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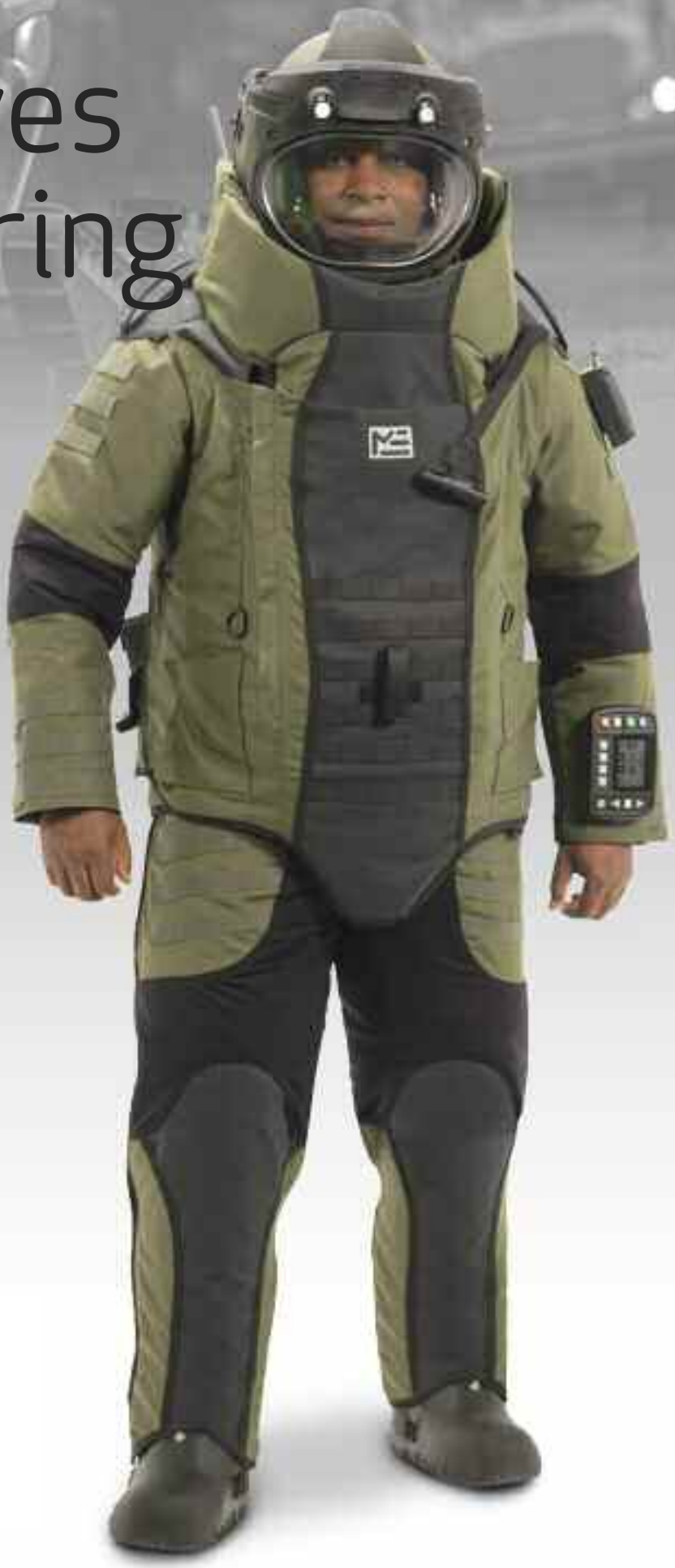


Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Meeting the IED scourge: enhanced protection and robotics for stand-off EOD

By **Andy Oppenheimer** AIExpE MIABTI

For several decades the improvised explosive device (IED) had been the weapon of choice for terrorists and insurgents. According to the UK-based charity Action on Armed Violence (AOAV), between 2011 and 2015 IEDs were responsible for over 59% of all global civilian deaths and injuries from explosive weapons. In 2015, 22 countries were impacted by suicide bombings, more than ever before recorded; there were 16,199 IED casualties, 85% of which were civilians.

The deployment by insurgents and terrorists of IEDs, in particular roadside IEDs, is the operational scourge of our time. They are used in vast numbers to maim and kill civilians and enemy forces, where they are highly effective at slowing troop movements.

In military arenas, troops face IEDs hidden along roads or in buildings. They have multiple disguises - as construction material, cement blocks, in anything from empty drinks cans to animal carcasses. Buried IEDs are often laid in 'daisy chain' configurations - a string of IEDs wired together so that a single signal will detonate all the munitions at the same time, or in sequence. Widely spread webs of IEDs, connected to one trigger wire, produce an explosive force multiplier against advancing forces.

The spread of ISIS

Forces driving ISIS out of occupied areas of Syria and Iraq, already plagued with years of IED attacks, are enduring an even deadlier round of their deployment by the most dangerous and brutal terrorist group in modern times. Where ISIS retreat or temporarily depart from areas under their control, buildings and streets are booby-trapped with hundreds of IEDs, some laced with chlorine or mustard agent, which have injured dozens of Iraqi EOD (explosives ordnance disposal) technicians.

As well as ongoing jihadist bombings in several African countries, mainly by Boko Haram and Al-Shabaab, ISIS attacks have spread to Libya, Turkey, Egypt, and Yemen as vehicle-borne IEDs and other suicide bombings. And to Europe - Paris in November 2015, Brussels in March 2016, and a host of other ISIS-inspired incidents which combine other M.O. (guns; knives; trucks to run over pedestrians) with person-borne and vehicle-borne IEDs.

