INNOVATIVE TECHNOLOGY

In our Winter/Spring edition, we explored the importance of innovation for the acquisition of military equipment. In this issue, we take this forward and look at particular innovative technologies. Doug Beason, from the Los Alamos National Laboratory in the US explains why Directed Energy Weapons will change future warfare; Dirk Ellinger, the German MoD Research and Technology Director, gives several examples of work in hand; and Ben Godfrey from MBDA looks at composite materials.

The E-Bomb: Changing the Way Future Wars Will Be Fought

by *Dr Doug Beason*

Doug Beason is Associate Director of the Los Alamos National Laboratory in the US, and a board member of the Directed Energy Professional Society. Here he describes the advances made in developing directed energy weapons and their effect on future operations. Portions of this article have been taken from the author's book, The E-Bomb, *published in the UK by Perseus Press, 2006, and reviewed in the Winter/Spring edition of* RUSI Defence Systems.

The Humvee-mounted Active Denial System (ADS) advanced concept development technology unit

The date is late fall, 2007, and a cacophony of sound reverberates through the city – sounds of cars honking, animals braying, police whistles blowing. The air is dense, humid and heavy with the smell of dung, car fumes and urine. Beggars crowd the street, fighting for rupees given in embarrassed sorrow by widows, visiting dignitaries and students who now stare agape at the world's most extreme poverty.

The place is New Delhi, India, home of the world's largest democracy and unwavering friend to the United States.

Until now.

An unruly crowd surges through the trash-laden streets, picking up stragglers as the mob grows in frenzy. Women and children slip around corners and cover their faces, trying to hide, but they are swept along with the roiling crowd. Shouts erupt, rocks are thrown. Within minutes, the growing riot approaches the iron gates of the American Embassy.

A glass bottle filled with gasoline and stuffed with a burning rag is hurled over the gate. Burning liquid from the Molotov cocktail splatters across the ground. Someone shoots a gun. In a panic, with unpredictable mob mentality, the crowd surges forward.

Stoic US Marines guarding the entry points fall back into position, drawing their automatic weapons. After the debacle of the Iranian hostage situation 30 years before, the marines are under unwavering orders not to give up the Embassy, no matter what. Their orders are 'shoot to kill'.

Their actions could set relations with the US back 50 years.

Behind them, hundreds of American and Indian Embassy staff members are hastily ushered into basement 'safe' areas. The situation is escalating out of control.

Women and children in the crowd are roughly grabbed, to be used as 'human shields' to prevent the Americans from stopping them. The rioters know the marines won't kill innocent women and children, and they use their hostages to advance toward the Embassy. The insurgents boldly shove their innocent shields in front of them as they advance.

The crowd surges forward. The guards must act.

The political balance with one of America's greatest democratic allies now hinges on the split-second decisions made by the gun-toting marines, young men only 19 and 20 years old, kids barely out of high school – not diplomats. Visions of their comrades being overrun at Fallujah and Mogadishu swirl through their heads. After the debacle of the Embassy being overtaken by terrorists masquerading as students in

Iran, the US government had sworn that no American embassy would ever be overrun again. Ever.

These young warriors are faced with immense pressure to react, to defend this small vestige of American soil ... but they also know their commander has provided them with an ace in the hole.

Up until now, the marines only had two options: to shout at the insurgents, pleading with them to stop – or to shoot them. A simple binary decision. Shout or shoot: to be screamed at or to die.

Today, there is a third option.

As the marines raise their rifles, a deep humming sound envelops the compound. Without warning, the rioters feel intense heat, as if a giant, invisible oven has suddenly opened in front of them. Within seconds the pain is unbearable. They cannot think, they cannot reason – they can only react.

They turn and flee, trying to escape as far as they can from the invisible heat. Screaming in pain, the rioters drop their weapons as they sprint away. No one looks back as they scramble to flee.

Curiously, none of the women or children in the mob are affected. As if divided by a Maxwellian Devil who can distinguish between hostile intent and innocence, only those people who had been carrying weapons had felt the intense, excruciating pain – a heat like that from a supercharged oven. The unexplained defensive weapon is that accurate, that precise.

In less than a minute the streets are clear, the compound is eerily quiet. Warily, the women and children disperse, unharmed.

As the marines put down their weapons, the only noise in the Embassy is the low mechanical thrumming that comes from a geodesic sphere, inconspicuously located on top of the sprawling building. Inside the sphere is a phased-array dipole antenna that directed the millimetre waves from the world's first non-lethal Directed Energy Weapon, 'Active Denial'.

Science Fiction? No … Active Denial is being tested today. And if funding had not been cut at the turn of the century, it could have been used to quell the urban warfare in Baghdad, in Fallujah and in other cities where allied warfighters have been stationed.

