Bosnia commenced in October 1992 and continued throughout the 1990s. Later, in 1999, British troops deployed to Kosovo for peacekeeping missions as part of the NATO Kosovo Force (KFOR). Both Bosnia and Kosovo were major troop deployments and asset intensive.

The arrival of Tony Blair as Prime Minister in 1997 saw the British Government embrace a policy of liberal interventionism. Britain was committed to peacekeeping/peacemaking missions; Kosovo was an example of this, as was Operation Palliser in Sierra Leone in May 2000. The Sierra Leone military inter-

vention was both rapid and decisive, which is what the British Government hoped to achieve in these missions. Unfortunately then came Afghanistan and Iraq, major missions that were neither rapid nor decisive. Major involvement in Iraq (Operation Telic) lasted from 2003 until 2009, while Operation Herrick in Afghanistan lasted from 2001 to December 2014. The negative impact of Afghanistan and Iraq on the British Army cannot be underestimated, and the effects are still being felt today.

Politics and Personnel

Between 1990 and 2015 the British Government embarked on a number of defence reviews, the first of which was 'Options for Change' in 1990, followed by 'Front Line First' in 1994, both of which were force reduction and cost cutting exercises. The Labour government that came to power in 1997 had their first review, 'Strategic Defence Review (SDR)', in 1998, which continued the trend of force reduction, cuts and restructuring. Post 9/11, the security situation had changed and this led to an addition to the SDR known as 'SDR Next Chapter' in 2002. This was followed by another review 'Delivering Security in a Changing World' in 2003, unsurprisingly more restructuring and more cuts were on the agenda.

After that came the 'Defence Industrial Strategy (DIS)' of 2005, the aim here was to come up with a strategy that would give the military the equipment that they needed, when they needed it and at best value for money. Key to this was the domestic defence industry that was to sustain capability in key technology areas. In 2010, a Conservative/Liberal Democrat coalition government came to power, and their first review, the 'Strategic Defence and Security Review (SDSR)', of 2010 contained more force reductions. By this point, an overspend of some £38Bn by the UK MoD had become a major political issue, further increasing the pressure for more cuts in defence expenditure. The most recent SDSR was in 2015 and called for the British Army to have a regular force of 82,000 trained troops and 35,000 reservists.

To provide some context, in 2015, the British Army had 87,060 regular troops, 2,870 Gurkhas, 25,880 volunteer reservists and 4,680 other personnel. By 1 April 2018, there were 81,120 regular troops, 3,150 Gurkhas, 29,100 reservists and 4,410 other personnel. However, according to the 'UK Armed Forces Quarterly Service Personnel Statistics' as of 1 April 2018, published by the MoD on 17 May 2018, British Army Full-Time Trained Strength (FTTS) personnel numbers as of 1 April 2017 were 82,650 and as of 1 April 2018 were 81,160, with these numbers including mobilised reservists and Gurkhas. This indicates that the British Army is under strength; the FTTS personnel numbers are the key measure of usable troop numbers. Furthermore, retention of trained personnel is proving difficult and recruiting is not providing the bodies necessary to meet requirements.

In 2010/2011, BAE Systems were awarded a contract to modernise CVR(T) armoured vehicles to the CVR(T) Mk 2 configuration, as illustrated by this SCIMITAR Mk 2 vehicle on operations in Afghanistan.

To summarise, the British Army has suffered from years of overcommitment and underinvestment, added to which the procurement system has proven to be unfit for the purpose on far too many occasions. On the positive side, there are now a number of procurement programmes in action that will see the acquisition of new armoured vehicle capabilities, either through the upgrade of existing systems or the acquisition of new equipment. However, these programmes are not without their problems, and there are doubts whether the army, in its current anaemic state, can absorb or even actually needs all of these promised new armour systems.

A recent report by the House of Commons Defence Committee 'Beyond 2%: A preliminary report on the Modernising Defence Programme (MDP)' issued on 12 June 2018, noted that: "there are serious deficiencies in the quantities of armour, armoured vehicles and artillery available to the British Army." The report stated that after the 2010 SDSR, the number of CHALLENGER 2 tanks was reduced by 40% and the number of heavy artillery systems by 35%. Currently, the British Army has 227 CHALLENGER 2 tanks; in 2010 they had 316.

The Defence Committee report mentioned the CHALLENGER 2 Life-Extension Programme (LEP) and also referenced the WARRIOR life-extension, a programme with an estimated cost of £1.3Bn. The report then stated that: "Reports emerging from the National Security Capability Review (NSCR) suggested that the number of WARRIORs due to be upgraded would be substantially reduced." In addition, it was noted that: "The army is procuring the next generation of Mechanised Infantry Vehicle (MIV), a procurement taking place outside of the MDP. We took evidence on this in April (2018) and, at that time, the MoD was not in a position to provide detailed figures on how much each vehicle would cost. A failure to manage costs could put further strain on an equipment programme already under enormous pressure."

Rectifying the serious deficiencies in quantities of armour and armoured vehicles available to the British Army, as noted above, would appear to be a work in progress. Evidence includes the CHALLENGER 2 LEP, the WARRIOR Capability Sustainment Programme (CSP), the 589 AJAX armoured vehicles order from General Dynamics Land Systems-UK and, as explained in the official MoD statement at the end of March, the decision to "rejoin the BOXER programme

The AJAX armoured vehicle prototype on display near the future vehicle assembly site in Merthyr Tydfil, Wales. AJAX will replace the CVR(T).

and explore options to equip the army with the 8x8 troop carriers to modernise its vehicle fleet and meet the army's Mechanised Infantry Vehicle requirement." The statement added that: "The MoD is now taking forward negotiations with the Organisation for Joint Armament Cooperation (OCCAR) and Artec. Looking forward to the Assessment Phase concluding in 2019, this will consider the comparable benefits of manufacturing locations and different supply chains for BOXER, as well as value-for-money. Any deal will be subject to commercial negotiation and assessment in 2019, and the aim is to have the first vehicles in service with the army in 2023."

Survival

As previously discussed, there are four major British Army armoured vehicle programmes: CHALLENGER 2 LEP, WARRIOR CSP, AJAX and MIV. All of which appear, at least on the surface, to be highly logical and just the sort of armour capabilities that the British Army needs. The downside is that the army is still under strength, retention and recruitment are still problematic and the procurement system is still plagued with issues. While there is talk in certain political circles of the need to increase defence expenditure, very few actually expect more money to be made available. Indeed the pressure is on to save money; programmes that are not going according to plan or are becoming difficult to justify for other reasons will become increasingly vulnerable to cancellation.

Of the four armour programmes, only two can be regarded as safe and secure at this point. The first of these is the AJAX, this is a family of vehicles with 589 being acquired under a £4.5Bn contract and the vehicle entering service in 2020. The AJAX contract covers six variants: 245 AJAX reconnaissance vehicles, 93 ARES reconnaissance support vehicles, 112 ATHENA command vehicles, 50 APOLLO support repair vehicles, 51 ARGUS engineer reconnaissance vehicles and 38 ATLAS recovery vehicles. Even if the MoD wanted to, it would prove very difficult to modify the AJAX contract in any significant way at this point.

The other secure programme is MIV, the decision to rejoin the BOXER programme to meet the MIV requirement is somewhat ironic. Back in March 1998, Britain had its Multi-Role Armoured Vehicle (MRAV) requirement; it was participating in the multinational BOXER programme to meet that requirement and intended to purchase 775 vehicles. Then, in July 2003 Britain cancelled MRAV, after spending some £57M on the programme. Now, some 15 years later, Britain is back into the BOXER programme and intends to order some 800 vehicles initially and perhaps more subsequently. Admittedly, there is still much work to be done on the BOXER programme in terms of both costs and contracts, but at this point, unless something absolutely calamitous emerges, this should be a guaranteed programme.

WARRIOR (FV510) Infantry Section Vehicles with additional protection provided by the TES(H) configuration in Helmand Province, Afghanistan, in 2013.

Uncertainty

The WARRIOR CSP programme got underway in June 2009, at which point the aim was to upgrade in excess of 550 vehicles. Originally, Britain acquired 489 Infantry Section Vehicles (FV510), 84 Command Vehicles (FV511), 52 Artillery Observation Vehicles (FV514), 19 Battery Command Vehicles (FV515), 39 Recovery Vehicles (FV513) and 105 Repair Vehicles (FV512). The current declared fleet is 336 FV510/511, 44 FV514, 20 FV513 and 56 FV512. The WAR-

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RIOR CSP was awarded to Lockheed Martin in 2011 and up to 380 vehicles (in five variants) are to be upgraded.
The problem with the WARRIOR CSP is that the programme has been running late and over budget. Added to which, structural deficiencies are reportedly being identified in some WARRIOR vehicles, and this will cause further problems. All of this makes the programme vulnerable. WARRIOR CSP is one of a number of British programmes whose size and cost were predicated on the British Army adopting a particular operational/

A German Army BOXER armoured vehicle participating in an anti-tank exercise in Lithuania

organisational structure. The problem is that structure is changeable and not set in stone. As a result, the number of systems that are necessary also changes and usually the number goes down. In the context of WARRIOR CSP, you have a delayed programme that still has risk, and the possibility of the unit cost per vehicle rising as numbers are reduced. As of November 2017 the MoD had spent £381M on WARRIOR CSP, the possibility of the MoD deciding to cut its losses on this programme cannot be ruled out.
The other major armour programme is the CHALLENGER 2 LEP, and this is also potentially vulnerable on a number of different fronts; there are those who feel that a tank is too big and too heavy, and that the British Army should be a medium-weight and therefore more easily deployable force. The opposing view is that, if the British Army is to confront a 'peer' competitor, it is going to need the firepower and protection provided by a tank and for that reason the LEP programme is vital. It should also be noted that the CHALLENGER 2 LEP will only be an interim capability and that a new tank system will be needed from the mid-2030s. This explains British interest in the Franco-German Main Ground Combat System (MGCS), but here politics comes into play: attempting to join a European tank programme might not be an astute political move in domestic British terms at this point. Equally, there has been little enthusiasm in Paris and Berlin for British participation in the major Franco-German defence programmes that have emerged recently. Potentially, this could mean that Britain has to look for other partners to meet a future tank requirement.
Prior to the CHALLENGER 2 LEP, there had been numerous failed tank upgrade programmes in Britain, including the CHALLENGER Lethality Improvement Programme (CLIP) and the CHALLENGER 2 Capability Sustainment Programme (C2 CSP). However, the LEP became a reality, with five teams bidding for the programme that was aimed at providing what the MoD called a "precision direct fire manoeuvre capability across a broad spectrum of operations."
In December 2016, competitive Assessment Phase (AP) contracts for the CHALLENGER 2 LEP were awarded to BAE Systems and Rheinmetall Landsysteme GmbH. Each competitor was provided with two tanks; one of which was in operational condition, while the other was to be used for subsystem integration and testing. The plan is that the two teams will complete the AP contracts in December 2018. By that time, industry will have responded to the invitation to tender for the Demonstration, Manufacture and In-service support (DMI) contract, with the DMI proposals to be evaluated after the AP offerings have been received. After which, by mid-2019, the CHALLENGER 2 LEP contract should have been awarded.
Original planning for the CHALLENGER 2 LEP called for the programme to cover all 227 remaining CHALLENGER 2 tanks. Whether all of these tanks will actually go through the LEP process is becoming increasingly doubtful. Potentially only 170 or even fewer tanks could be upgraded. What the current, accident-prone British Government will be keen to avoid is another procurement-related scandal, and this is something that should preserve the LEP programme, although it cannot protect the number of tanks to be upgraded.
Outside of these armour programmes, there are a number of studies taking place within Active Protection Systems (APS), in both soft-kill and hard-kill formats in the UK for both tanks and other armoured vehicles. In the MEDUSA Technical Assessment Programme (TAP), the Defence Science and Technology Laboratory (Dstl), is investigating a number of APS options. As a part of this, Dstl has awarded QinetiQ a contract to evaluate an APS for armoured vehicles; this will use the Hensoldt MUSS (Multifunctional Self-Protection System), a soft-kill APS system as used on the German Army PUMA IFV. Other industrial partners in this assessment programme include Textron and Frazer-Nash.
Dstl also acquired the Rheinmetall ROSY rapid obscuring system and have tested it on a CHALLENGER 2. They have also acquired elements of the IMI IRON FIST hard-kill APS for testing on CHALLENGER 2 as well. In September 2017, Dstl placed a contract with Leonardo to participate in the Icarus Technical Demonstration Programme (TDP) to develop a Modular Integrated Protection System (MIPS). Leonardo will be responsible for the development of an MIPS Electronic Architecture (EA). According to Dstl, the MIPS EA will: "provide a common infrastructure that will deliver UK operational sovereignty and enable 'best of breed' commercial off-the-shelf APS sensors and countermeasures to be selected, integrated and deployed to defeat a wide range of current and future battlefield threats." Leonardo has listed their industrial team for Icarus as: BAE Systems, Lockheed Martin UK, Ultra Electronics, Frazer-Nash, Vetronics Research Centre, Abstract Solutions, Roke Manor Research and SCISYS. Dstl is also working on a number of other APS developments with both domestic and foreign partners. ■

Wave of the Future?

Hybrid and Electric Drive for Armoured Combat Vehicles

Sidney E. Dean

Electric drive and hydrogen-electric fuel-cell based hybrid drive have become a technically and economically viable power source for civilian passenger and commercial vehicles. Armed forces are increasingly looking to introduce this cutting-edge technology into their own fleets. Diesel-electric hybrid drive is also under serious consideration.

Electric drive: An electric drive system is powered by high-capacity battery packs which are connected to drive units mounted directly in the wheel hubs, eliminating the need for heavy and bulky mechanical drive shafts ("drive-by-wire"). While the battery packs themselves tend to be heavy, the elimination of the mechanical transmission system can balance out the additional burden. Batteries must be charged from an external generator or power grid. Electric drive vehicles currently have a shorter operational range than conventionally powered vehicles.

Hybrid drive: A hybrid drive system consists of an on-board power source which activates on-board electric generators. These generators in turn are linked via cable to electric drive units mounted directly in the wheel hubs, again eliminating the need for a mechanical transmission system. The most frequently considered power sources are diesel engines ("diesel-electric hybrid drive", although any internal combustion engine type is feasible) and hydrogen fuel cells ("hydrogen-electric hybrid drive"). Hybrid systems generally offer an operational range comparable with conventional combustion engine propulsion systems.

Currently the focus is on military utility vehicles which are, for all intents and purposes, rugged counterparts of civilian trucks. However, there is considerable interest in eventually replacing the diesel engines of heavy Armoured Combat Vehicles with electric or hybrid propulsion systems. Electric or hybrid drive would have several advantages over the current hydrocarbon-based propulsion:

Author

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Graphics: US Army

The Next-Generation Combat Vehicle which the US Army hopes to field in the 2030s is expected to have electric or hybrid drive.

- instantaneous high torque for improved acceleration and potentially improved speed;
- improved manoeuvrability for 6x6 and 8x8 vehicles, as the hub-mounted electric motors allow the driver to adjust the rotation speed of individual wheels;
- lower propulsion system weight;
- fewer moving parts to maintain;
- stationary on-board power generation (enabling operation of additional electronic systems including directed energy weapons, active protection systems and electronic warfare suites);
- on-board water generation;
- less danger of explosion or fire if hit by enemy ordnance;
- significantly reduced thermal and acoustic signature, and no visible exhaust (all-electric and hydrogen-based hybrid systems);
- in some instances significantly reduced logistics footprint.

