Protective Technologies

by ***Matt Minshall***

Matt Minshall is a former Army officer who saw service in Belize, Canada, Germany, Northern Ireland, Zimbabwe, Oman and Sierra Leone. Since retiring from the Army in late 1995 he has been a defence and security consultant specialising in MoD defence and maritime security. In this article he looks at protective technologies for both mounted and dismounted soldiers for reducing casualties from IEDs and roadside bombs.

Demographic increases in developing countries and the need to control diminishing resources probably mean that we have entered an era of persistent conflict. In recent years our military operations have seen a shift in the style of engagement as part of the changing face of modern warfare. IEDs and roadside bombs are being effectively utilised by an often invisible enemy who is able to hide among the local population and practise unconventional and asymmetric warfare against all elements of our deployed forces. We are taking a heavy toll in lives and disabling injuries and, while all losses are a tragedy, they are accepted as a facet of war if all possible protection measures have been utilised. Research and development into protective measures must be exhaustive if we are willing to send a dwindling youth population into danger.

Technology may dominate the battlefield and provide the winning factors, but only face-to-face dialogue will win the peace. This process begins with the soldier on the ground, in danger, and we must seek to protect him by all means available. While there are evolving measures – by prediction, deterrence and neutralisation – that seek to prevent an enemy hitting its targets, the need for effective passive armour will continue and research must persist in this field. Technology, which is essential for development, is only there to assist or enable soldiers to perform their roles. Tank battles are not fought between tanks, but between soldiers using mobility, protection and firepower. All technology should be examined, but its role must be applied with common sense; and we must remember to equip the man – not man the equipment. We must seek to protect the soldier in every aspect – by training and procedures, strategy and deployment timing, legal support and political loyalty, welfare and post conflict care and, the most publicly debated, that of physical protection.

The aim of this article is to examine areas where protective technology can keep soldiers away from harm, and to argue the case for the continuance of the need for effective passive solutions – such as hard armour plates, blast deflectors and spall liners – when technology is found wanting.

The Threat

So, how can we physically protect our servicemen and women? The general threats to soldier and vehicle include those in the table below. This range of threats is not new but their applications – particularly in the use of IEDs – are, and ballistic protection must develop quickly to stay ahead. Manufactured munitions effects can be predicted and their data is defined by NIJ[1] and NATO STANAG 4569[2] criteria, against which protection measures may be created. An IED, however, can be multi-faceted – from a handful of simple explosives embedded with nails, to artillery shells embedded in concrete, and simple shaped charges causing devastating explosively-formed projectiles (EFPs). The performance of IEDs is difficult to predict and although many organisations are working hard to establish predictive data, it will take time to formulate and may never be precise.

Threat	Abbreviation	Delivery	Weapon/Effects	Comments
Kinetic Energy Weapons	KE	High-velocity weapons, Grenades, Mortars, Mines	Bullets, Shrapnel, Fragments	
Chemical Energy Weapons	CE	Low-velocity missiles	Shaped Charges (HEAT)	
Improvised Explosive Devices	IED	Non-factory explosive devices	Blast, Shrapnel, Fragments, Heat	Including Explosively Formed Projectiles (EFP)
Note: This is a generic listing based essentially on counter-insurgency threats				

[Chart courtesy of Greg Dennison, senior research engineer, Remington Arms Company, inc., NDIA Small Arms Symposium, Las Vegas, 11 May 2004]

Survivability Against IEDs

The favourite and well-used illustration of the survivability onion[3] is shown at Figure 1.

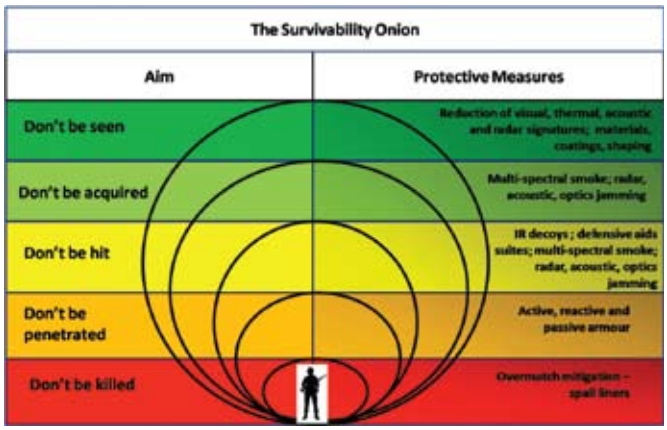

Figure 1: Survivability Onion

But with the greatest current threat to our forces being the roadside bomb and IED we can adapt the onion as shown in Figure 2.