Artist's conception of the US-Israeli Mobile Tactical High Energy Laser (MTHEL) (courtesy of Northrop Grumman)

And countless lives might have been saved.

Technology Wins Wars

The size of the army matters, but it's the technology that wins wars.

At the height of the Roman Empire, Roman legions armed with arrows, long-staffs and shields used precise, steadfast formations to devastate the more numerous, but ill-equipped, barbarian hordes.

The invention of the stirrup in the sixth century gave horsemen the ability to use their mount as a lethal weapon for the first time – an astonishing transformation from the centuries-old use of transportation or ploughing, allowing warriors to combine their horse's mass and speed with their devastating thrust of a spear.

In 1232 during the battle of Kai-Keng, the Chinese repelled Mongol invaders with the first known use of rudimentary rockets powered by gunpowder, called 'arrows of flying fire'.

On 9 August 1945, a lone B-29 bomber flew over Nagasaki, Japan, and dropped a single atomic bomb that ended World War Two.

And in February 1991, precision-guided 'smart' bombs, ground-hugging cruise missiles and invisible Stealth fighters forced the massively equipped and much more numerous Iraqi army to its knees.

In 2003, the war in Iraq just missed seeing the introduction of a new generation of sophisticated weaponry, a new type of weapon based not on missiles, bombs or bullets … nor on anything you can hold in your hands. This weapon is made of ordinary light – in the same spectrum of energy found in your microwave, your light bulb or in your TV remote control. It's called Directed Energy (DE).

Science Fiction?

The date is just before the end of the decade. The place is Osan Air Force Base, home of 7th Air Force and the 51st Fighter Wing, located just 48 miles south of the Demilitarized Zone, the DMZ. Negotiations have broken down and tensions between North and South Korea have never been higher.

The International Atomic Energy Agency has been barred from inspecting North Korean nuclear power plants, and although North Korea has been claiming for years that it has nuclear weapons, only now is there indisputable evidence that enough plutonium has been siphoned away from the residual commercial fuel to construct numerous atomic bombs.

45,000 American troops are stationed on the 55-year-old DMZ, along the 38th parallel. They are on highest alert as 500,000 South Korean soldiers back them up. But facing them across the border are over 1.5 million North Korean regulars ... armed with an unknown number of Taepodong-3 ballistic missiles, now in all probability tipped with nuclear warheads. And all can reach the western United States within 45 minutes of launch.

Home to the last oppressive, totalitarian government in the world, little is known about the North Korean capabilities, or its motivations. All that is certain is that the world sits at the brink of war.

Suddenly, seven sleek missiles roar from silos deep in the valleys of North Korea. Three rockets streak to the south, arrowing toward Seoul and its five million inhabitants. The other four missiles veer east – heading for San Francisco, Los Angeles, Seattle and San Diego.

Within seconds the missiles break through the cloud layer. In another two minutes they will exhaust the fuel in their upper stages and will soar unfettered to their targets in an arcing, parabolic trajectory. Officials estimate that 10 to 50 million deaths will occur over the next few days. Nothing can be done. The situation is hopeless.

Until now.

Orbiting at 40,000 feet above ground in a 'racetrack' pattern, 100km south of the DMZ, two specially modified 747s fly safely away from enemy fire. Infrared seekers onboard the 747s pick up the bright rocket plumes as the Taepodong-3 missiles break

through the cloud layer.

In milliseconds – mere thousandths of a second – low-power targeting and tracking lasers lock onto the missiles. On-board computers calculate trajectories and, in the nose of the converted 747s, concave mirrors five feet across swing toward the still-rising missiles.

Roaring to life, giant turbo-pumps at the rear of the planes blast a supersonic mixture of hydrogen peroxide and iodine through specially designed nozzles, ready to power the world's largest laser. At the front of the plane, deformable mirrors shaped by hundreds of actuators, embedded behind each mirror's highly-polished surface, change the mirror's surface hundreds of times a second.

This is 'adaptive optics', invented by the military and now used by every major astronomical telescope in the world. Adaptive optics make a perfect laser beam as the deformities in the atmosphere are taken out of the laser, even before the beam leaves the plane.

Thirty seconds after the Taepodong-3 missiles break cloud layer, nearly a million watts of invisible laser energy streak from each of the 747s at the speed of light. The 747s hold their beams razor sharp against the missiles, heating their metal skin with enough power to allow the missile's fuel tanks to explode from internal pressure within seconds.

One by one, like picking off skeet targets at a shooting range, infrared beams from the two AirBorne Lasers jump from missile to missile. Exploding debris falls on enemy territory, leaving South Korea and the United States unharmed.

Again, is this Science Fiction? No. The first 747 AirBorne Laser is undergoing flight tests today.