Industry and armed forces of numerous nations are pursuing or investigating next-generation propulsion concepts for armoured combat vehicles. include the following:

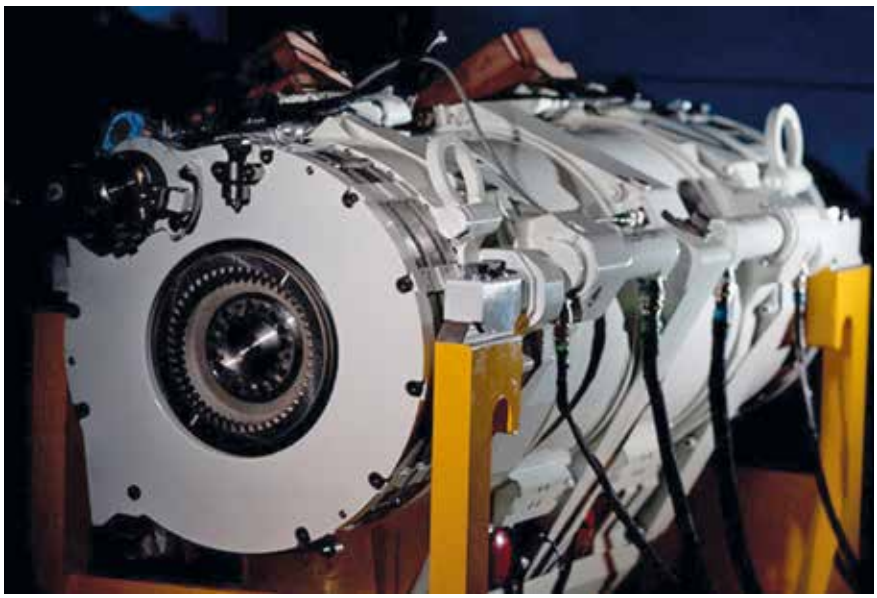
United States

The United States Army experimented with electric drive options for the Abrams Main Battle Tank (MBT) as early as 2010; even earlier (2003-2009) the Army envisioned its abortive Future Combat System vehicles to all be equipped with hybrid diesel-electric propulsion systems. While the concept of electric/hybrid drive appeared promising, the technology at that time proved to be too immature. But that is changing, according to Donald Sando, head of the Capabilities Development and Integration Directorate of the Army Manoeuvre Centre of Excellence (AMCE) at Fort Benning, Georgia.

Speaking at the Association of the US Army (AUSA) annual convention in October 2017, Sando declared that the Next-Generation-Combat Vehicle (NGCV), which is expected to become a family of armoured combat vehicles replacing both the M2 BRADLEY IFV and the M1 Abrams MBT, is likely to run with electric motors and high-capacity batteries capable of being recharged with 10 kW to 50 kW generators. "That's a generational change. And we're going to do it," Sando said. "If

they're not electric or hydroelectric [that is, hydrogen fuel-cell driven] then I'm wrong." During the same presentation he categorically ruled out retrofitting current combat vehicles with an electric propulsion system.
Major General Cedric Wins, commander of the Army Research, Development and Engineering Command (ARDEC), agreed with Mr. Sando's assessment. Also addressing the AUSA convention, Wins spoke in terms of 15-20 years for fielding. In fact, the NGCV is still in the early planning phase. Concept demonstrators have been ordered but will not be delivered until 2022. Over the next six years, various technologies will be explored for their suitability on the NGCV. Proposals include hydrogen fuel-cells and all-electric propulsion systems. "There is a huge amount of investment that would have to occur in research and development" before electric or hybrid powered armoured fighting vehicles could become operational, Wins cautioned.
Both Sando and Wins pointed to private industry's advances in alternative propulsion systems, and they clearly stated that the military intends to capitalise on that expertise. Put another way, the army does not plan to lead the R&D efforts itself, but will rely on and coordinate with industry to determine which civilian developments can be adapted to military requirements. "It's hard to believe that if industry moved in the direction of electric-powered vehicles, that the army would not be somewhere near there," General Wins said at the AUSA convention.

Photo: QinetiQ



The E-X-DRIVE hybrid propulsion system for tracked vehicles

United Kingdom

In the United Kingdom, QinetiQ and BAE Systems have partnered to continue developing and marketing the E-X-DRIVE (a hybrid-electric drive transmission designed for tracked military vehicles up to and including 70+ tonne MBTs) and QinetiQ's HUB-DRIVE Unit (designed for wheeled armoured vehicles). QinetiQ has been pursuing the technology since 1999, and provided it to the US Army for testing in 2012.
The E-X-DRIVE and HUB-DRIVE concepts call for replacing the standard diesel engines of armoured vehicles with on-board diesel generators to produce electricity. The drive shafts, differentials and transmission systems would be replaced by compact electric motors. The design significantly reduces weight while improving torque and vehicle mobility and "potentially" fuel economy. According to QinetiQ, the HUB-DRIVE in its current configuration could be retrofitted on all operational 8x8 armoured vehicles. Be eliminating the need for the current under-vehicle drivetrain, the technology would allow greater flexibility when designing next-generation vehicles. In 2015 and 2016 the Pentagon's Defense Advanced Research Projects Agency (DARPA) awarded QinetiQ contracts to make the firm's hybrid drive available for the agency's Ground-X Vehicles Technologies (GXV-T) programme. The GXV-T programme, in DARPA's own words, "seeks to disrupt the current trends in mechanised warfare" by identifying technologies to radically improve mobility and survivability of armoured fighting vehicles while simultaneously reducing weight and signature.

Sweden and Finland

An early attempt to field tactical vehicles with hybrid drive is Sweden's SEP armoured vehicle series developed by BAE Systems Hägglunds. Testing began in 2000 on a tracked variant, and in 2003 on the 8x8 armoured personnel carrier. The vehicle is outfitted with two Steyr diesel engines which are connected to ZF electrical generators. The generators are connected by cable to the electric motors embedded in each wheel hub. When the SEP is not in motion, the generators charge the vehicle's batteries. When switching to battery power, the SEP can run in silent mode. Another advantage of the system is reduced diesel fuel consumption, as the SEP runs part of the time on electric drive. However, the SEP was cancelled in 2008. Notably, the Ministry of Defence explained the decision with the high cost of developing the SEP

Photo: US Army

All manned vehicles of the proposed Future Combat System were to be equipped with hybrid drive. The programme was terminated in 2009 over cost issues and technical difficulties, not specifically related to the drive concepts.

without at least one foreign partner; had Britain joined the programme as originally expected, Stockholm would have procured the hybrid-drive vehicle. The Swedish Army ended up buying the Finnish-built BAE Patria AFV and the Patria Combat Vehicle 90, both with conventional diesel engine propulsion.

Israel

Outside Europe and North America, Israel is a leader in hybrid propulsion research and development. The Israeli Defence Force (IDF) is currently pursuing Project Carmel, a technology demonstrator for a next-generation light tank to be fielded in the late 2020s. According to IDF Brigadier General (retired) Didi Ben-Yoash, who now runs Project Carmel, hybrid drive is considered essential for the new tank. Details of the system are still under development. At this point observers speculate that the hybrid drive will be of the diesel-electric variety rather than hydrogen-electric.

Epsilor Electric-Fuel, an Israeli subsidiary of US-based Aerotech, is currently developing enhanced battery solutions for the Merkava IV MBT deployed today. These new lithium-ion batteries have three times the energy-density of currently employed lead-acid batteries, yet retain the standard T6 form employed in heavy armoured vehicles. These new batteries are primarily designed to enable extended silent watch operations (during which the tank shuts off its engine but continues to run sensors and other electrically powered equipment) by today's generation of heavy tank. However, Epsilor and numerous other companies are constantly pursuing greater efficiencies. Lithium-ion batteries' cost per kilowatt-hour has dropped by sixty percent over the past five years, said Epsilor's vice-president for marketing, Felix Frisch; during the same timeframe the energy density of lithium-ion batteries has improved by 35 percent. If this trend continues at the same pace, battery technology will be well positioned to support hybrid-drive armoured combat vehicles in the next decade. "Militaries that embrace this revolution early on will be the first to benefit from the way electric power can be used to change the way armoured vehicles are used and supported in the field," Frisch said during a manoeuvre warfare conference in May 2017.

China

China is developing an as yet unidentified (in the West) state-of-the-art Infantry Fighting Vehicle which is thought to have a hybrid propulsion system. Presumably being developed by NORINCO, The new IFV – presumably being developed by NORINCO – might be the unidentified new armoured vehicle whose photo was posted on the CJDBY website in February 2017. The Chinese Army has been experimenting with non-conventional drive for some time, including testing of an MBT prototype dubbed the T-95E circa 2010. Based largely on the abortive Russian T-95, the T-95E featured a hybrid diesel-electric drive; lessons from that testing programme will have supported the current IFV development.

Photo: BAE Systems

BAE Systems has partnered with QinetiQ to market hybrid propulsion systems for armoured fighting vehicles. BAE Hägglund's SEP armoured vehicle, shown here in the tracked configuration, was developed in 2004 with an optional diesel-electric hybrid drive.

Logistics impact

Despite the promised performance enhancement of electric and hybrid systems, it is the logistics aspect which is receiving the most attention. Advocates of new propulsion systems stress the benefits of eliminating the reliance on hydrocarbon fuels such as diesel and J-8. Main Battle Tanks (MBTs) and Infantry Fighting Vehicles (IFVs) are the most fuel-intensive ground vehicles. For example, a single M1 ABRAMS MBT requires nearly two gallons per mile travelled. A company of 14 M2 BRADLEY IFVs consumes 2,300 gallons of fuel daily during operations in rugged terrain, according to a US Army logistics forecasting model published in 2016. Over the past two decades heavy brigades have repeatedly stalled in combat zones because they had outrun their supply vehicles and had to wait for fuel. The other side of this coin: a significant percentage of coalition casualties in Afghanistan and Iraq were suffered by supply convoys. Reducing or eliminating the reliance on diesel fuel would enhance operational flexibility and reduce risk.

On the other hand, switching to a hydrogen-based hybrid propulsion system could conceivably even complicate battlefield logistics, at least in some theatres. Diesel can be procured from local suppliers almost anywhere; liquid hydrogen for hybrid-driven tanks would, by contrast, have to be shipped into some regions. As an alternative the military could set up in-theatre facilities to extract hydrogen from military grade fuel, but this would be a new logistical burden, and would still require convoys to supply the operational vehicles in the field. Likewise, purely electric vehicles would require access to an established power grid, or would require mobile generators (and the fuel to operate them) to accompany combat units. Establishing a power grid in underdeveloped and hostile terrain could end up dwarfing the logistical and engineering challenge of establishing fuel depots and convoys.

Perhaps this is why acceptance of non-traditional drive concepts for heavy armoured vehicles has remained slow. STK's TERREX Armoured Fighting Vehicle, in production since 2006, was originally designed with an optional hybrid drive system; neither Singapore nor Indonesia nor Turkey were interested, opting instead for conventional diesel propulsion. More recently, in 2015, Turkey's Otokar proposed an electric drive for Ankara's new Altay MBT. The Turkish Army preferred to stay with a tried-and-true conventional drive system, which Otokar is now offering in its 2017 bid for the Altay development project. And in 2013 BAE's platform manager for the CV90 stated that his firm was considering upgrading that vehicle to a hybrid drive, both in order to reduce fuel consumption and to enhance performance; however, no decisions have been announced to date. Until laboratories demonstrate battery packs and hybrid systems with greater efficiencies, most Western armed forces will be wary of experimenting with promising but unproven battlefield technology. It seems that China, and perhaps Israel, appear more willing to accept the risks in order to reap the tactical advantages the new technology purports to offer. ■

Surviving the Blast

MRAPs and Lessons Learned from the Mine and IED Threat

John Antal

Mines and IEDs kill and wound more soldiers on today's battlefields than any other weapon. Armoured vehicle designers have therefore drawn important lessons for the development of Armoured Fighting Vehicles (AFVs) concerning crew survivability.

Technology changes warfare. In the past 17 years of war, the US and its NATO allies have been fighting against the never-ending threat from mines and Improvised Explosive Devices (IEDs). If this threat was from mechanically activated mines and IEDs, much like the pressure or tilt-rod mines of WWII and the Cold War, the legacy set of equipment developed in the late 20th century could have handled the challenge. As it was, the exponential commercial development of mobile communications and the miniaturisation of components that occurred in the past 20 years has created a perfect blast storm that made most of the deployed military systems vulnerable. The result was a rush to retrain soldiers to deal with the threat and then a heroic effort to enhance vehicle protection. Vehicle protection was upgraded primarily by adding more steel to existing vehicles, then by fielding special Mine Resistant Ambush Protected vehicles (MRAPs), and also by adding electronic systems to find and jam command-detonated mines and IEDs.

New threats are emerging as the US and NATO focus on challenges from near-peer competitors. As armies consider how to develop the next generation of combat vehicles, the lessons of the past two decades are being assimilated. Armoured vehicle designers understand that mines and IEDs kill and wound more soldiers on today's battlefields than any other weapon. They also know that the development and employment of MRAPs on the battlefields of Iraq and Afghanistan have generated significant lessons learned with regard to crew survivability for Armoured Fighting Vehicle (AFV) design. As the US and NATO contemplate the development of the next generation of combat vehicles, these lessons are being incorporated into new designs. Let's review some of the best armoured vehicles to see how the mine and IED threats are being addressed.

Photo: US Department of Defense

A US Army paratrooper takes cover from behind a MAXXPRO MRAP as he fires his M4 carbine at insurgents during a firefight in Afghanistan's Ghazni province, 30 June 2012. MRAPs address the threat of mines and IEDs in combat in Iraq and Afghanistan.

Author

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MRAPs

Cougar

The US military spent nearly US$50Bn to quickly field 29,000 MRAPs for service in Afghanistan, Iraq and Syria. The advanced ballistic and blast-protected COUGAR provided much of that capability. The COUGAR MRAP is touted as the most survivable MRAP on the market. It is produced by General Dynamics Land Systems. The COUGAR comes in two main configurations: Category I (4x4 wheel) and II (6x6 wheel) versions. The COUGAR 4x4 can transport 6 soldiers while the COUGAR 6x6 can seat 10 combat-equipped soldiers. The COUGAR's anti-mine, anti-IED capabilities are significant and include a "V" shaped hull; the ability to add side armour to inhibit mine and RPG attacks; ballistic glass to provide vision for troops to see and engage enemies through the gun ports in the glass while not exposing themselves to fire; multi-point, racing style harnesses to allow crewmembers to better survive a roll-over; internal fire extinguisher systems; and the ability to support electronic countermeasures including

the AN/VLQ-12 CREW DUKE V3 counter remote-controlled IED (RCIED) electronic warfare system, which neutralises electronically activated, remote-controlled road-side bombs and IED attacks.

MAXXPRO

The MAXXPRO MRAP was designed by International Truck, Navistar Defense, in cooperation with the Israeli Plasan Sasa, who designed the state-of-the-art lightweight ballistic protection and survivability armour. MAXXPRO can survive a 7 kg (15 lb) land mine blast without any injuries. The MAXXPRO's anti-mine, anti-IED capabilities are significant and include ballistic glass protection; roll-over harnesses; add-on armour capability; and can support counter RCIED electronic jammers. The MAXXPRO comes in two categories: the MAXXPRO Dash (Category 1) and the MAXPRO Plus (Category 2). The MAXXPRO has a V-shaped hull and a two-piece design that adds to crew and vehicle survivability. To date, Navistar has produced seven MAXXPRO variants under contract: the original MAXXPRO, MAXXPRO Air Force, the MAXXPRO Plus with improved protection, MAXXPRO ambulance (production orders were for the

Photo: Spc. Elisabeth Freeburg / US Army

The M-ATV (Mine-Resistant, Ambush-Protected All-Terrain Vehicle), built specifically for the mountainous Afghan terrain, parks next to the larger MAXXPRO DASH MRAP. The first M-ATVs designated for Afghanistan arrived at Kandahar Airfield by air transport on 22 October 2009.