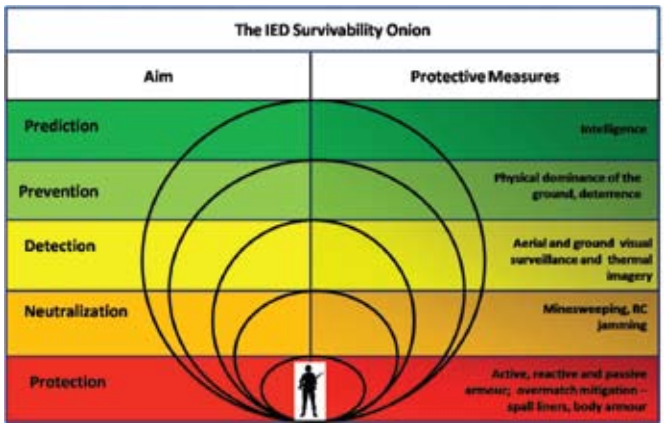

Figure 2: IED Survivability Onion

The aim, in all cases, is to stay as far in the green zones as possible to minimise casualties. So the intention is that we predict, detect and neutralise as early as possible, or as it has been described, 'left of boom'[4] – in other words to prevent strikes.

Active Defensive Systems (ADS) offering early detection and stand-off disruptive measures against RPG7-type missiles – such as Trophy[5] and Shark[6] – are maturing, but ADS may not be constantly efficient against an innovative enemy who will swiftly adopt tactics that will overcome the effectiveness of such expensive technology.

The use of basic technology to create stand-off defence is manifest in steel bar, grill or cage armour. This has the effect of initiating the shaped charge warhead away from the vehicle, thus reducing the penetration capability. Although simple and effective, this solution is cumbersome and heavy, but clever use of aluminium provides similar protection, at less than half the weight of traditional steel.[7]

Reactive Armour

If strikes cannot be avoided then the next stage is armour that reacts to the impact of a weapon to reduce the damage done to the vehicle being protected. It is most effective in protecting against shaped charges and long rod penetrators. The most common type is explosive reactive armour (ERA). Reactive armour, however, can be defeated with multiple hits in the same place, as by tandem-charge weapons – such as RPG 29 [8] – which fire two or more shaped charges in rapid succession. Without tandem charges, hitting the same spot twice is much more difficult.

Another form of reactive armour is Electric Armour, which is being actively researched by government[9] and industry. This armour is essentially made up of two or more conductive plates separated by space or an insulating material, creating a high-power capacitor. In operation, a high-voltage power source charges the armour. When an incoming body penetrates the plates, it closes the circuit to discharge the capacitor, transferring energy into the penetrator, vaporising it or turning it into a plasma significantly diffusing the attack. It is not known whether this will function against both kinetic energy penetrators and shaped charge jets, or only the latter. This technology has not yet been introduced on any known operational platform, not yet being sufficiently mature to risk soldiers' lives with.

Electric Armour is made up of two or more conductive plates separated by space or an insulating material, creating a high-power capacitor.

Composite Armour

However good the intelligence, technology and tactics, strikes are inevitable. Therefore in the foreseeable future there seems to be an important role for passive armour systems, and the need to find solutions with the highest protection level at the lowest weight must endure. Steel armour is far too heavy for the modern concept of light, well-protected highly mobile vehicles. Therefore composites are now commonly in use. Composite armour consists of layers of different material such as metals, plastics, ceramics or air. Most composite armour is lighter than metal equivalents, but instead occupy a larger volume for the same resistance to penetration. It is possible to design composite armour that is stronger, lighter and less voluminous than traditional armour, but the cost is often prohibitively high (as shown in Figure 3), restricting its use to

especially vulnerable parts of a vehicle. The future demands that military vehicles will be smaller, lighter, but with equal or greater mobility and offensive effectiveness than current steel-based examples and composites – high-strength, light metals are the only solutions.