New Technology, New Thinking

DE weapons – lasers and high-power microwaves (HPM) – have come of age. Over the past two decades, DE power has increased by nine orders of magnitude – over a billion times – from milliwatt to megawatt. This is like supercharging your laser-pointer used for highlighting PowerPoint slides to shoot down ballistic missiles a hundred kilometres away.

DE is making revolutionary, world-changing advances in warfighting and battling terrorism. And it's doing so today. It's happening so fast, it's the equivalent of a 'Military Future Shock'.

The Tactical High Energy Laser (THEL) pointer-tracker which follows the target and points the laser

The first DE weapons are being developed, and in the next few years when they are unleashed on the battlefield, they'll be more revolutionary than the longbow, machine guns, stealth airplanes, cruise missiles, nuclear submarines, or the atomic bomb. The war with Iraq may very well be the last not to depend on DE weapons.

The reason is that national leaders will soon have the ability to respond to threats anywhere in the world, and instantly deter them with infinite precision, and all at the speed of light.

And more profound, the dynamic change made to international relations will reverberate throughout society. It will transform our way of life. This is because DE is not just about winning wars; it's more than just a new weapon in the warrior's arsenal. It's about a completely new way of thinking, a new way of employing both strategic and non-lethal force, and interacting in the international community.

The large, mechanistic allied defence establishment that served so well throughout the Cold War will be transformed to a lighter, more agile, and information-centric force –shifting hundreds of thousands of people and billions of dollars from the government to the commercial marketplace.

Over the next decade, the shift will result in the most profound change to the US Defense Department since World War Two. Just as tourism was revolutionised by the jet engine, and communication was forever changed by the transistor, the next societal change will be fuelled by DE, and specifically in the form of Directed Energy Weapons (DEWs).

The Next Big Thing

But does everyone have this view? And if DEWs are so revolutionary, then why aren't they being championed as 'the next big thing'?

DEWs have many critics, and societies such as the American Physical Society (APS) – the world's premier organisation of physicists – have sponsored several politically-charged studies as they themselves are skeptical of the benefits and capabilities of this controversial use of DE. The first APS study was conducted in 1986 in response to President Reagan's Strategic Defense Initiative (sometimes referred to as 'Star Wars').

The criticism is not limited to strategic uses of laser weapons; High Power Microwaves have their foes as well. Human rights advocates are up in arms both about the long-term, unknown effects of Active Denial, and the possibility of receiving eye damage from the AirBorne Laser as laser light glints off ballistic missiles.

Other criticisms face DEWs as they make their way to the battlefield: what happens if they proliferate – that is, what if gangs get them, criminals that could disrupt our way of life? Or even worse, what if terrorists obtain DEWs?

And are there any long-term effects that might occur when exposed to DE? For example, how many remember American soldiers marching and flying into atomic fallout clouds in the 1950s, or US citizens being used as unsuspecting LSD and bio-warfare test subjects?

Apart from its potential, DE's future is ridden with political and societal uncertainty. So the question is: will politicians ever allow it to be used under fear of these possible long-term effects?

Well, they'd better decide fast, because DE is not science fiction. DEWs are real weapons being tested in real scenarios, today. DE is maturing on a daily basis, and advances in technology are accelerating its use.

The only reason these major DEW systems were not used in the last war with Iraq is that they were still being tested by PhDs, and were not yet ready for the battlefield. Largely shrouded in a highly classified environment, DEW research is conducted by a cadre of closed-mouthed technical wizards. The government labs that worked on revolutions of military affairs in the past – nuclear weapons, stealth airplanes and precision-guided weapons – have now turned their talent to what they hope is their next ace in the hole: DEW.

And they're on a path to move them to the battlefield. What they're betting on is that before the world knows it, DEW will break into the headlines as it provides an

overwhelming, asymmetrical advantage in war.

And those nations that are not prepared to exploit DE will stagnate … or, even better for us, lose by clinging to outmoded, traditional forms of warfare. They will fall behind in the same manner as civilisations that clung to the bow-and-arrow lost to the rifle … just as bullets and bombs will fall to DEW.

Cheaper, Faster, Better

When the laser was invented on 6 July 1960, everyone from military strategists to science fiction writers predicted that DE would be used as weapons. But people were quickly disappointed when lasers didn't cause a 'Buck Rogers' blow-it-up effect, like you'd see in a *Star Wars* movie. Tests showed that the most sophisticated lasers in the early sixties only produced a low-power, although intensely brilliant, point of light. The reason was that the technology for producing the laser was relatively immature.

In the early 1960s, laser power levels were measured in thousandths of a watt. Typical laser pointers today, available for a few dollars at any office store, produce unwavering but low-power beams on the order of 5 milliwatts (or 5 thousandths of a watt), a hundred thousand times less power than the light bulb shining in your hallway.