Dash variant), MAXXPRO MEAP (MRAP Expedient Armor Program), the MAXXPRO Dash for Afghan operations, and the MAXXPRO Recovery Vehicle (MRV), for recovering stuck vehicles. The firm has also developed a cargo flatbed and tractor (18-wheeler truck's front end, but with mine protection) variants. The MAXXPRO's "V" shaped hull "does a very good job of redirecting energy," reported Bob Walsh, the Vice President and General Manager of Navistar Defense, LLC. Walsh also remar-

ked that the MAXXPRO is easier to repair than many other MRAPs: "Being cab-on-chassis, you're able to pull off this body and slide a new chassis in." In September 2017, Navistar Defense was awarded a US$29.6M federal contract by the US Army Contracting Command for system sustainment and technical support services for the in-production and out-of-production Mine Resistant Ambush Protected MAXXPRO family of vehicles.

L-ATV (Light Combat Tactical All-Terrain Vehicle)

In spite of their success, many MRAPs are often criticised for their size and lack of manoeuvrability. Recognising the need to protect from mines and IEDs, the US military needed a wheeled vehicle built like a tank, but with lower weight and greater manoeuvrability that could run like a HMMWV. The answer was the L-ATV (Light Combat Tactical All-Terrain Vehicle) by Oshkosh. In 2015, the US military selected Oshkosh to produce the L-ATV. This vehicle carries four combat-equipped soldiers, has improved mobility and protection, including blast protected seats for the crew. According to Oshkosh: "The L-ATV's armoured capsule is scalable and can accept multiple armour configurations to protect troops from IEDs and today's other prevalent battlefield threats. The capsule is optimised for protection, weight and mobility, and its modular and flexible design allows the vehicle to accept a greater range of upgrades and continuous enhancements. The protection system can withstand underbelly blasts. The L-ATV can accept add-on armour packages and a host of counter RCIED electronic systems to operate according to the mission requirements." The basic L-ATV has no armament, but the vehicle can be fitted with a wide array of machine guns, grenade launchers, and smoke dispensers. Oshkosh was awarded a US$6.75Bn low rate initial base contract with eight option years to procure the first 16,901 vehicles for both the army and Marines. According to the study "Joint Light Tactical Vehicle (JLTV): Background and Issues for Congress, by Andrew Feickert", the Oshkosh L-ATV "offers protection levels greater than those of up-armoured HMMWVs and comparable to those of original MRAP class designs, but in an overall vehicle package that is considerably smaller and lighter than vehicles procured under the US Marines MRAP procurement."

Wescom Defence's Portable Explosives Minefield Breaching Systems (PEMBS)

(ck) Unconventionally deployed mines, booby-traps, unexploded ordnance and man-made obstacles are designed to bring military operations to a standstill. Portable Explosive Mine Field Breaching Systems (PEMBS) are designed to mitigate these threats and are an effective means to safely eliminate them. PEMBS are also used for humanitarian de-mining.

A minefield is designed to create an obstacle which will take out the momentum of movements of military forces. To maintain the advancement of troops and avoid rerouting the troops to a position that could favour the enemy forces, a fast and effective way to overcome minefields is essential in combat.

Wescom Defence's Portable Explosives Minefield Breaching Systems (PEMBS) offer a quick and effective way to safely eliminate deployed land-mines as well as man-made obstacles, such as triple barbed wire. These systems are categorised into Heavy Portable Systems, Light Portable Systems and Heavy Duty Portable Systems.

PEMBS feature a detonating cord with a package of explosives contained in either one or two rucksacks which is deployed across the chosen area by means of a rocket. Products from WesCom include the Heavy Portable Explosive Minefield Breaching System (H-PEMBS), which features a rocket projected detonating cord, attached to containers filled with high explosives. The detonation creates a clearly visible path (approx. 55 metres) through a minefield. There is a Light Portable Explosive Minefield Breaching System (L-PEMBS) alternative, which leaves a footpath of approximately 74 metres after detonation and a Heavy Duty version – the Heavy Duty Portable Minefield Breaching System – which is manufactured with a rocket projected detonating cord, designed like a rope ladder. For this product, metal tubes are filled with highly explosive material and after detonation form a path up to 80 metres wide through the minefield.

Ongoing training is essential for effective use. WesCom Defence offers a selection of appropriate training products, including the Training Heavy Portable Minefield Breaching System (THPEMBS), which can be re-used several times in practice. A version of the lightweight portable system is also available as a training system - the Training Light Portable Minefield Breaching System (TLPEMBS) - and a Training Heavy Duty Portable Minefield Breaching System MRL80.

The portability and the simplicity and effectiveness of these systems make PEMBS a suitable tactical solution for major battlefield threats.

WesCom Defence, part of WesCom Signal and Rescue, is a world-renowned specialist in pyrotechnic products for signalling, illumination, training and simulation. Thanks to the company's experience and extensive production capacities, WesCom Defence can develop tailor-made pyrotechnic products for the defence industry based on the latest developments in pyrotechnic technology. For more information about WesCom Defence, to see the full range of products and product capabilities, or to contact the company, please visit: **www.wescomdefence.com**

Infantry Fighting Vehicles (IFV)

T-15 ARMATA BMP

Russian developers at Uralvagonzavod have taken notice of the counter-mine and counter-IED strengths of MRAPs and, using their previous experiences in Afghanistan and Chechnya, are building new capabilities into their advanced IFV designs. The T-15 BMP (Боевая Машина Пехоты, or BMP, stands for IFV) uses the same chassis as the T-14 ARMATA Main Battle Tank. It is expected to replace the BMP-2 IFV and MT-LB Armoured Personnel Carrier (APC) in the Russian Army. The T-15's engine is located in the front of the hull to allow an infantry squad to be carried under armoured protection in the back of the vehicle. The T-15 BMP three-man crew sits in a protective capsule in the hull behind the engine, but forward of the remote-controlled turret. The T-15 includes the Malakhit dual-layered reactive armour and active and passive protection systems, and special paint to reduce its infrared signature and provide enhanced stealth. The T-15 also includes a reinforced hull for counter-mine and counter-IED protection as well as an electronic jamming system to neutralise radio-controlled anti-tank mines and command detonated IEDs.

NAMER Heavy APC and IFV

The NAMER is an Israeli Ordnance Corps-made Heavy APC that is based on the MERKAVA 4 Main Battle Tank chassis. Developed in 2008, the NAMER is a major part of the Israel Defence Force's (IDF) modernisation plan and saw combat with the Golani Brigade during the 2014 Gaza conflict. In Hebrew, NAMER means Leopard and also serves as an abbreviation for "Nagmash" (APC) and "Merkava" (Tank). The NAMER weighs 60 tonnes

Photo: Ishaiabigail

The NAMER is an Israeli-made armoured fighting vehicle based on the MERKAVA tank chassis that is used by the Israeli Defence Forces. In 2012, the NAMER was tested by the US Army at the Maneuver Battle Lab's Ground Combat Vehicle assessment at Fort Bliss, Texas.

and has a crew of three positioned in the hull. The NAMER can be equipped with a number of different automated turret systems, and in 2017 the Israeli Defence Ministry unveiled an IFV version fitted with an unmanned turret armed with a 30mm cannon and the ASPRO-A TROPHY Active Protective System (APS) to defeat incoming projectiles. The combat-proven TROPHY APS, developed by Rafael Advanced Defense Systems Ltd., provides all-around coverage against RPGs, anti-tank missiles and tank HEAT (high-explosive anti-tank) rounds. Once the TROPHY system detects a threat, it automatically tracks, classifies the threat, determines the best intercept point, and then launches a countermeasure. The Israeli-made 4th-generation SPIKE tandem warhead anti-tank missile can also be added for the IFV configuration. The NAMER has a specially designed V-hull belly armour pack and electronic counter-mine and counter-IED systems can also be added. In 2012, the US Army considered the NAMER for the Ground Combat Vehicle (GCV) programme and tested the vehicle at Fort Bliss, Texas, but the GCV programme was cancelled in 2014. Undaunted, the Israelis continue to praise the NAMER and in 2015, Israel's MoD stated: "The NAMER is considered to be the most protected armoured combat vehicle in the world, which proved its abilities during fighting in Operation Protective Edge against many threats."

KF41 LYNX IFV

The Rheinmetall LYNX KF41 (KF stands for "Kettenfahrzeug", or tracked vehicle in German) is a German-made next-generation family of vehicles that offers state-of-the-art firepower, mobility and protection. The LYNX consists of a modular design that comes in two primary versions: the KF31 and KF41. Both versions have a driver in the hull and a two-man crew in the turret. The engine is in the front and the exhaust in the rear. Weighing up to 38 tonnes, LYNX KF31 can seat 3+6 soldiers. LYNX KF41 is slightly larger and can carry 3+8 soldiers. Rheinmetall's LANCE turret for the KF41can support a 30mm or 35mm cannon and the turret ammunition is separated from the crew for added protection. Both versions can be configured for IFV, C2 (command and control), reconnaissance, repair and recovery, and ambulance variants. The vehicle interior has a spall liner, decoupled seats, and mine and IED protection packages that can be exchanged in the field. The KF41 does not have a V shaped hull, but its mine protection is highly effective against heavy blast mines, explosively formed projectile mines and IEDs. The KF41 also has passive and reactive systems to defeat rocket-propelled grenades and antitank guided missiles and provides roof protection against cluster munitions. Rheinmetall's SOLAR SIGMA Shield Mobile Camouflage System can also be fitted to the entire vehicle to reduce heat loading as well as thermal and IR signatures.

Main Battle Tanks

T-14 ARMATA

The latest Russian-made tank, the T-14 ARMATA (Армата), is an innovative, fifth-generation, main battle tank that represents a technological leap in manned-tank design. The ARMATA's weaponry and armour have been maximised for open combat, and much of its new technology is truly impressive. It appears that the Russians have taken the mine and IED threat seriously in the design of the T-14. The tank is modular and divided into three compartments: a forward crew area; a remote-controlled unmanned-turret positioned on top of the hull configured with a 125mm 2A82-1M smoothbore cannon with a 45-round automatic loader; and the engine is at the rear of the tank. The three-man crew sits in an armoured capsule composed of the equivalent of 900 mm of Rolled Homogeneous Armour (RHA). The tank's millimetre-wave radar and Active Protection System (APS) empower the ARMATA to automatically detect, track, and intercept incoming kinetic and tandem anti-tank munitions. Unlike legacy tanks in the NATO armies, stealth technology has been built into the design to generate reduced visibility and "dynamic signature changes" in the radio, infrared, and magnetic bands. This feature is reported to inhibit recognition of the tank's systems. Russian Uralvagonzavod officials, who built the tank, claim that the ARMATA is "invisible to radar and infrared detection due to radar-absorbing paint and the placement of components with heat signatures deep within the hull." The tank is also capable of generating a multispectral smoke screen in the infrared and millimetre wavelengths to conceal the tank from enemy weapons. These capabilities combine to hide the ARMATA and could inhibit targeting and the timing of command-detonated mines and IEDs. To compensate for the flat hull, the ARMATA has additional armour plate in the hull for counter-mine and counter-IED protection. Although untested in combat and with fewer than 100 systems to be deployed to the Russian Army by 2020, the ARMATA appears to be a formidable next-generation tank design that NATO armies can learn from to develop their own next-generation combat vehicles.

M1A2 SEPV3

The M1 ABRAMS Main Battle Tank has been the cornerstone of the US Army and US Marine Corps' ability to fight combined arms warfare since the early 1980s. The US Army deployed M1 Tanks to Iraq, but not to Afghanistan. The US Marines used M1 Tanks in both Iraq and Afghanistan. In Iraq and Afghanistan several M1 Tanks were disabled due to mines or IEDs.
To counter the mine threat, a variant of the M1 Tank, the M1150 Assault Breacher Vehicle (ABV), nicknamed "SHREDDER", was developed as a mine- and explosives-clearing vehicle and equipped with a mine-plough and explosive line charges. The US Marines used the M1150 SHREDDER in Southern Afghanistan in 2010 with great success. In 2013, the US Army deployed six SHREDDERs to Korea to the 2d Infantry Division, but there are only a handful of these special tanks. The major challenge for the army and Marine Corps is how to upgrade new versions of the M1 to keep the tank fleet relevant in view of the extensive mine and IED threat. The M1A2 SEPV3 (Systems Enhanced Package Version 3) is the answer to this question and the latest adaptation of the M1 series tank. The M1A2 SEPV3 has significant upgrades that include enhanced fire cont-

rol, power generation, and improved crew protection. Learning from mine and IED attacks in Iraq and Afghanistan, the developers of the M1A2 SEPV3 have increased the tank's passive defence by adding a new armour package for the hull and turret. In addition, the M1A2 SEPV3 has the AN/VLQ-12 CREW DUKE V3 counter

Photo: Staff Sgt. Timothy R. Koster / US Army

US Army M-ATV MRAPS at the demarcation line outside Manbij, Syria, in July 2018

remote-controlled IED (RCIED) electronic warfare system. This state-of-the-art jamming technology is the latest version of the RCIED system used on MRAPs in Iraq and Afghanistan and employs an advanced software-defined architecture that supports rapid reconfiguration to adapt to the constantly evolving threat environment. In 2015, the US Army provided US$92.2M to General Dynamics Land Systems to upgrade its M1A2 SEPV2 ABRAMS tanks to the M1A2 SEPV3 configuration. The first ABRAMS M1A2 SEPV3 initial production vehicle was delivered to the US Army in October 2017. Also that October, General Dynamics Land Systems received a US$270M contract from the US Army Tank Automotive Command to manufacture 45 ABRAMS M1A2 SEPV3 tanks. Unit fielding is expected to begin in 2020. "These vehicles are not just about assuring our allies, or deterring or coercing potential adversaries," Maj.Gen. David Bassett, program executive officer for Ground Combat Systems said in an October 2017 interview. "They are about compelling our enemies and winning the multi-domain battle." With these developments it appears that the US military is adapting its legacy M1 tanks with the lessons of mine and IED combat in Iraq and Afghanistan in mind.

LEOPARD 2

The German built LEOPARD 2 Main Battle Tank was produced in the 1970s by Krauss-Maffei, now Krauss-Maffei Wegmann (KMW), of Munich, Germany. KMW developed a mine-protected tank version in July 2004 with a kit that consists of add-on armour that includes a new armoured plate to reinforce the hull against mines and IEDs. Tests conducted in February 2004 demonstrated that the new LEOPARD 2 armour package successfully protected the tank crew from the detonation of an anti-tank mine under the tank. A small number of LEOPARD 2 A4Ms were deployed by Canadian, Danish, and German NATO forces to Afghanistan with success. Several of these LEOPARD 2s were damaged by mines and IEDSs but were repaired. The greatest shock to the LEOPARD's counter-mine and counter-IED reputation occurred in 2016, when 10 Turkish Army LEOPARD 2A4 Tanks (older export versions without some of the countermine upgrades) were destroyed in combat during Operation Euphrates Shield. The Turkish LEOPARD tanks were ambushed by ISIS fighters using a combination of mines, IEDs and anti-tank missiles at al-Bab, in northwest Syria. ISIS took photos of the destruction and posted them to their social media sites to brag about the destruction of Germany's "best" tank. To address this challenge and upgrade the tank for use by the Bundeswehr, Rheinmetall has produced a new LEOPARD 2A7V configuration (V stands for improved). The LEOPARD 2A7V has new state-of-the-art capabilities to meet emerging threats in Europe and includes upgraded protection to address the mine and IED challenge. The LEOPARD 2A7V model is equipped with a modular protection kit with passive armour modules to provide 360° protection to the crew from anti-tank missiles, rocket-propelled grenades (RPGs) and reinforced hull shielding to protect against mines and IEDs. In September 2017, Rheinmetall was awarded €118M to upgrade 104 LEOPARD 2s for the Bundeswehr to LEOPARD 2A7Vs. The new LEOPARD 2A7V will enter service between 2019 and 2023.