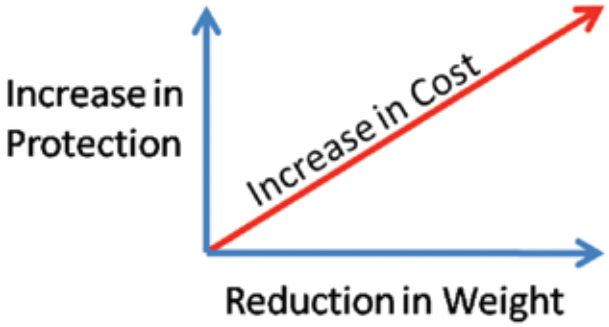

Figure 3: Essential cost challenge to composite ballistic protection

Composite armour is designed to absorb the energy of the impact, and prevent penetration and internal damage by the projectile or its residual effects. Composite armour is usually provided in modules or tiles, such as LIBA®,[10] which are composed of a mosaic of hard (ceramic) materials, and soft but strong backing made of composite fibres. The frontal plane is covered with softer material – such as rubber or other composites – which is used to dissipate the initial impact and minimise the damage to the internal mosaic, thus retaining its multi-hit capability.

Composites can also mitigate the effects of overmatch by chemical energy weapons, such as RPG 7, by the provision of a spall liner, as shown in Figure 5.

Survivability of Dismounted Soldiers

Protection for dismounted soldiers is just as complicated to address. The Survivability Onion may be further adapted from the point of view of the infantryman for whom it will probably look like Figure 6.

Body armour must find the compromise between tactical mobility and protection; meaning high protection at low weight. The basic components of helmet, soft armour covering the torso and hard armour insert plates covering vital organs are commonly provided, yet still cumbersome and limit full tactical flexibility. Composites are the key to body armour. Modular tactical systems which combine hard and soft armour are now available and they can range from a light vest of soft armour – providing kinetic energy and blast protection – up to torso-covering, flexible ceramic plates which prevent penetration from high-velocity armour piercing incendiary ammunition and supported by neck, groin and limb cover, but we need to look at every aspect that technology can bring.

Therefore in the foreseeable future there seems to be an important role for passive armour systems, and the need to find solutions with the highest protection level at the lowest weight must endure

Operational necessity is funding technology and rapidly reducing the time between fantasy and reality. The comic book superhero of a few years ago may be the soldier of our grandchildren's era, or even sooner: for example, liquid and electric supported systems have gone from the presumptuous

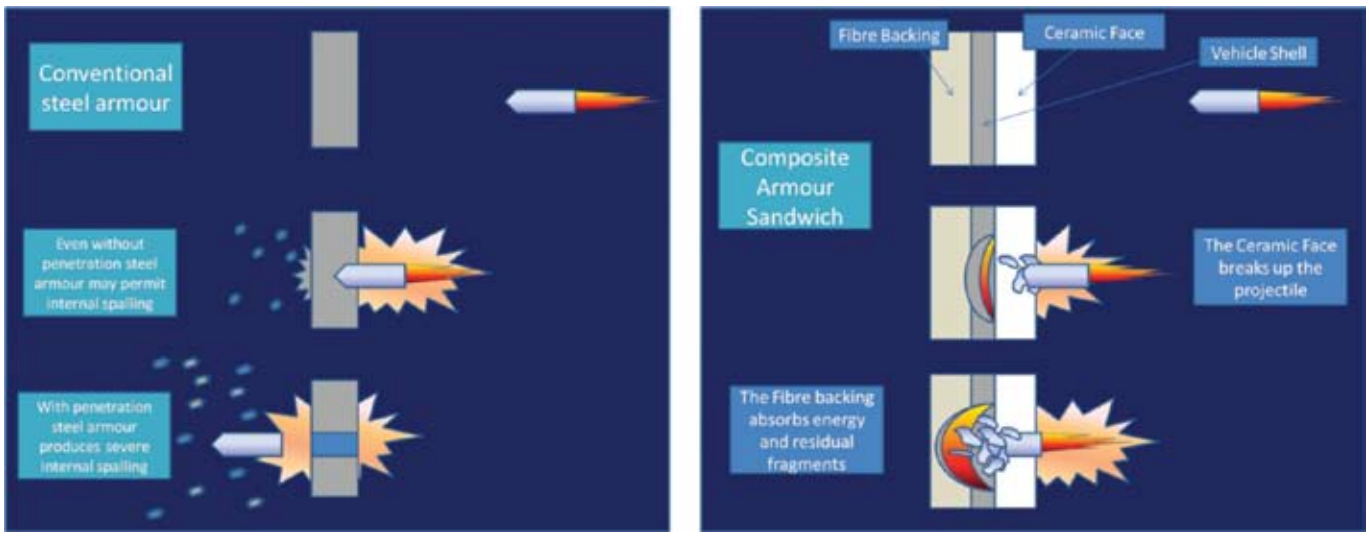

Figure 4: Illustration of conventional steel armour compared to composite sandwich of ceramic and fibre armour solution.