Laser weapons require a billion times more power. But, because of investments in science and technology over the last 40 years, DEWs are now poised to be a cheaper, faster and better method of winning wars and saving lives.

Despite DE's obvious advantages, what about good old 'bombs and bullets', the stuff that won wars for years?

One problem with them is that bullets and bombs have reached the limit of their ability. Military authorities cite that in World War Two it took approximately 5000 bombs to destroy one target.[1] In Vietnam, the addition of laser-guided technology dropped that number to around 500, an increase of a factor of 10. Precision-aiming technology advanced, and by 1991 in the Iraq war it took approximately 15 bombs to destroy a target; in Kosovo, then Afghanistan, that number dropped from 10 to 5 bombs. Even more precise weapons were used in the 2003 war with Iraq, and ratios approached one target killed for every weapon dispensed.

However, with the ultimate limit of one bomb being used to destroy one target, warriors can't do any better: they will be limited by the number of bombs they can carry, even if they use a weapon system such as the B-2, which can hit dozens of targets per flight.

Another drawback is that bombs and bullets reach their target by following the law of gravity – that is, they travel in trajectories constrained by ballistics and thus take a finite time, sometimes up to minutes, to reach their target. This is where DEWs can radically change the nature of warfare, and why national and military leaders are so excited about its use: not only because it ignores the law of gravity or that it's incredibly precise, but because it can engage a target near-instantaneously, thousands of times faster than any conventional weapon.

Speed of Engagement

DE travels at the speed of light – 186,000 miles a second. This velocity may be incomprehensible to anyone who is used to the normal world where people jog at 3 miles an hour, cars zip down the Interstate at 65 miles an hour, and the fastest airliners traverse the Atlantic at speeds approaching 600 miles an hour. Even the world's absolute speed record, held by astronaut General Tom Stafford, commander of Apollo X, when his spacecraft returned from orbiting the Moon, stands at only 28,547 miles per hour, or 8 miles a second or 0.002 % the speed of light – yet still the world's all-time speed record for a human.[2]

Light, be it produced from the sun or from a light bulb hanging in your hallway, travels fast enough to circle the Earth over 7 times in a second. That means that DE – light that is actually in the form of lasers or microwaves – can reach its target in less than the blink of an eye.

Another way to view this is by comparing the equivalent muzzle velocities as a way of measuring military effectiveness. A bullet's muzzle velocity may be as high as 6000 feet a second, but DE's 'muzzle velocity' is greater than 982,000,000 feet a second – over 160,000 times faster than a typical bullet.

Another advantage to DE is that it can flood areas, allowing one DEW to defeat hundreds or even thousands of targets, as opposed to the best, absolute limit of one bomb killing one target. This gives the military the ability to carry a 'deep magazine', and thus shorten the so-called 'logistics tail' of ferrying a crate of bullets or bombs from the factory to the war zone to the fighter.

The Impetus for the Next Revolution

World-changing events are fuelled by revolutions in military affairs, and they are brought about by inventions of disruptive technologies so profound that they forever change the nature of society.

DEWs are so different from traditional weapons that they will be the impetus for the next revolution. As such, DE will change strategy, national policy and ultimately, affect billions of dollars in funding for the military Services.

Despite the dissimilarities of lasers and HPM, both are DEWs and their similarities far outweigh their perceived differences. That's because lasers and HPMs both:

- Exploit different parts of the electromagnetic spectrum.
- Travel at the speed of light.
- Are impervious to the effects of gravity or ballistic motion.
- Are ultra-precise, allowing for enormous amounts of energy to be applied exactly where the warfighter wants – in contrast with kinetic energy precision weapons, which, although accurate, have devastating, unintended 'collateral' effects due to blast and fragments.

Such an ultra-precise weapon, capable of striking around the globe near instantaneously, provides the technological advantage needed to defeat the next generation of adversaries.

And that advantage is only provided by DEWs capable of engaging the enemy at the speed of light – true 'E-Bombs', exploiting the electromagnetic spectrum. ■

NOTES

Doug Beason's book, *The E-Bomb,* is published by Da Capo Press, priced £15.99. To order the book for the offer price of £13.99 inc. p&p, call 01235 465500, or email direct.orders@marston.co.uk, and quote reference EBDB01.

1 Actual accuracy numbers are inferred from the US Strategic Bombing Survey: Summary Report (Pacific War), 1 July 1946, Washington D.C., US Government Printing Office, 1946. The Strategic Bombing Survey gives gross numbers that range from 10% of bombs hitting the target area (250 feet to 1000 feet from target) to 50% for low-altitude, carrier-based planes

2 Biography of astronaut General Thomas P. Stafford, National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, Texas 77058