Attack from below is only part of the problem to countering mines and IEDs. Attack from the top is the next big challenge to address in the development of Next Generation Combat Vehicles. For example, the Russian military is developing a top-attack antitank mine designated as the PTKM-1R. The PTKM-1R mine is a green cylinder the size of a fire extinguisher that weighs close to 20 kg and is designed, according to the Russians, to create an impenetrable minefield. The PTKM-1R is similar to the US Textron Defense Systems M93 HORNET Wide Area Munition (WAM) and represents the new capability of top-attack smart mines.

Conclusion

Surviving the blast has become a prerequisite for next-generation armoured vehicle design and should not be considered just a special case for counterinsurgency (COIN) operations. MRAPs have saved many lives, but they are predominantly wheeled vehicles and primarily defensive. Modern armies will not employ MRAPs as they do tanks and IFVs in combined arms combat against a peer-adversary. MRAPs are only armoured trucks that have limited offensive capability for high-intensity operations. As heavily armoured troop carriers, MRAPs do not meet the requirements of the new mission set emerging in Europe and Asia. As new, smarter mines are developed – consider the development of the Russian top-attack smart anti-vehicle mine PTKM-1R – the ability to counter the mine and IED threat becomes even more important. Most legacy AFVs are not designed with robust active or passive counter-mine or counter-IED capabilities. Reinforcing existing hulls with new materials such as the new "Super Bainite" steel may provide a solution for legacy vehicles, but the cost of new materials technology and the simple physics of armour versus counter-armour makes a "silver bullet" solution unlikely. Passive and active counter-mine and counter-IED systems, as well as stealth, should be considered as an integral part of next generation combat vehicles. Armoured vehicles have a long shelf-life as few militaries can afford to start over with totally new systems. The design of the next generation of combat vehicles, either manned or unmanned, must incorporate the lessons learned from the past 17 years if vehicles and crew members are to survive the blast. ■

Countering IEDs

New Developments or More of the Same?

Dan Kaszeta

IEDs are usually a cheap and primitive threat, but that's why they're dangerous, because they are widespread and can be manufactured and planted quickly. There is a range of countermeasures from very low to very high technology. For every high-tech widget in the Counter-IED box there is a torch, a shovel and a wheelbarrow that are probably just as useful.

Threats from improvised explosive devices (IEDs) are not a new phenomenon. They have existed in one form or another since the advent of gunpowder. Indeed, the UK has an unofficial holiday (Guy Fawkes Day), which commemorates an unsuccessful IED incident in 1605. The various post 9/11 conflicts, principally but not exclusively the wars in Iraq, Afghanistan, Syria, and Yemen have seen large numbers of IEDs used in asymmetric warfare against both military and civilian targets. IED casualties have been an important factor in these conflicts. International and domestic terrorists make frequent use of IEDs to further extremist agendas. Consequently, governments have spent large amounts of money to counter the IED threat.

Counter-IED Operations

Counter-IED (C-IED) operations include a broad range of disciplines, including search operations, intelligence, combat engineering, and explosive ordnance disposal (EOD), to name only a few. Also, C-IED is related to, but distinct from, traditional countermining operations (mines are not improvised) and disposal of ordnance that did not function (these are malfunctions, not intended devices). Many of the products and technologies from one discipline are used by the other.

However, mine warfare and demining are somewhat beyond the scope of this article. The threat from IEDs can be described as a largely low-technology threat which is combated with a spectrum of countermeasures ranging from very low technology to very high technology. Much of the defence media world obviously focuses on the high technology products now available, but much of the counter-IED world is basically low-tech. For every high-tech widget in the EOD team's truck, there is a flashlight, a shovel, and a wheelbarrow, which likely get at least as much use. So, therefore, the role of simple everyday items in counter-IED work should not be forgotten. However, this article seeks to provide an overview of new developments in the field.

Author

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Philosophy

An overarching development has been the evolution of a philosophical framework. Finally, one important development has been philosophical. The major western militaries and their security services now tend to look at the IED threat as a system. The use of IEDs involves a variety of activities ranging from procurement of materials and production of devices, through reconnaissance and target selection, placement, and detonation of the device. A comprehensive counter-IED strategy looks at every part of this operational cycle or system and plots to disrupt any plotted use of IEDs.

A large part of the effort to disrupt, deter, or prevent IED employment, across the full "system" involves intelligence efforts, traditional security disciplines, diplomacy, and law enforcement. These efforts occur, by necessity, well before the construction and emplacement of devices. While much of this work is, by necessity, very sensitive, a number of tools and products are marketed to aid these activities. Numerous software tools are aimed towards the C-IED market. Indeed, these are too many to mention. Some are proprietary tools developed within government organisations. Commercial products are available as well. One that keeps appearing in the European space is iThink, a product by Indra (Spain). Also of note are information-sharing efforts such as the EU's Bomb Data System, which is funded by member states specifically for sharing information on IEDs.

Electronic Countermeasures

IEDs need some mechanism to cause them to function. A wide variety of means have been used to set off IEDs, including radio communications (especially mobile phones), wire, timing, and various types of sensors ranging from crude booby-traps to sophisticated repurposing of intrusion detection technology. An entire discipline of electronic countermeasures has arisen around the overall goal of disrupting the radio communication used to detonate an IED. A typical device might include a mobile phone or something less sophisticated such as a

Photo: Harris

The Harris CREW Vehicle Receiver/ Jammer (CVRJs) is a vehicle-mounted electronic jammer designed to prevent the detonation of IEDs, which are often triggered by off-the-shelf technology like mobile phones. CVRJ counters existing and evolving Radio Frequency (RF) threats by jamming transmitted RF signals.

Photo: L3 Micreo

L3 Micreo's SILVERSHIELD is intended for vehicle-mounted use against IEDs using mobile phones.

remote control toy as the primary means of detonation. A large variety of techniques can be used, ranging from very crude jamming of large swathes of the radio spectrum to extremely sophisticated specialist methods. Myriad products in this space exist, largely but not completely for use in military operations. Two large programmes of particular interest in the electronic countermeasures (ECM) space are worthy of specific mention. The Joint Counter Radio-Controlled Improvised Explosive Device Electronic Warfare (JCREW) is a very large US Navy-led programme to develop and procure the latest generation of smart jamming technology. The prime contractor is Northrop Grumman, and the expected overall programme value of the various contracts may exceed US$500M. There is a dismounted version for use with soldiers and marines, a vehicle-mounted edition, and systems for fixed site use. Several generations of JCREW equipment have served long and hard in places like Afghanistan and Iraq.

An Australian effort in this ECM arena is something called the SILVERSHIELD programme, with L3 Micreo. SILVERSHIELD is intended for vehicle-mounted use against IEDs using mobile phones. Approximately 13,000 systems are being provided to Afghanistan for use in force protection for military and police users. This particular system is part of a broader programme called REDWING, which has fielded systems such as the GREYGUM for use on light vehicles and the GREENGUM for use by soldiers on foot.

Detection: Point and Standoff

Not every device can be interrupted by ECM. Devices initiated by a command wire or by means such as sensors and pressure plates are still difficult to counteract. There is a distinct and persistent operational requirement for the detection of IEDs. However, detecting IEDs from a safe distance is still quite difficult. Numerous techniques are available for point detection of explosives, such as trace detection, manual search techniques, and the use of detection dogs. While there are incremental improvements in this area, radical new developments in these established techniques are few at this time.

It is worth examining X-ray detection technologies as useful technologies for the detection of IEDs. The use of x-ray systems for detection of objects in containers and baggage has been ubiquitous for many decades now, and still has a place in the detection of IEDs. Smaller, more portable systems are used by EOD technicians to examine suspicious devices. Larger systems are in use at ports, borders, and at checkpoints that can scan cars, trucks, cargo containers, and even railway carriages. Companies such as Smiths Detection (UK), AS&E (USA), Rapiscan (USA), L3 (USA), and Scanna (UK) are all leaders in the conventional x-ray space. Of particular interest in recent years has been the advent of x-ray systems that can detect the presence of bulk explosives, obviously of interest in vehicle-borne IED (VBIED) detection. This has led to vehicle-mounted systems that can literally drive down the street, scanning vehicles and looking for the presence of explosive materials. These tend to be lower energy systems, using principles like "backscatter" so they are safer to operate around the public than massive cargo scanning systems that can represent a radiation safety risk.

Point detection methods, however, are inherently dangerous, because they involve close proximity to dangerous devices. Detection of possible IEDs at some degree of stand-off distance would be greatly desirable. Effective stand-off detection of IEDs remains a bit of an elusive target for the major militaries of the world, but serious research and development efforts have gone into this area of inquiry.

Systems designed for standoff detection of explosives concealed on a human body, such as suicide bombers, is somewhat easier than stand-off detection of vehicle-borne IEDs (VBIEDs) such as car and truck bombs, or roadside devices of many descriptions. This is because, from a technical perspective, it is far easier to "see" through clothing than, say, a car or truck. Systems that work in the infrared or radar spectrum can sense when someone has some bulk material (like explosives) and/or wiring under their clothing. These systems have been in use for some years, but the operational ranges are both limited and classified. However, distances of perhaps 100 metres or so are certainly feasible. The author did some consulting work on a prototype system 10 years ago. One cur-

Photo: QinetiQ

QinetiQ's SPO system enables the operator to scan crowds and search for anomalies without the need to disrupt the flow of foot traffic through the area.

Photo: U.S. Army

The DOK-ING MV-4 Mechanical Anti-Personnel Mine Clearing System is used to clear areas infested with land mines. The machine digs and pounds the soil, which results in the detonation or shattering of anti-personnel (AP) mines.

rent system is the COUNTERBOMBER, a product by the company Rapiscan (USA), and it has seen service with the US military. QinetiQ (UK) has a system called the SPO which uses passive millimetre wave technology. Various versions of the QINETIQ system have been marketed, often for transportation security purposes, for a decade.

A promising technology worth exploring is laser spectroscopy. The basic concept is that lasers can be used at some distance to interrogate objects. The laser light would interact with molecules of explosives (or related molecules of interest such as by-products or precursors) and a sensor would be able to discern this interaction from a distance. Techniques like Raman and FTIR spectroscopy clearly work at very short distances (i.e. centimetres) and are used for a variety of chemical identification applications. However, using lasers at a distance poses a number of challenges, not the least of which is the hazard of setting off a device by shining a laser on it. Also, the wide variety of materials in the environment makes for interesting problems in interpreting signals. However, progress has been made. Some firms, such as Laser Detect Systems (USA/Israel) have fielded products. Advertised range is low, however. Laser Detect System's R-SCAN boasts a range of 30 metres, well within the hazard range of all but the smallest IEDs. However, this is an area where technology is likely to improve. A variety of prototype systems are in the development pipeline and several governments, first and foremost the US Government, are expending resources to fix this capability gap.

It is worth mentioning that IED detection has been plagued by pseudoscience and frauds, resulting in deaths. Various devices, often claiming to use "magnetic resonance" or to be the equivalent of "divining rods" have been appearing on the market periodically for decades. Now discredited trade names like "Sniffex" and "ADE-651" are associated with these scams and frauds. A UK businessman was sentenced to prison for selling discredited products in this field. None has ever been demonstrated to work, nor has any ever been proven to have any functional components with any scientific basis. It is likely not a coincidence that the various large contracts for their procurement happen to occur in countries infamous for corruption in public procurement. However, the fact that there clearly is demand for products that promise a magic solution to a hard problem shows how difficult the IED problem is for some parts of the world.

Robotics: UGVs and UAVs

Remote detection is still in its infancy. There is a need to get close to possible IEDs in order to verify their danger or to render them safe. The time-honoured method for this is to use robotics. There have been interesting developments in either the conventional ground robots, or "unattended ground vehicles" (UGVs) as well as in the aerial drone/UAV space. Small robots have been used for decades for reconnaissance, detection, investigation, and disruption of IEDs. Small and large UAVs do much reconnaissance work in route clearing and scouting for possible IEDs, as well as monitoring suspicious activity that might be IED emplacement.

Small, remote controlled UGVs for C-IED work are numerous and there are dozens, if not hundreds of manufacturers in this space. However, an area where some interesting developments have occurred has been on the larger end of the robotics market. Large UGVs, some the size of trucks, can provide an element of brute force that small robots cannot. Larger systems, such as the DOK-ING (Croatia) series of UGVs, can knock holes in walls, push cars off the road, and clear potential IEDs while the operators

Masthead

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are safely well away from the action. One DOK-ING system, the MV-4, was adopted by the US military as the M160 and has seen much combat in Afghanistan, surviving very large explosions. A company making similar products, MineWolf, faced financial difficulty and their intellectual property was acquired by Pearson (UK).

Disruption

When an IED is found, it can be avoided and bypassed for some time, but often the problem will persist until something is done about it. The neutralisation of IEDs can take many forms. The stereotype of a man in a bomb suit clipping a wire is based on reality, but the true reality is that every other option for disposing of an IED will be considered before putting a highly trained technician at risk. Disablement and disruption techniques range from crude to elegant, but most are significantly low-tech in their approach, such as controlled explosions and the use of disruptors (the early ones were often based on shotguns, or indeed actual shotguns) to attack critical components of the device.
An area where technology comes into the disruption business is the possible use of high-energy lasers. The Australian branch of L3 responded to Australian requirements for C-IED technology by developing the HELA, the high-energy Laser Array. This project appears to still be in the development pipeline, but shows the promise of using lasers to burn through the outer layer of IEDs and disrupt the components. Similar projects are in the development pipeline in the USA and elsewhere.

Forensics

After the discovery, disruption, or use of an IED, there are a range of activities that can exploit the materials recovered from an incident. IED forensics is a growing discipline and both material exploitation of intact or disrupted devices and post-blast investigation after a detonation can provide extensive intelligence information and/or forensic evidence useful in criminal prosecutions. There are technologies and products for the examination of explosive material. Many of these are very similar to those used for detection and identification of chemical warfare agents and hazardous materials, addressed in previous issues of this publication. Both manufactured and homemade explosives leave much evidence of their origin, and this can lead to the networks that procured and made the devices. Other techniques exist for forensic exploitation of electronic components. For example, even a highly damaged mobile phone can reveal interesting information. Further, conventional criminological evidence, such as fingerprints, can be gleaned from fragments and components. To be useful, however, literally dozens of processes and techniques need to be used together.
One excellent example of IED forensics in practice is the French Counter-IED Exploitation Laboratory. This is a combined deployable asset which has everything that technicians could want or need to exploit IEDs or the components thereof. The French lab was demonstrated at NATO headquarters and has deployed to Mali. Indra, the Spanish company, makes entire deployable IED labs for interested customers.

Conclusion

The IED threat is complex and is not amenable to an easy solution. C-IED comprises a bewildering array of low- and high-technology processes and solutions. There is a thriving marketplace serviced by both large defence conglomerates and smaller firms, with some interesting and possibly revolutionary technologies now in use and in the development pipeline. ■

Force Multiplication Options for the Infantry

David Saw

Operational requirements based on experience gained in the field should offer a far better guide to what is truly necessary than requirements based on theoretical studies. Of course that assumes that the right lessons are learned from actual combat operations, something that is not always guaranteed, and that the funding is available to support the acquisition of new equipment and the tactical/technical innovations made necessary by operational experience.