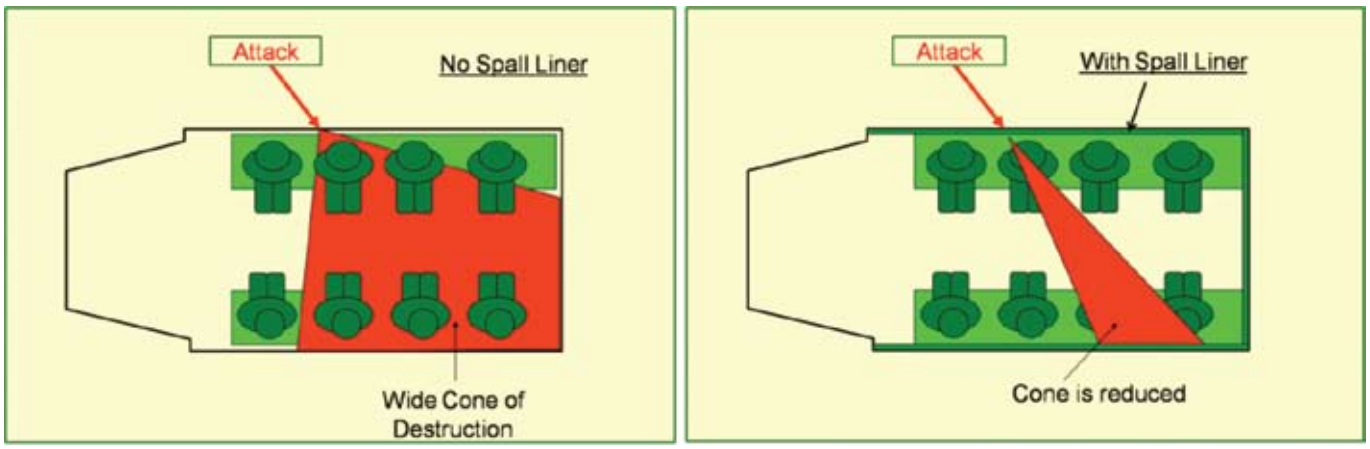

Figure 5: Mitigation effects of employing a spall liner

to the possible within a relatively short period and these should be examined.

Liquid Body Armour

One of the latest concepts of body armour is both flexible and lightweight and is realised by the addition of liquid to existing materials.[11] It is not yet mature enough to be reliable, but it has the potential to be a replacement for or supplement to cumbersome vests.

It is possible to design composite armour that is stronger, lighter and less voluminous than traditional armour, but the cost is often prohibitively high

There are two types of liquid body armour in development both with a base of aramid[12] commonly used in bulletproof vests. When a projectile hits an aramid surface, the layers of material spread the impact over a wide surface area and the aramid fibres stretch, expending energy and slowing it down in the process. Although aramid is a fabric, it does not have the same flexible properties as clothing. Twenty to forty layers of aramid are required to stop a projectile, and the layers are relatively stiff. It is also heavy, with a vest weighing as much as 4-5kg, even before ceramic inserts for additional protection are added.

The term 'liquid body armour' is often misleading. It is not a loose fluid flowing between layers of solid material. Both types of liquid armour in development work without a visible liquid layer, using instead aramid soaked in one of two fluids.

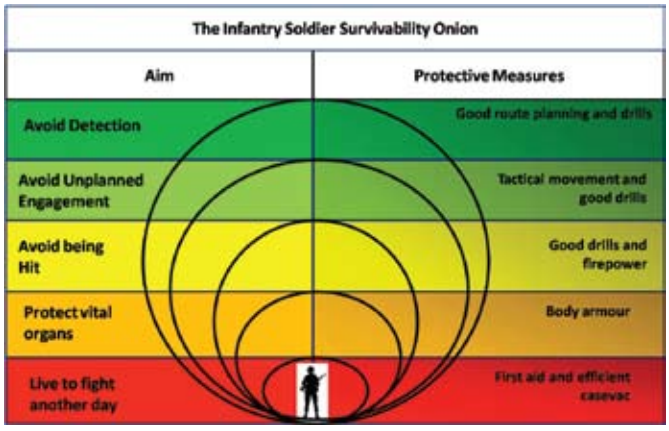

Figure 6: Survivability Onion for dismounted soldiers

Both types of liquid armour in development work without a visible liquid layer, using instead aramid soaked in one of two fluids

The first is a shear-thickening fluid (STF), made of silica (sand) particles suspended in polyethylene glycol (lubricant) which hardens rapidly when encountering mechanical stress or shear. In liquid body armour using STF, the fibre strands of aramid are fully permeated by the fluid. When an object strikes the aramid, the fluid immediately hardens, making the aramid stronger. The hardening process happens in milliseconds, and the armour becomes flexible again afterwards.