The US and European militaries can now draw on extensive operational experience gained in the crucible of combat in Afghanistan, Iraq, West Africa and other parts of the world. There is no doubt that much has been learned in these conflicts and that this has resulted in significant changes at the operational and tactical levels. However, while combat experience drives change and the acquisition of new or modified equipment, the process of understanding the real lessons learned and of absorbing new equipment is only part of the story.

In many respects the reaction to operational requirements driven by recent combat experience can be characterised as being a process of looking for more performance and effectiveness in a format that is less weight intensive. There is a need for more firepower, but this is not just suppressive firepower; what is needed is more accurate and therefore effective fire. Potentially, this is to be achieved by weapons and ammunition that are lighter than those currently in service with the infantry. Another requirement is for increased protection for the individual soldier, but the key is that this additional protection comes with a reduced weight burden.

Other areas of concern include communications. Here the need is to operate reliably and securely, to be capable of moving ever increasing quantities of voice, data and video communication and again the aim is to reduce the weight burden on the individual soldier. More performance is also wanted from night vision equipment and weapon sights, with reduced weight as a part of the package. Added to this is the need for higher performance batteries capable of delivering higher performance for longer periods and capable of being rapidly recharged and all at a lighter weight than previous generation batteries. The changes driven by operational experience gained since 2001 cover practically every area experienced by the infantry soldier, from combat clothing and boots to combat helmets and beyond.

In principle, all of these positive developments from uniforms and boots, to protection, to weapons and sights, sensors and communications equipment should have increased the combat power of the infantry. In theory this is correct, but in reality things are very, very different. All of these expanded capabilities come with a cost and that cost is in increased weight. In Dismounted Close Combat environments the increased weight burden that the infantry is expected to carry reduces their mobility and in turn that reduces tactical flexibility and can increase their vulnerability. The other aspect of increased soldier loads is the prevalence of orthopaedic or musculoskeletal injuries. There is very little point in providing your soldiers with all of this wonderful equipment if utilising it will put them on the injured list. Furthermore, these injuries can have long-term consequences with the potential to force early retirement.

Carrying the Load

The scope of the problem of injuries as they impact the US Army was revealed during testimony by General Mark A. Milley, US Army Chief of Staff, in testimony to the Senate Armed Services Committee on 25 May 2017. General Milley noted that while recruitment and retention goals were being met, the problem was that readiness was not at the levels required, predominantly due to manning issues. At the root of this readiness/manning problem is the number of non-deployable troops in the US Army.

Although General Milley did not disclose the full extent of the non-deployable problem in the US Army, in questioning by Sen-

Photo: Sergeant Joseph R. Chenelly, U.S. Marine Corps

US Marines in Afghanistan during Operation Enduring Freedom in November 2001. The amount of weight the individual soldier was carrying had grown to such an extent that operational effectiveness was lost due to fatigue and load-derived injuries.

ator Jack Reed (Democrat, Rhode Island) some more facts came to light. Senator Reed said that: "I understand 10% of the non-deployable personnel are non-deployable for medical reasons?" In response General Milley stated that: "About 85% to 90% are medical, the rest of them are legal or other reasons." The Senator then enquired whether the medical causes of the high non-deployable rate were due to enhanced training, lifestyle or other factors? General Milley responded: "The majority (of those medical causes) are orthopaedic-type injuries. Most are recoverable with some extended profiles. So they are non-deployable in the short-term. Total Army, out of the one million-plus troops, about 20,000, two percent or so, are hard down. They will never be able to deploy. And those we are working through the Integrated Disability Evaluation System (IDES) system." (Note: IDES is the precursor to the soldier being released from the military and their care handed over to the Veteran's Administration).

The loss of 20,000 trained personnel is an extraordinary number to be dealing with and the US Army is taking steps to reduce the numbers of non-deployable troops caused by medical problems. This process is helped by the fact that high-intensity combat deployments are fewer than previously, meaning fewer medical injuries. However, it is worth noting that US Army readiness is far lower than it needs to be. As recruitment targets are being met, the objective is to fill out the current force structure and then use this as a basis for expanding the size of the force in the future.

Apart from restoring its numbers, the US Army has also developed a number of modernisation priorities. General Milley and then Acting Secretary of the Army Ryan D. McCarthy issued a document called "Modernisation Priorities for the United States Army" in October 2017. Amongst the listed priorities was 'soldier lethality'.The document described this as: "Soldier lethality that spans all fundamentals – shooting, moving, communicating, protecting and sustaining. We will field not only next-generation individual and squad combat weapons, but also improved body armour, sensors, radios, and load-bearing exoskeletons."

Photo: U.S. Marine Corps

Marines in the Infantry Officer Course during a live fire exercise at the Twentynine Palms training area. The US Marines conducted a study on soldier loads in combat and discovered that the assault load of a Marine rifleman was 44 kg (or 57% of body weight); the recommended maximum was 30% of body weight.

Exoskeletons and Arms

This listing of 'soldier lethality' modernisation priorities is highly significant, especially the reference to load-bearing exoskeletons. The US military has been interested in the possibilities offered by exoskeletons since the 1960s, the problem was that while the concept might be understood, the technology and materials necessary to make it a valid proposition was not available at that time. Now the situation is very different; the necessary technology and materials are available, and there are a number of exoskeleton and related programmes on the verge of delivering a deployable capability to the US military.

United States Special Operations Command (USSOCOM) is working on a programme known as the Tactical Assault Light Operator Suit (TALOS). Thus far, unpowered versions of this exoskeleton have been tested. The objective is to provide the operator with increased protection as well as enhanced mobility and load-carrying capability. It had been hoped to have a fully functional TALOS system ready this year, but now the plan is to have a fully powered version of TALOS ready in 2019. If all goes well at that point, they will look to upgrade the materials used in the construction of TALOS and that will be the precursor to the system being deployed operationally. TALOS is far more than a technology demonstrator. The objective for USSOCOM is to get a fully operational system deployed into the field as soon as possible.

Lockheed Martin has been working on exoskeleton programmes for some time. Their current offering is the ONYX system which is an exoskeleton focused on the lower part of the body, or, to be more precise the legs. ONYX will enter field testing by the end of this year with the 10th Mountain Division at Fort Drum, New York. The process will see an initial user testing phase, with user ideas then incorporated into an evolution of the system and then a further testing phase, followed by more user input and more testing. By the time this activity is complete in 2020 and, assuming that all has gone well, the ONYX system would be ready for production and subsequent service entry.

ONYX will not make a user cover the ground faster but it will increase endurance and reduce fatigue, enabling soldiers to carry heavy loads of equipment with fewer ill effects. The system will also reduce stress on the legs and this will go a long way to reducing the incidence of orthopaedic injuries. There are still issues to resolve though. One of these is power, and here the requirement is for a lighter weight battery system with more power output. The weight of the ONYX system is another area to be tackled, with new materials being an area of interest.

There are also a number of unpowered exoskeleton programmes being worked on in the US, as well as programmes focussed on powered systems, often also referred to as 'wearable robotics'. The US is not alone in working towards exoskeleton capabilities. Russia has been working on both powered and unpowered systems and Hyundai in the Republic of Korea (ROK) have demonstrated powered exoskeletons for medical and industrial uses, with the same technology obviously providing the basis for a military system.

Photo: Lockheed Martin

The Lockheed Martin ONYX is an exoskeleton focused on the lower part of the body and is due to start trials with the US Army shortly. ONYX will increase endurance and reduce fatigue, enabling soldiers to carry their heavy loads of equipment with reduced injury risk.

Meanwhile, researchers at the US Army Research Laboratory (ARL), part of the US Army Research, Development and Engineering Command, have developed a system known as the THIRD ARM. In response to ongoing requirements to increase soldier lethality, ARL came up with the THIRD ARM device. Although development is still at an early stage, the device is already showing considerable promise. On the surface, it is not a sophisticated device, it is unpowered and has a rather simple design, and it is attached to the waist of the soldier. Made from composite materials, it is a lightweight device (1.8 kg) and its function is to stabilise the weapon that the soldier is using and also remove the weight burden of the weapon on the arms of the soldier. The end result is a system that reduces fatigue due to reduced weight burden and is more accurate as the weapon is stabilised. The system has been tested with the M4 and the M249, as well as with the M240B machine gun that weighs 12.25 kg. Studies on the device continue, with one of the next steps being the integration of other heavier weapons.

Other Approaches

What is immediately apparent is that in the US strenuous efforts are underway to deal with the intertwined issues of reducing the impact of soldier loads, which leads to less fatigue, fewer injuries and an end result of a more effective soldier. The real surprise is why it has taken so long to start looking at solutions to increased soldier loads and the negative consequences of carrying such loads.

When the US Army became engaged in Afghanistan, there was suddenly great concern over the loads soldiers were carrying in combat. This led to a search for more information and it was discovered that the US Army had never performed a study of soldier combat loads; the only data they could find were drawn from a US Marine Corps report based on data from August 1942. This resulted in the Center for Army Lessons Learned (CALL) being commissioned to conduct a study of battlefield loads in "The Modern Warrior's Combat Loads, Dismounted Operations in Afghanistan", with research being conducted in the field in April/May 2003. Unsurprisingly the study established that soldiers were carrying loads that were far too heavy.

In September 2007 the US Marine Corps generated a report by the Naval Research Advisory Committee, under the auspices of the Office of the Assistant Secretary of State of the Navy (Research, Development and Acquisition). The report was entitled "Lightening the Load" and work commenced on the study in February 2007. Sources consulted included the US Marine Corps, US Army, US Department of Defense (DOD), and US Navy Science and Technology (S&T) organisations and industry. Also consulted were foreign militaries from Canada, France, Germany, Singapore and the UK to understand how they were developing Lightening the Load (LTL) initiatives.

The context for the study focused on the three main load categories of a Marine rifleman: the Assault Load, the Approach March Load and the Existence Load. The assault load covers what is needed to conduct combat operations indefinitely with minimal degradation in combat effectiveness. The recommended soldier load is 22.68 kg, or some 30% of soldier weight based on the average 76.77 kg weight of a Marine. The study found that theactual combat load of a Marine rifleman was 44 kg or 57% of body weight. The approach march load is based on conducting a 20-mile (32.18 km) march within eight hours, maintaining 90% combat effectiveness. The recommended load in this context is 34.47 kg or 45% of body weight, in reality the actual load was 55.79 kg or 73% of body weight. The existence load covers limited movement within the confines of transportation platforms and limited marching from landing zone into a secure area. The recommended load is 57.6 kg or 75% of body weight, in reality the load

Photo: US Army ARL

The US Army Research Laboratory (ARL) has developed a system known as the 'THIRD ARM'. The objective of the system is to stabilise the weapon and reduce the weight burden on the arms of the soldier. The M249 shown here being supported by the system has a basic weight of 8.16 kg.

was 75.75 kg or 99% of body weight.
Significantly, the LTL report noted the paucity of information on soldier loads and the impact that these loads had on the effectiveness of a soldier – remember that the first Marines deployed in Afghanistan in 2001 and in Afghanistan in 2003. Which begs the question, why did it take so long to think about these issues? The LTL report also

Photo: Rheinmetall

The Rheinmetall Canada MISSION MASTER Unmanned Ground Vehicle (UGV) already has its first export customer. The system is capable of semi-autonomous or autonomous operation, and the cargo variant can carry a 600 kg payload. Systems of this nature are an effective means of reducing infantry combat loads.

quoted a statement from the Commanding Officer, 1st Battalion, 3rd Marines, on 14 November 2006, who said: "We were ordered to wear everything everywhere in the mountains all the time… Even if you were in great shape, you couldn't keep up with the enemy." Again, one has to wonder who thought that was a good idea.
The LTL report also decided to look at the soldier load question in a different manner to the previous US Army effort. They focused on the Marine Rifle Squad, which consists of the squad leader and three four-person fire teams, as well as an attached US Navy hospital corpsman for a total of 14 personnel. The average load of a squad in combat is given as some 735 kg, which is some 408 kg in excess of the recommended soldier load in combat. The LTL report broke down squad load into four categories: 37% was weapons, ammunition and optics, 35% was Personal Protective Equipment (PPE), 26% was food, water, clothing and other, while 2% was accounted by communications equipment. The LCL report noted that the communications load "will increase dramatically in the near and mid-term due to increasing Intelligence, Surveillance, Reconnaissance (ISR) and communications connectivity - and could approach 10% of the squad load."
Finding a solution to the overload problem proved difficult. The LCL report commented that there was no "silver bullet" to weight reduction at the squad level. They stated that:"Load reduction must be addressed in terms of S&T efforts for future weapons and equipment, weight transfer off the squad members and new tactics." The LTL report noted: "Improved/specialised nutrition, physical training, and ergonomics would have a positive, but minimal impact on load carrying capability."
Solutions were possible though. The report believed that planned S&T efforts could make some headway in reducing the overload weight at the squad-level. They believed that 136 kg or 33% of the overload could be saved through "weight reduction developments in advanced personal protection and other equipment." Added to which another 136 kg or 33% of the overload could be saved through "the use of small-unit organic vehicles or other weight transfer techniques." Finding a way to the save the other 136 kg of overload was not addressed.

The Problem Remains

It is now 11 years since the LTL report was published and it would fair to say that there has been progress on LTL initiatives, or, to be more precise the need to reduce combat loads has been understood. Thus far, fielding reduced-weight equipment alternatives for the individual soldier has made limited progress, although any loss of weight helps. The provision of vehicles to carry soldier loads is an obvious avenue for weight reduction; the problem is that conventional vehicles require a driver and impose their own logistic burden. The obvious solution to this dilemma was what the US Army called an "autonomous logistics and equipment vehicle" or more commonly the "robotic mule." A few early systems were tested in Afghanistan, but now the US Army is looking to procure between 2,700 and 5,700 (depending on funding) of these Unmanned Ground Vehicles (UGV) under the Squad Multipurpose Equipment Transport (SMET) programme.
Four contenders have been shortlisted for the SMET programme: the Polaris Industries/ Applied Research Associates /Neva Systems MRZR-X, General Dynamics Land Systems Multi-Utility Tactical Transport (MUTT), HDT Global HUNTER WOLF and the Howe and Howe Technologies RS2-H1. They will be evaluated and a winner selected with the system to be fielded by 2021. According to the US Army the objective of the SMET system is for the UGV to carry some 453 kg of soldier load.
Other UGV alternatives exist. For example, at the Eurosatory exhibition in Paris in June, Rheinmetall Canada displayed their MISSION MASTER UGV. This system is ready for deployment, indeed there is already a first customer for the system, and the variant at Eurosatory was outfitted for the carriage of cargo, although other missions include casualty evacuation/rescue, surveillance, CBRN detection and combat. For example, Germany has reportedly shown interest in a version of the MISSION MASTER mounting the MBDA ENFORCER guided-missile system as a combat UGV. MISSION MASTER can be operated autonomously or semi-autonomously and carry a 600 kg payload.
It is quite possible that the powered full-body exoskeleton will provide the ultimate solution to the requirements of the infantry for load carriage, increased endurance and reduced fatigue. While we wait for exoskeleton technologies to evolve into deployable production systems, it would seem that the optimum LTL strategy is to reduce the soldier load by transferring it to vehicles, depending on requirements, such systems could be UGVs or something as simple as an All Terrain Vehicle (ATV). We have now reached the point where the need for LTL for the infantry is well understood and justifiable, now the challenge is to actually make it happen and field solutions. ■

"OCCAR stands ready to take the challenge"

Photos: OCCAR

Interview with Major General Arturo Alfonso-Meiriño, Director OCCAR-EA

ESD: This year, OCCAR commemorates its 20th anniversary. What were the reasons and the motivation to establish OCCAR as an international procurement agency 20 years ago? Who was involved? What were the objectives?

Alfonso-Meiriño: The Organisation for Joint Armaments Cooperation (OCCAR), whose Executive Administration I have the honour to lead, celebrates the 20th anniversary of the signature of its Convention by the governments of Germany, France, Italy and the United Kingdom, that took place on 9 September 1998. This Convention was then ratified by their respective parliaments in 2001, and by Belgium in 2003 and Spain in 2005.

The OCCAR Convention, which is based on the 1995 Franco-German "Baden-Baden Principles", assigned to that new Organisation the specific mission of promoting cooperation, improving efficiency and reducing the costs of armament procurement programmes. And all with the vision to become a centre of European excellence in the management of complex armaments programmes.

With a clear European vocation, referred to in its preamble and articles, and a strong support to the European identity of Security and Defence and to the strengthening of the European Defence Technological and Industrial Base (EDTIB), it pursued the industrial consolidation of the sector and the unification of the regulatory framework of the defence market in Europe – a market traditionally operated nationally and individually by European nations on the basis of "national security interests" and thus very much fragmented.

This European vocation needs to be framed in the historical context of 1998. At that time, the European Security and Defence Policy was still emerging, and far from "Common". Equally distant was the creation of the defence-related European institutions, such as the Military Staff of the European Union (EUMS), the Military Committee (EUMC), or the EDA. The OCCAR Convention also predates the involvement of the European Commission (EC) in industrial and defence market issues, made official with the publication in 2009 of its defence related directives.

ESD: In what way has the task spectrum of OCCAR developed and changed in the course of the 20 years of its existence? What services can OCCAR offer to non-OCCAR nations?

Alfonso-Meiriño: Twenty years after its introduction, the vision of the founding fathers of OCCAR, regarding the European identity of security and defence, has become a reality.

The evolution of the European Security and Defence Policy, now called "Common", has been unstoppable in recent years. The leadership of the EU Council in the more political issues of defence, and of the EC in those related to the defence industry and market, always in coordination with the European Parliament, are today a fact. An undeniable fact even for Eurosceptics, both traditional and those that have arisen on the political scene in the last electoral rounds of several Union Member States (MS).

Moreover, OCCAR has established itself as a true centre of excellence in its field of competence and has proven not to be a closed club. The participation of nations such as Lithuania and Slovenia in the 8x8 BOXER armoured vehicle programme is a good example.

With regard to our tasks, the Convention sets out that OCCAR can: perform management of assigned cooperative and national programmes, including In-Service Support (ISS) and research; contribute to the harmonisation of technical specifications; coordinate joint research activities and studies. However, since OCCAR received its legal status in 2001, it has consolidated its expertise in the development, production and ISS phases. Although all tasks can be accomplished, OCCAR is not active in research and technology that is of low technological readiness, nor the harmonisation of requirements, where the European Defence Agency (EDA) has a clear role.

ESD: What reasons are behind new nations joining OCCAR?

Alfonso-Meiriño: I believe the OCCAR business model holds some key differentiators that have helped OCCAR build its reputation as a centre of excellence.

The OCCAR model is based on a Central Office (CO) that supports the Programme Divisions (PDs) in all corporate issues. Moreover, the PDs are operationally autonomous, although always under the responsibility and supervision of the Director. Besides, the current size of OCCAR-EA, minimally hierarchical, allows a fast and effective admin-

The BOXER Programme provides the armies of Germany, The Netherlands, Lithuania, Slovenia, Australia (shown) and perhaps in future the UK with a new generation of all-terrain armoured utility vehicles.

istration of the corporate and programme aspects, and entails a very low administrative cost overhead of only 1.3%.
The supervision of the six MS in the management of the Organisation ensures the continuous updating and harmonisation of its legal and regulatory framework, and the rapid and efficient integration of new programmes, new phases in existing programmes or new Participating States (PS). In practical terms, it means that there is no need to go looking for common ground every time a new programme/phase/Programme Participating State is integrated.
The roles defined for the so-called Programme Boards and Programme Committees, in which representatives of each of the PS are integrated as customers, ensure total transparency and control over their respective programmes, protecting the joint and individual interests of OCCAR, as well as of the MS or non-MS.
This is what OCCAR offers to the non-MS. As you can see, the same rights and obligations in the programme they participate in, minimum overhead cost and total control.

ESD: Which future tasks resulting from PESCO initiatives could be accomplished by OCCAR?
Alfonso-Meiriño: On 8 December last year, the Council of the EU established the Permanent Structured Cooperation (PESCO). PESCO will allow MS, whose military capabilities meet higher criteria, to make binding commitments within the framework of the EU; on 6 March this year, this initiative materialised in 17 projects with diverse participation of 25 of the 28 MS of the Union.
The European Secure Software Defined Radio Programme (ESSOR) is one of the 17 identified PESCO projects and is being managed by OCCAR. It started in 2008 with the joint work of the governments of Finland, France, Italy, Poland, Spain and Sweden, and has recently entered the Operational Capabilities phase (OC1), without the participation of Sweden, but with the integration of Germany under way. This programme has an important requirement for interoperability and a clear European identity and is aimed at providing efficient communications at the level of army brigade and below, building a secure high-speed mobile ad hoc network. The ESSOR programme is undoubtedly an excellent candidate for the EDIDP, thus if funded by this EC initiative it would receive an additional 10% bonus.
But there are other PESCO projects, the Maritime Semiautonomous Systems for Mine Countermeasures Belgian-Netherlands initiative, or the family of armoured vehicles led by Italy, that may come to OCCAR in the future if they develop further and the nations so wish. OCCAR stands ready to take the challenge.

The TIGER helicopter programme is one of the complex capability-building programmes managed by OCCAR.

ESD: The TIGER helicopter fleet is to become subject to a midlife upgrade. What is to be accomplished? What is the task of OCCAR in the scope of this programme?
Alfonso-Meiriño: The TIGER Helicopter Programme is one of the complex capability-building programmes managed by OCCAR, currently going through a transition phase. This programme has been managed since 2001, although it started as a Franco- German development in September 1998. This system, already operational in the armies of Germany, France, Spain and Australia, is available in four different variants. Germany has contracted 68 UHT helicopters of the 163 ordered by the three European nations, with 67 already delivered, and the last one expected during the month of July, and with it, the end of the UHT production. The UHT variant can be deployed for armed reconnaissance, anti-tank missions, anti-helicopter tasks and escort/combat support missions, depending on the choice of weapons. The TIGER programme is entering into the preparation phase of its Mid-Life Upgrade with the aim to get the first entry into service of the Mark III helicopter in 2025 for France and 2026 for Germany. The three nations are currently harmonising their requirements with the view to place the Mark III development contract in 2020. OCCAR would be entrusted by the Programme PS to manage the Mark III programme.

The upgrade has the double objective of tackling the obsolescence and the modification of its systems, including armaments, and thus requires an important technological development.

ESD: After Germany, The Netherlands and Lithuania, Slovenia and Australia have selected the BOXER vehicle. The UK is considering rejoining the programme in light of the country's MIV requirement. What effect does this have on OCCAR's work?

Alfonso-Meiriño: As I mentioned earlier, the Convention has a clear European vocation, and the BOXER programme is an obvious example, as it comprises a Member State, Germany and two non-MS, the Netherlands and Lithuania, that will shortly be joined by Slovenia and the UK (currently in integration).

Australia has decided to procure the BOXER vehicle but directly through industry, so for the moment they do not intend to join OCCAR.

The Convention allows for this model, where MS work with non-MS in a programme, but OCCAR is so flexible that even a programme with participation of non-MS would find a place in the Organisation.

The fact that Slovenia and the UK are in the process of integration means of course that some activities need to be undertaken, such as the conclusion of a MoU, Programme Decision and contract placement. In this particular case, as the PD already exists, it is up to the Division to proceed with these integration activities; which can require that the nation in integration provides Detached National Experts (DNE) to cope with the extra work. This is the case with the UK, which has already sent several DNEs to work with the PD in Bonn. The integration process also requires the involvement of the OCCAR CO, and thus the integration of any new Programme Participating State or new phase or programme is subject to approval by OCCAR's Board of Supervisors. This is the highest decision-making body in OCCAR, and their decision, based on my assessment of the resources needed for the completion of the integration, is meant to avoid other areas suffering from the new processes to be undertaken, as this would result in damage to our reputation.

ESD: What are the current participants in the European MALE RPAS programme? What are the next steps?

Alfonso-Meiriño: The MALE RPAS has four PS; Germany, Spain, France and Italy. Belgium follows this programme with great interest from its observer status that was obtained in 2017.

The MALE RPAS programme is a candidate for EU funding.

The programme is currently in the final steps of its stage 1 for the definition phase that started in 2015. The PS have already decided to go ahead with a second stage of a global nature, which will involve a contract for the development, production and initial in-service support in the course of 2019 of a RPAS. MALE RPAS is expected to have a takeoff weight of approximately 11 tonnes, will be powered by two turbo-prop engines and is scheduled to enter into service in 2025.

The industrial set-up is currently under negotiation and counts with Airbus Defence and Space GmbH at the level of main contractor, and with Leonardo, Dassault Aviation and Airbus Defence and Space S.A.U. as major subcontractors, but will undoubtedly bring on board a broad spectrum of European SMEs for future phases, given the EU initiatives requirements.

Taking into account the developmental nature of this programme and that the industrial set-up complies with the EU EDIDP requirements, I believe this programme is a firm candidate to receive EU funding as well.

ESD: Based on last year's political directives, the bilateral armaments cooperation of France and Germany seems to be getting momentum? What support can OCCAR render in the scope of these efforts?

Alfonso-Meiriño: Indeed the meeting of the French and German Ministers of Defence on 19 June with the signature of the two Letters of Intent for the collaboration in the Future Combat Air System and the Main Ground Combat System has meant a step forward. France and Germany have a long history of cooperation, they are both pushing for the European strategic autonomy requested by the High Representative Federica Mogherini in her Global Strategy, and these future programmes are a means to achieve it, in supporting the EDTIB.

OCCAR's role in support of these efforts will very much depend on the will of these nations.

Then again, OCCAR's core business is the management of complex armaments programmes, which is the case in these two initiatives, and one of the missions assigned by the founding fathers was precisely to support the EDTIB. OCCAR is ready to take the challenge, if these two nations so wish.

ESD: The UK is planning to leave the EU (and thus the Common Defence and Security Policy) in 2019. Will Brexit have an effect on OCCAR?

Alfonso-Meiriño: As you know, the UK is one of the founding members of the Organisation and since OCCAR is not part of the European Union, BREXIT does not affect it, a priori.

OCCAR nations are studying the impact on the A400M programme, as it follows UK law. Also, the potential impact on the trade or the transfer of defence-related products is being evaluated, but it is our understanding that there will always be a trade agreement between the UK and the European Union to facilitate such transactions.

The participation of the UK in programmes managed by OCCAR, funded by the EDIDP initiative, would also constitute no barrier, as I particularly do not believe that these fund incentives have sufficient weight to invalidate other reasons that would bring any nation to a bilateral/multilateral cooperation with the UK.

ESD: What are the advantages resulting from the cooperation with other international organisations like EDA, NSPA, EATC?

Alfonso-Meiriño: OCCAR has a long-standing cooperation with the EDA,

with which an Administrative Arrangement (AA) was signed in 2012, and an interface document with the organisation was updated only last year. The EU Council of 2012 invited EDA to seek the greatest synergies with OCCAR, noting the close working relationship between the two organisations. EDA has a role in the identification and preparation of new cooperative opportunities between its participating MS, so they have an important role in the upstream part of the definition of a programme. Then, when a programme is mature, they may, using the existing mechanisms (AA, interface document), transition the programme to OCCAR. So we see each other as mutual reinforcing partners, with no duplication of efforts.

OCCAR has a long-standing collaboration also with NSPA. OCCAR is a customer of this NATO Agency for some diverse activities in the In-Service domain for some of its programmes. For instance, in the case of TIGER, a Service Level Agreement was concluded for the invoicing through an IT system, called NAMSIS, whereas for BOXER the Service Level Agreement was signed only last year for the ammunition of the Lithuanian variant.

On the other hand, NSPA is an OCCAR customer for the MMF Programme, and OCCAR procures the aircraft, currently 8 but with a potential to become 11, should more nations decide to join.

I believe the cooperation between the two organisations is a great example of the relationship and complementary efficiency in the domain of acquiring and supporting the military capabilities needed for the European nations.

And last but not least, our cooperation with EATC focuses on the A400M and aims to achieve an efficient European air transport and increased European airlift capability. Within the European air transport domain, there are common activities relating to the A400M capability within the remit of EATC. We actually meet at least once a year, also with EDA, because we consider that increased cooperation between the three entities can bring significant added value to their respective MS by exploiting synergies and maximising cost effectiveness, enabling the successful multinational operation of the aircraft is in the benefit of the respective MS.

ESD: Can you confirm that Germany has plans to join the ESSOR project and has accepted to pay a share of the development costs already invested?

Alfonso-Meiriño: The ESSOR PS indeed recognise the strategic importance of Germany joining the ESSOR Programme. On the other hand, Germany fully recognises the significant effort and investment provided by the ESSOR PS in order to achieve the results that are today on the table, as well as the new developments foreseen in the OC1 Phase, which represent the foundation to complete the development of the High Data Rate (HDR) waveform.

Germany is willing to participate in an active role in the future development of ESSOR and will benefit from the ESSOR outcomes and knowledge so far accumulated, therefore Germany's contribution to the programme will take into account the investments and risks sustained by the other ESSOR PS to achieve the successes of the programme to date.

The interview was conducted by Peter Bossdorf.

Hard Cases for Tough Times

Tim Guest

Rugged cases, for the shipping and transit of vital and often sensitive equipment, weapons and ammunition over tough terrain, are widely used by both military and civil agencies alike.

Getting sensitive devices and critical equipment across rugged terrain and ensuring it arrives at its destination in one piece and fully operational cannot be guaranteed if it makes the journey unprotected. Uphill, down dale, over rocks and water, everything from electronic devices, radios, optical equipment, search and rescue (SAR) devices, weapons and ammunition need to be protected en route to their point of application if a mission, military or otherwise, is to be successful. And whether such equipment is man-portable and carried by individuals, or transported by vehicle, boat or aircraft, there are numerous options from a wide variety of vendors available to encase and protect equipment in order to ensure its integrity and operability.

The following article looks at the need for rugged cases to carry tactical mission equipment, as well as some of the processes involved in their manufacture and some of the vendors and their products active in this sector.

Setting the Scene

The increasing use of, and reliance on, high-tech devices and electronics by military, special operations forces, security, SAR and other user groups has seen a growing need for protective and often bespoke, application-specific cases to protect equipment from the rigours of often perilous transport. While military cases through the ages have been constructed from a variety of metals and woods, today's cases draw on the latest injection-moulding processes using state-of-the-art polymer-based materials. Many vendors produce standard off-the-shelf systems that can be shipped quickly for more common applications. Airtight, waterproof, dustproof and corrosion resistance are typical in most portfolios and, depending on the application, internal moulding to provide a fitted, shaped interior for a specific device is usual. At the same time, bespoke solutions for specific users and uses are also offered by most. And while many OEMs provide a one-stop shop making both the case shell and the custom foam interiors, the latter is also the preserve of specialist companies working with the outer shell OEMs; companies like Weepack in France, which specialises in polypropylene 'mousse' interiors. According to commercial director Gilbert Juan, talking with ESD, Weepack often works with end customers who have procured OEM cases such as Peli and MAX cases, and 3D design polypropylene interiors for specific needs and user specs. In the defence and aerospace field, such customers have included the French Ministry of Defence, as well as leading vendors like Rolls Royce, Thales and UTC Aerospace.