The other fluid that can reinforce aramid is magnetorheological (MR) fluid.[13] MR fluids are oils that are filled with iron particles comprising between 20% and 40% of the fluid's volume. When

exposed to a magnetic field, the particles line up, thickening the fluid dramatically, affecting both the shape and the viscosity of MR fluids. The hardening process takes around twenty thousandths of a second. The effect can vary and this technology currently may only be offering the soldier a heavy jacket with no protection.

The Duty of Care

After 9/11 the West reacted by engaging in two major operations and this has so far cost well over $1 trillion.[14] Technology is expensive and we must be careful that we do not assist terrorists in one of their key strategic aims, which is to "strangle the enemy financially",[15] in pursuit of a gold-plated platinum shield, when simpler solutions may serve.

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In summary, protection of our soldiers is a fundamental duty of care. This article has demonstrated that active and reactive protective technology can provide the necessary battle-winning force protection and that all contemporary technologies must continue to be explored, exploited and employed. However, even with sophisticated technologies there will always be a requirement for common-sense solutions such as effective passive armour, which is reliable, affordable and relatively easily improved with simple technology for which adequate resources should be allocated based on threat-based operational requirements. ■

NOTES

1 NIJ – US National Institute of Justice: the law enforcement agency that is the research and development branch of the Department of Justice

2 NATO AEP-55 STANAG 4569 is a NATO Standardization Agreement covering the standards for the "Protection Levels for Occupants of Logistic and Light Armoured Vehicles". The standard covers strikes from kinetic energy, artillery and IED blasts

3 The survivability onion is well used and may originate from Integrated Survivability Assessment, a paper by Gary L. Guzie of the US Army Research Laboratory in April 2004, although it may well have been devised earlier

4 Left of Boom, a term used to describe the prediction, detection and neutralisation of attacks before strikes, is possibly first mentioned in the *The Washington Post* series of articles 'About Left of Boom: The Fight Against Roadside Bombs', Sunday 30 September 2007

5 The Trophy Active Defense System (ADS) was developed by RAFAEL aiming to provide armoured vehicles with a new level of protection against most current anti-tank threats. The Trophy active protection system creates a hemispheric protected zone around the vehicle where incoming threats are intercepted and defeated. It has three elements providing threat detection and tracking, launching and intercept functions. Source: http://defense-update.com/products/t/trophy.htm, accessed 22 November 2009.

6 The SHARK active protection system is developed under cooperation between Thales and IBD. It is designed to protect armoured fighting vehicles from shaped charge (RPGs and anti-tank missiles) and IED while degrading the potential threat of KE threats. Source: http://defense-update.com/products/a/ads-ibd.htm, accessed 22 November 2009.

7 Such as BAE Systems LROD Cage Armour

8 Source: http://world.guns.ru/grenade/gl04-e.htm, accessed 19 November 2009

9 Source: http://www.dstl.gov.uk/access/science_spot/case_studies/electric_armour.php, accessed 19 November 2009

10 Lightweight Improved Ballistic Armour (LIBA®) made by TenCate Advanced Armour is made up of ceramic pellets in a rubberised resin with fibre backing. It has high multi-hit capability, is resistant to shock and vibration and can be repaired easily in the field

11 Source: http://science.howstuffworks.com/liquid-body-armor1.htm accessed 31 October 2009

12 Aramid fibres are a class of heat-resistant and strong synthetic fibres. They are used in aerospace and military applications, for ballistic-rated body armour fabric, and as an asbestos substitute. The name is a shortened form of aromatic polyamide. They are fibres in which the chain molecules are highly oriented along the fibre axis, so the strength of the chemical bond can be exploited

13 A magnetorheological fluid (MR fluid) is a type of smart fluid. It is a suspension of micrometre-sized magnetic particles in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid. Importantly, the yield stress of the fluid when in its active ('on') state can be controlled very accurately by varying the magnetic field intensity. The result is that the fluid's ability to transmit force can be controlled with an electromagnet, which gives rise to its many possible control-based applications

14 *The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11*, Amy Belasco, specialist in US defense policy and budget, Congressional Research Service, 28 September 2009

15 'The Strategy and Objectives of Al-Qaeda', *The American Thinker*, 9 February 2007 http://www.americanthinker.com accessed 27 November 2009