And as well as foam interiors, cases used in many operational scenarios may require alternative interiors comprising rigid rack mount systems, instead, such as with cases used as mobile armouries to house several rifles.

Vendor Views

Lucio Sirotti, Export Director at the MAX cases' manufacturer, Plastica Panaro, told ESD that its cases, used by UN agencies and military organisations around the world, are produced with an injection moulding process, using a polypropylene-based compound that the company has developed. Plastica Panaro makes its own custom foam inlays and screen prints its cases, if required, with a customer logo or brand name. Max cases, IP67 certified and meeting Stanag 4280 and DEF STAN 81-41, go through rigorous testing including vibration testing to ensure they are dustproof, shock resistant, waterproof and can operate without losing their integrity in temperatures between +90 and -30°C. Key solutions include its MAX540 H245 TR with a telescopic handle and wheels, cubed foam and padded dividers internally; the MAX800GPB (convoluted foam interior), MAX800S (cubed foam interior) and MAX800SAD (high-density foam interior), all systems for a range of military uses. Another example for secu-

Photo: Peli-Hardigg

Rugged, militarised cases keep even the most sensitive electronics and comms equipment intact in the harshest environments.

Author

Tim Guest is a defence and aerospace journalist and former officer in the Royal Artillery.

rity/military use is the MAX620 H250 BL, which is tailored to carry pistols and magazines. Managing Director at CP Cases Peter Ross, told ESD that the manufacturing process in relation to the company's own cases uses modern high-performance materials, such as composites and multi-shot moulded products, which have "elevated the mechanical performance of the company's range of ruggedised cases and containers for military deployment". The users' choice of product type is usually dictated by the application. CP Pro flight cases were the first of their type in Europe, introduced in 1971, and still designed and manufactured today when the application demands, typically when large and/or heavy and delicate equipment is being handled by third parties. When essential equipment is used in war zones and the like, in latitudes that span the tropics to the poles, more sophisticated rugged enclosures are required. They still have to accommodate violent drop, shock, vibration and climate protection, but then also have to be lightweight, and small. Ross added that the company offers a "one stop shop" to its customers, delivering complete design and manufacturing services from start to finish. "We design and build all our interiors, with a fully functioning foam engineering shop, 3D modelling facilities and prototyping service." The company seals its products against ingress from extreme climatic conditions as a long-time, tried-and-tested service. It uses in-house rain and immersion test facilities and all its mail product lines have been through accredited third-party test and accreditation to both military and commercial test specifications, such as MIL-STD-810 (US specs) Def Std (British specs) IP and STANAG specs.

The company has four primary product lines for military applications, all dependent on customer requirement and field use demands. These are: the AMAZON range, the ERack lightweight 19" racks, suitable for EMC-screened applications, the AirShip ultra-lightweight rigged containers for man-pack carrying applications and finally climate-controlled 19" racks for rapid deployment scenarios where both heating and cooling systems are incorporated to protect sensitive electronics, communications and encryption equipment.

According to Ross, CP Cases maintains readily available stock for quick-ship requirements, and has been called upon many times to deliver in days, and sometimes only hours, when an urgent need arises. He said the AMAZON cases had been in use recently with the Italian civil emergency rescue services assisting in the Genoa viaduct motorway collapse. The 'rotationally-moulded' AMAZON range are among the company's most popular military-certified products and are in use all over the world with many military and security-related customers. Bespoke solutions include blast and bullet-proof cases for specific international security agencies.

Photo: Plastica Panaro

Drone station carried in a MAX case from Plastica Panaro

Vendors on the Case

Peli-Hardigg cases are some of the best-known solutions in widespread military use and like other manufacturers follow stringent development and production processes to meet exacting user requirements and military standards. What the company calls its Advanced Case Solutions combine materials science, packaging engineering, project management and manufacturing processes that deliver de facto industry standards such as its cushioning curve formula. Its single-lid containers have been adopted by many defence and security agencies worldwide to protect sensitive technologies deployed in the most demanding environments, from drones to communications and electronics equipment and devices, to personal small arms and weaponry of many kinds.

Photo: DroneCases

Tethered drone flying from its DroneCases military case

Photo: Peli-Hardigg

Cases from a range of vendors are used in a wide variety of operational applications in command posts, temporary field medical records stations and many more settings.

The company designs the internal make-up of its cases, from simple foam cushions to extremely complex metal structures for use in dramatically diverse shipment, storage and user conditions to ensure interior stabilisation for any equipment is total. From deck-mounted equipment to bezel-mounted electronics with integrated exhaust fans, as well as cases with multiple access points and interface portals.

Metal decks or cradles are used to secure heavy equipment, and elastomeric shock mounts isolate metal fixtures from the case shell. Shock-absorbing foam is designed and shaped specifically to custom fit any equipment or component, with a variety of densities and material compositions available depending on application and need. Peli Advanced Case Solutions cases are designed to operate in extreme temperatures, to withstand radical oscillation or direct impact, to remain water tight when immersed in water, and to maintain seal integrity when exposed to chemicals or fine dust particulates. When military and OEM customers need to certify a case will perform to such specific requirements, Peli's Advanced Case Centres in the UK, France and the US subject cases to a range of rigorous lab tests including drop, vibration, leak, heat and dust tests under precise control conditions.

Peli-Hardigg mobile military cases cover operational scenarios from mobile armouries, to mobile medical and other mission critical carrying needs. Its mobile armoury range, for example, offers over 40 kinds of cases to house various numbers of rifles (such as the M4 Carbine), pistols (such as the M11 and Beretta 9mm), from a single weapon up to six or more M4s, or 24 M9 Berettas and more. Combinations of personal small arms, sights and magazines are accommodated by the designs of rack mounts and moulded interiors. Cases are also offered for grenade launchers, such as the M19, sniper rifles, such as the M24 with scope, and machine guns such as the M240B together with a spare barrel and, in the case of the new M240G, its infantry modification kit.

Photo: Peli-Hardigg

Tactical mission equipment of all kinds can be safely transported, knowing it will remain intact over the toughest terrain and road journeys.

Peli's mobile medical cases are rotomoulded solutions and include in-field portable solutions that are watertight, airtight and impact resistant and many combinations and customisations of interiors can be made to meet varying mission requirements. Some of its MEDCHEST range have wheels for mobility and can be outfitted with custom drawer dividers or foam dividing units; they are used to carry and deploy a wide range of field medical instruments and critical supplies.

Italian specialist case maker HPRC produces a wide range of standard, off-the-shelf case designs, as well as custom fit cases for various end user groups for civil as well as security applications. Its custom inlays are made from polypropylene of different densities and its milling processes enables the production of single-piece inlays but with several different depths. Multilayer inlays are made for customers whose requirement is to carry many small or different pieces of equipment in the same case. All HPRC cases go through stringent testing to withstand drops, impacts, watertight integrity and are suited for use in temperatures between -40 and +80°C. Its HPRC3500 is a backpack case suited for applications such as drone/UAV carriage and can incorporate a cubed foam interior. It meets ATA300, IP67, STANAG 4280 and DS 81-41 approvals.

Maibach in Germany produces the MILTAINER-TSC (Transport and Storage Container) range, which is constructed of glass-fibre reinforced plastics meeting German military specification VG 95 613. While the range includes larger storage containers in its TSC, HD (heavy duty), MD (medium duty), LW (lightweight), and RM (rotomoulded) ranges, it also comprises smaller portable and wheeled cases for tactical applications in its IM (injection moulded) range that are shock resistant, have been drop tested to ATA300 and MIL-STD-810 standards, comply to IP67 waterproof requirements. The LW range includes stable portable systems for use as tactical containers for manual

transportation in the field, with parts such as fasteners and wheels recessed into the body of the case to enhance resilience in extreme environments.

Photo: Peli-Hardigg

Cases to transport personal small arms and weapons, as well as specialist sniper rifles and field armouries, are offered by several case makers.

Another Italian player active in this sector is GT Line, which produces its Explorer Cases range of waterproof/watertight cases that are made from copolymer propylene at three manufacturing plants which it says are "strategically based around the world" to support the needs of its international customer base, which includes humanitarian, security and offshore industry users. It produces a range of heavy duty gun cases as well as offering armoury configurations of its appropriate cases to suit a wide range of small arms. Its Explorer Case 15416, for example, it claims to be "the longest rifle case" available on the market, is suited to carrying a .50-cal sniper rifle. The company says that mechanical strength is one of the most important aspects of such a long case; protecting and maintaining a zero POA/POI during transportation, the case must keep its rigidity, although without compromising transportability, or becoming too heavy. This is where GT Line's construction process comes in, with the properties of the copolymer polypropylene offering extreme rigidity. The case balances the use of ribbing with the polymer compound to deliver its high specs. In the UK, Leafield Cases, delivers solutions to sectors with mission critical needs that are waterproof and dustproof to IP67 standards and certifications include to STANAG 4340, DEF-STAN 81-41 Level J, DEF-STAN 81-144, MIL-STD-810G and ATA300. Like some of the other players in this sector, Leafield uses rotational moulding to produce detailed and robust cases, including those in its AEGIS range that it says, due to the process, are more resilient and durable than aluminium or wooden cases. They have more consistent wall thickness than blow-moulded cases, are more economical to 'tool' than injection-moulded cases and, in this age of environmental concerns, are completely recyclable. Leafield says that the process allows cases and lids to be produced with twin walls for greater strength and rigidity, and fittings and features can be readily moulded into the case walls and incorporated in the overall design. The company has developed its own 'multi-part mould' approach that it says enables handles, tie-down points and other features to be incorporated into the products. From a customer perspective this means that bespoke specs can be designed into a case quickly to meet specific needs. DroneCases in Germany works with Leafield and its AEGIS range, as well as using plastic cases from SKB to support the growing use of drones in military and civil sectors.

Photo: Peli-Hardigg

Peli's AIR cases are available for a range of demanding security applications.

Not to Forget Good Old Wood

With all this talk of polypropylene and rotational moulding you'd be forgiven for thinking that other, traditional materials are a thing of the past for the supply of cases for defence applications. One company proving this assumption wrong is Luxembourg-based No-Nail Boxes, which produces over 300,000 collapsible plywood boxes per year with some 90% of those meeting specific customer requirements; many of those clients are military in nature. It supplies its products, including ammunition/munitions boxes, to the likes of the Belgian, Dutch, French and Netherlands Armies and other NATO organisations.

Final Thought

With the plethora of heavy duty, high-spec, rugged cases available for a wealth of vendors, there is no excuse for sensitive and critical equipment to arrive at its operational destination in anything but one piece. Defence and security users have a huge choice and given the processes available and on offer from most makers even the most exacting end-user needs can be accommodated into a case design to protect mission equipment of all kinds. ■

European SHORAD Systems

Doug Richardson

On the night of 6 January 2018, a swarm of 13 piston-engined drones attacked Russia's Hmeimim Air Base in Western Syria and a Russian naval facility in the nearby port of Tartus.

According to Russian statements issued following the attack, seven drones were shot down by missiles launched by Pantsir SHORAD (short-range air defence) systems, while the remaining six were defeated by electronic-warfare measures. The most recent significant incident to involve the use of SHORAD systems, it illustrates the tactical importance of these unglamorous but vital missile systems.

SHORAD systems protect high-value ground targets against attacks by aircraft, helicopters, and air-to-surface missiles. Most have a maximum range of around 10 km, but some recent developments have extended this to around 20 km or more, overlapping with the lower end of the range coverage of medium-range SAM systems.

Most are mounted on wheeled or tracked vehicles to have the mobility needed to provide defence coverage either for a temporary asset such as a refuelling or regrouping area, or for rapidly-moving friendly forces. Where fixed assets such as an airfield or command centre need permanent protection, a SHORAD system could be installed on a shelter or other form of redeployable cabin, but a mobile system is able to rapidly change location in order to avoid being attacked.

The first Western attempt to create a mobile SHORAD system was the General Dynamics MIM-46 MAULER programme, begun by the US in the late 1950s with the aim of developing a self-contained system mounted on a single-tracked chassis. The 54 kg missile would have used radar beam-riding guidance coupled with passive infrared (IR) terminal homing, but the programme was plagued by technical problems and inadequate funding and was cancelled in 1965.

In the US, MAULER was replaced by the Philco-Ford (later Loral) MIM-72 CHAPARRAL, which used a surface-launched version of the IR-guided SIDEWINDER air-to-air missile. CHAPARRAL remained in operational service from 1969 until the 1990s, but the US made no further attempts to develop a more effective SHORAD solution. As a result, this class of weapon became a European speciality, and has remained so until the present day.

Photo: Rosoboronexport

Recent combat experience in Syria may have enhanced the sales prospects of KBP's PANTSIR (SA-22 GREYHOUND) combined gun and missile system.

By the end of 1962, the UK had cancelled its planned PT.428 missile system, a radar-guided weapon broadly similar to MAULER. Since a practical SHORAD mission required a less complex engineering solution the one that had been planned for MAULER and PT.428, the obvious choices were either semiautomatic command-to-line-of sight (SACLOS) guidance or passive IR homing. Engineers at what was then British Aircraft Corporation concluded that a SACLOS missile coupled with an optical tracking system seemed to be a more practical and potentially low-cost solution. They started work on a programme originally known as Sightline, then as ET.316, before finally being designated as RAPIER.

The RAPIER used semi-active command to line-of-sight (SACLOS) guidance. As the operator tracked a target using an optical sight, a sensor would detect any deviation between the missile's flight path and the line-of-sight to the target, then send the radio commands needed to steer the missile back onto the line-of-sight.

The complete system was designed in a towed configuration, and consisted of a launcher armed with four missiles (two mounted on either side of a surveillance radar), a tripod-mounted optical tracker, and an optional MARCONI Blindfire radar. Its designers were sufficiently confident in the potential accuracy of the system that they decided to use a missile whose 0.5 kg semi-armour-piercing warhead had no proximity fuze, but relied on a contact fuze. Following the Falklands War in 1982, RAPIER was initially credited with having downed 14 Argentinean aircraft, and achieving a further six "probables", but later analyses suggested that a more realistic figure was around four "kills".

Author

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

Photo: Rosoboronexport

JERNAS is the export version of MBDA's RAPIER Field Standard C.

In 1963 Nord Aviation of France and Bölkow of Germany began a study that resulted in the launch of the Roland programme as a joint development in 1964. The two companies later became Aérospatiale and MBB of Germany, and founded the Euromissile company that would become responsible for ROLAND, with Aerospatiale focussing on the ROLAND 1 day/clear-weather system and MBB tackling the ROLAND 2 all-weather system. Both used SACLOS guidance.

The French Army ordered a version based on the Giat Industries AMX-30R tracked chassis. A total of 83 ROLAND 1 and 98 ROLAND 2 systems were delivered. Deliveries of 140 systems to Germany began in June 1981. ROLAND 1 became operational in 1977, followed in 1984 by ROLAND 2. Export customers for the system were Argentina, Brazil, Iraq, Nigeria, Qatar, Spain, Slovenia, the US and Venezuela.

The US order proved controversial. Although Hughes was awarded a development contract in January 1975 for an American version of the ROLAND II, the resulting programme was repeatedly reduced in size. Issued to only a single Army National Guard battalion, the system was withdrawn from service in 1988.

Development of what would become the CROTALE system began in 1964 when South Africa awarded what was then Thomson-Houston a development contract for a mobile SHORAD system. Once again, SACLOS guidance was used. The resulting system used separate radar-equipped acquisition vehicles and firing vehicles. It entered service with the South African Armed Forces in 1971 under the designation CACTUS. In the same year, the French Air Force ordered one acquisition vehicle and two firing units for trials.

Most of the CROTALE systems produced for the French Armed Forces or for export were mounted on a P4R (4 × 4) wheeled vehicle, but a shelter-mounted variant was also produced to protect static targets. The system evolved through five variants – the original 1000 series, the 2000 series incorporating IFF and a TV camera, the 3000 series with automatic TV tracking), the 4000 series with a radio datalink that replaces the inter-vehicle cables used in earlier versions, and the 5000 series which added an optical tracker and an improved surveillance radar with a range of up to 18 km.

Versions designated SHAHINE were developed for Saudi Arabia. SHAHINE 1 was based on the CROTALE 1000 series and used the AMX-30 tank chassis, while the follow-on SHAHINE 2 was based on the 4000 series and delivered in versions based on the AMX-30 chassis or a towed shelter.

By the 1980s, RAPIER, ROLAND, and CROTALE were showing their age, so all three received an injection of new technology. The end results were the RAPIER Field Standards B2 and C, CROTALE NG, and ROLAND 3.

In 1985, development started on a new RAPIER tracker fitted with an IR thermal imaging system in place of the original optics. The launchers were upgraded to carry six missiles, while a Tactical Control Console allowed four RAPIER launchers to be controlled from a central location. This version was designated RAPIER DARKFIRE, and was deployed by the UK forces as Field Standard B2.

The new fire unit developed for RAPIER Field Standard 3 is armed with eight missiles, with four being mounted on either side of the new electro-optical (EO) tracking system, while a separate 3-D Dagger radar was used for surveillance. Full-scale production of Field Standard 3 began in 1993, and the system entered service three years later.

The only customer for Jernas export version was Malaysia, which ordered the system in 2002, and declared it operational in 2006.

The 1990s also saw the introduction of a new Mk2 variant of the RAPIER missile. This has a maximum range of 8 km, and is fitted with an IR proximity fuze.

Thales Defence Systems' CROTALE NG is based on the VT-1 missile. This has a maximum speed of Mach 3.5, and a range of about 11 km. CROTALE NG entered production in 1990, and is currently in service with the French Air Force, and has been exported to Finland, Georgia, and Greece.

Firing trials of a new CROTALE NG variant known as CROTALE Mk3 started in 2007, and the new variant has demonstrated a range of more than 15 km. It can operate in a stand-alone mode or in conjunction with other Mk 3 systems.

Introduced in 1989, the ROLAND 3 missile has a more effective warhead, an improved proximity fuze, and a maximum range of 8 km. In 1998 France and Germany embarked on a VMV upgrade programme intended to allow their ROLAND systems to remain in service until 2015/20. This involved replacing the existing optical sight with a GLAIVE electro-optical integrated IR sight assembly whose 8-12 micron band thermal imager, eye-safe laser range-finder, and IR localiser would give the system a third operating mode. It also simplified the man/machine interfaces by installing a microprocessor-based BKS system consisting of the LS control and guidance computer, KS co-ordination computer, and the BK commander's operations and fire unit control panel.

Upgraded French ROLAND systems will be able to fire the VT-1 missile, but Germany did not require this capability. Although devel-

Photo: MBDA

A modernisation programme has maintained the effectiveness of MBDA's ROLAND system.

opment of an improved missile designated RM5 was funded by France and Germany, it failed to attract orders and was shelved in 1991. Development of a further-improved ROLAND system designated M3S was begun in 1996. This adds new surveillance and tracking radars to the VMV configuration, but has yet to attract a customer.

In 2001, MBDA made the first vertical ground launches of MICA air-to-air missiles. These and subsequent tests confirmed the viability of MICA as a SHORAD system, and in 2005 France announced its first order for what became designated VL MICA. The system is made up of a Tactical Operations Centre (TOC) and between three and six multi-round launchers for MICA missiles fitted with either IR or Radio Frequency (RF) seekers. It can provide 360 degree coverage against aircraft, helicopters and air-to-ground missile threats. Once launched, the missiles fly under inertial guidance, then transition to the seeker for the homing stage of flight.

MBDA and Diehl BGT Defence are developing the LFK NG short-range missile which is intended to replace the FIM-92 STINGER MANPAD missiles that currently equip Germany's WIEZEL 2 OZELOT short-range air-defence vehicles. Due to be fielded under Germany´s Flugabwehr (SysFla) SysFla air-defence project, the LFK NG is a 28 kg missile with IR-homing guidance, and a maximum range of 8 km.

By the late 1990s, the UK faced the problem that RAPIER (and the Royal Navy's SEAWOLF short-range SAM systems would need to be replaced. Realising that a single type of missile could meet both requirements, MBDA began work on the Common Anti-air Modular Missile (CAMM), a 99 kg vertically-launched missile suitable for land and naval use.

Once launched out of its canister by a cold-gas system that will produce a minimal launch signature, the missile will fly a turnover manoeuvre towards the threat, ignite its rocket motor, then fly towards its target. Initially it will use inertial guidance updated by a dual-band two-way datalink, switching to a Ku-band active-radar seeker for terminal homing.

The CAMM missile first entered service as part of the SEA CEPTOR naval SAM system aboard the Royal Navy's Type 23 class frigate ARGYLL, which made its first firings last year. Development efforts are now focussed on the land-based variant. A truck-mounted launcher able to carry 12 missiles was used for early test firings, and a similar scheme was adopted for the Rheinmetall MAN Military Vehicles HX77 8x8 launcher vehicle which is now being delivered to the British Army as part of the SKY SABRE air defence system. Other components of the system are a truck-mounted Saab GIRAFFE Agile Multi-Beam (AMB) medium-range 3D radar, and a Rafael Advanced Defence Systems Modular, Integrated C4I Air & Missile Defence System (MIC4AD) fire-control centre.

Photo: MBDA

MBDA displayed the land-based version of its CAMM missile at the DSEI 2017 exhibition in London.

Photo: MBDA

The use of a vertical-launch technique has given MBDA's MICA air-to-air missile an additional SHORAD role. Fighter aircraft and surface-to-air launchers can draw on a common stock of RF – or IR-guided missiles.

Russia's first SHORAD systems were IR guided weapons similar in concept to the US CHAPARRAL. Although the 9K31 STRELA-1 (SA-9 GASKIN) and 9K35 STRELA-10 (SA-13 GOPHER) were deployed in large numbers, Russia's equivalent to RAPIER, ROLAND and CROTALE was the radar-guided Almaz-Antey 9K33 OSA (SA-8 GECKO). Test firings began in 1965, and showed the need for an extensive redesign of the missile and launch vehicle. Series production of the resulting OSA-M began in 1971, allowing the system to enter service in the following year. The OSA system was mounted on a wheeled vehicle fitted with an H-band surveillance radar, a J-band target-tracking radar, an 9Sh33 electro-optical tracker, and four ready-to-fire 9M33-series missiles. These are steered by a command-guidance system.

The system sold well on the export market, entering service with around 25 countries, and production ended in 1998. Although at least five users have retired the system, the numbers remaining in service have made the OSA an attractive candidate for

modernisation schemes that replace much of the existing electronic subsystems with modern equivalents. These include the Tetraedr 9K33M3-1T OSA-1T, and the Polish OSA-AKM-P1 Zadlo.

First fielded in 1986, the Almaz-Antey TOR (SA-15 GAUNTLET) is based on a tracked chassis whose turret carries a target-acquisition radar, a tracking radar, and eight vertically-launched missiles. The first version to enter service was the 9K330. This was based on the GM-355 chassis manufactured by MMZ. This was followed by the 9K331 TOR M1, which used the GM-5955 chassis and had a second guidance channel, so could engage two targets simultaneously.

The next major upgrade was the 9K332 TOR-M2E. Offered on an either wheeled or tracked chassis or in towed form, it has an improved fire control radar coverage, and four guidance channels, allowing up to four targets to be engaged simultaneously. It can be armed either with eight 9M331 missiles or 16 of the newer 9M338 missiles.

HISAR-A is the short-range component of Turkey's planned tactical SAM system. Like the longer-ranged HISAR-O, it uses a single-stage missile powered by a dual-pulse solid-propellant rocket motor guided initially by datalink, switching to an imaging infrared (IIR) seeker for terminal homing. Both missiles have a high degree of commonality, and use the same seeker, control system, high-explosive fragmentation warhead, and impact and proximity fuzes. Development of the radar, command & control, and fire control systems for both programmes is by Aselsan, while Roketsan is responsible for the missiles.

Two types of self-propelled launch system are planned; one based on an armoured vehicle, and the other on a wheeled chassis. Both will be armed with vertically-launched missiles. The tracked system will include a fire-control system incorporating a 3D phased-array search and track radar, and an electro-optical system incorporating thermal and daylight TV cameras, but the wheeled version will have no sensors but will be linked to a command control system via a mast-mounted datalink.

Russia's KBP 2K22/9M311 TUNGUSKA (SA-19 GRISON) combines gun and missile armament. Intended to defend motorised and armour formations, it consists of a GM-352 tracked chassis fitted with an E-band search radar, a J-band tracking radar, eight Fakel-designed KBM-built 9M311 missiles, and two 30 mm liquid-cooled 2A38M twin-barrel cannons. The guns can be fired on the move, but the vehicle has to halt in order to fire its missiles.

This tactical limitation was removed in the follow-on system. KBP's 96K6 PANTSIR-S1 (SA-22 GREYHOUND) retains the two 2A38 30 mm guns of the TUNGUSKA (with a reduced ammunition load), but can fire guns or missiles while moving. The system entered service armed with 12 command-guided 9M335 missiles (also referred to as the 57E6). These are similar to the 9M311 missiles used on TUNGUSKA, but have a longer tandem boost motor and a larger-diameter second stage. These changes extend the range to 12 km, or 18-20 km in the case of the 57E6E export version.

Initial TV reports of the Russian deployment of PANTSIR to Syria showed the standard version, but later footage showed the much-improved 72V6-E4 combat vehicle, which has a surveillance radar based on two phased-array antennas mounted back-to-back. The original radar could conduct only a single engagement, leaving the system's electro-optic sensor unit to handle a second. The new radar operates at a frequency of about 40 GHz, and can guide missiles against three targets simultaneously, while the EO subsystem handles a fourth engagement. The designation PANTSIR-S2 has been associated with a version that is reported to team six 57E6E missiles with two 30 mm cannons.

Planned developments of several SHORAD systems look to blur the boundaries between this class of weapon and medium-range SAM systems. The PANTSIR-SM variant currently entering service has a new missile with a maximum range of 40 km, while in March of this year, Russia's Interfax news agency reported that work was under way to develop a hypersonic missile for PANTSIR that would have a maximum range of 50-60 km.

MBDA has studied a longer-ranged version of its CAMM missile. Developed as a private venture, CAMM Extended Range (CAMM-ER) would use an elongated missile powered by a new rocket motor of extended length and increased diameter, and fitted with cruciform strakes intended to improve the missile's lift-to-drag coefficient. These changes would give the missile a maximum range of 45 km. The first customer for the new variant was Italy, which needs to replace its current ASPIDE/SPADA systems.

Despite the US DoD's traditional disinterest in the SHORAD mission, it seems that the concept is now being re-explored. In February 2017, the US Army sought sources for "Manoeuvre-SHORAD" solutions. But it is questionable whether this will prove a marketing opportunity for European systems. In the mid-1970s, the US ROLAND programme was touted as a demonstration that the US DoD was prepared to procure a major weapon system from Europe. In practice, it proved the opposite. ■

Photo: Aselsan

Turkey's HISAR-A will be deployed in the truck-mounted configuration shown here, or on a tracked chassis equipped with vertical launchers.

Photo: Rosoboronexport

Almaz-Antey's TOR (SA-15 GAUNTLET) vertically launched missile system has attracted orders from more than ten export customers.

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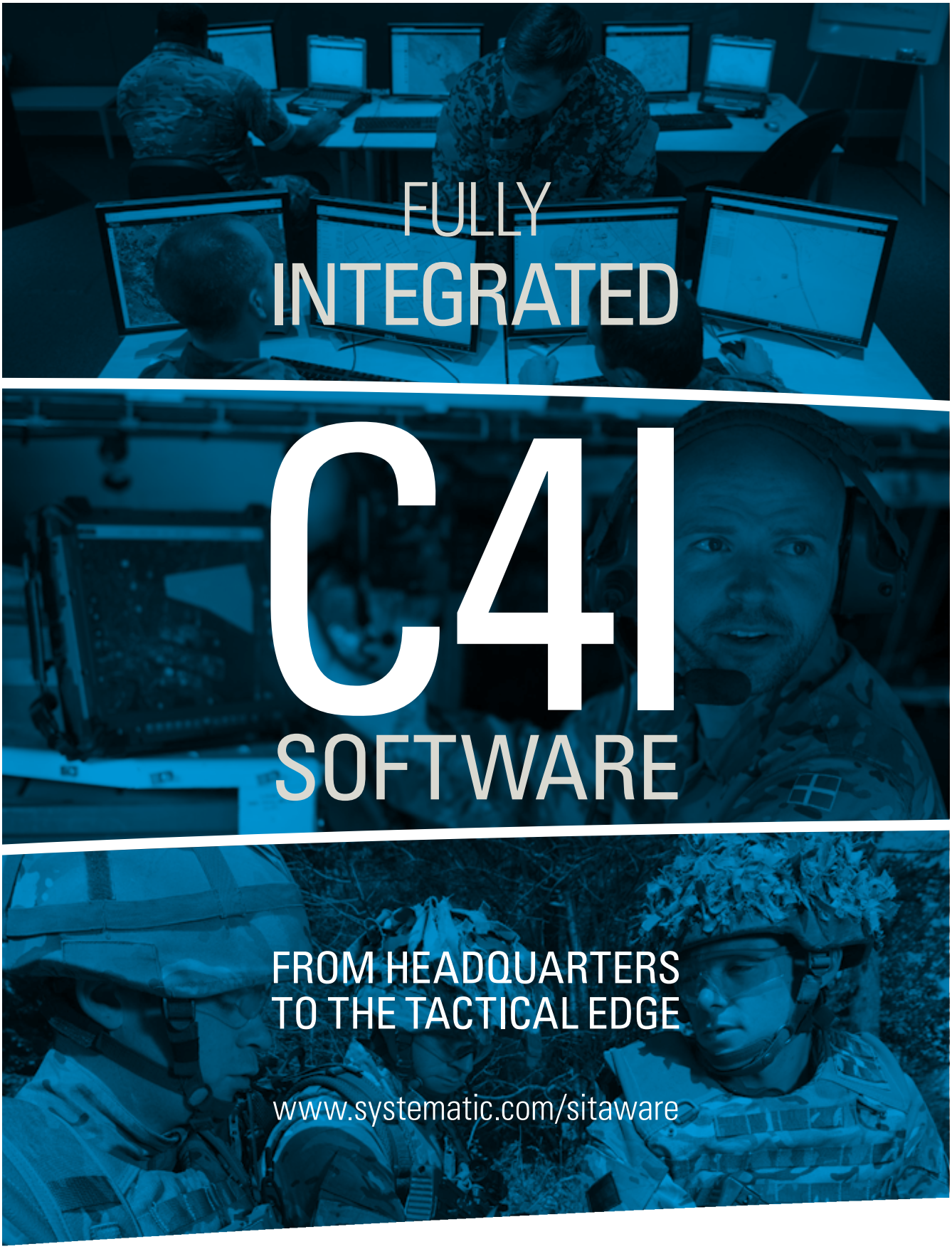

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