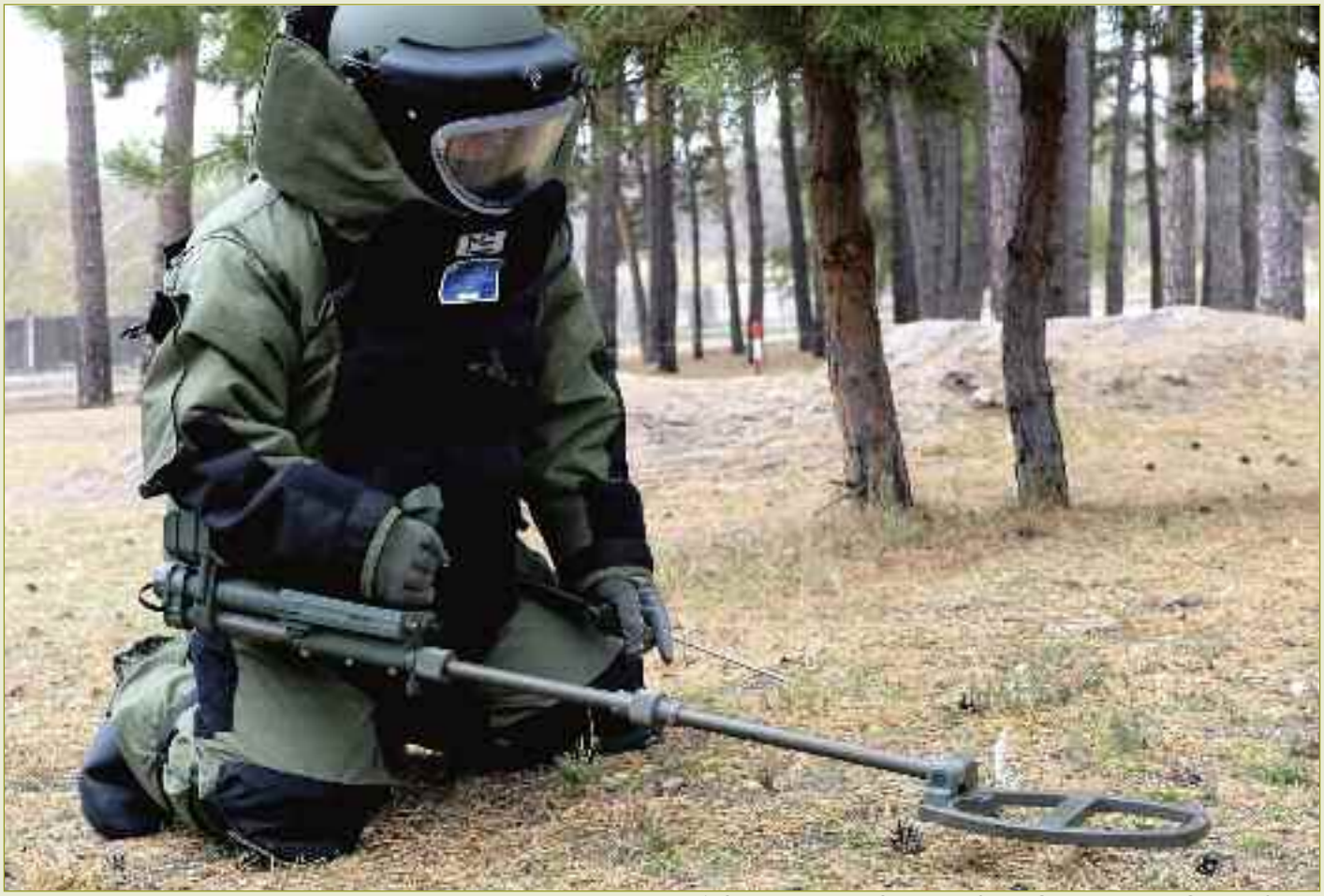
And ISIS is not the only group involved. The threat of IED deployment continues in Northern Ireland, by dissident republican groups, and by right-wing extremists on the rise in many countries.

And terrorist IEDs are not the only fruit. To name just one other example that required an EOD response, in January bomb disposal teams were called out to almost 600 schools in the wake of UK government advice about stocks of a potentially hazardous chemical, 2,4 dinitrophenylhydrazine (DNPH). This warning sparked a flurry of calls to the Army, which carried out hundreds of explosions. The Department for Education said it worked with the Army to support schools with "necessary disposals".

Protecting the bomb techs

Enhanced fragmentation such as ball bearings is regularly used in IEDs deployed by ISIS, Boko Haram, and many other terrorist groups. When the devices are triggered, the blast propels them like bullets to wreck life and limb. Other long-lasting injuries such as traumatic brain injury (TBI) as well as PTSD (post-traumatic stress disorder) are all too prevalent.

How do we protect the troops and bomb technicians who, in many countries, risk their lives to protect civilians and comrades from the scourge of IEDs? Advancing detection and dismantlement technologies and equipment provide a stand-off distance from the IED to protect the EOD technician: UGVs (unmanned ground vehicles – robots) and robotics, sensors, X-ray systems, jamming systems, sensors and disruptors, and ground penetrating radar (GPR) carried on blast-resistant vehicles. In both military and civilian arenas many bombs are set off from a distance rather than attempts at dismantlement.



NATO has assisted in EOD training for the State Emergency Service of Ukraine. ©NATO

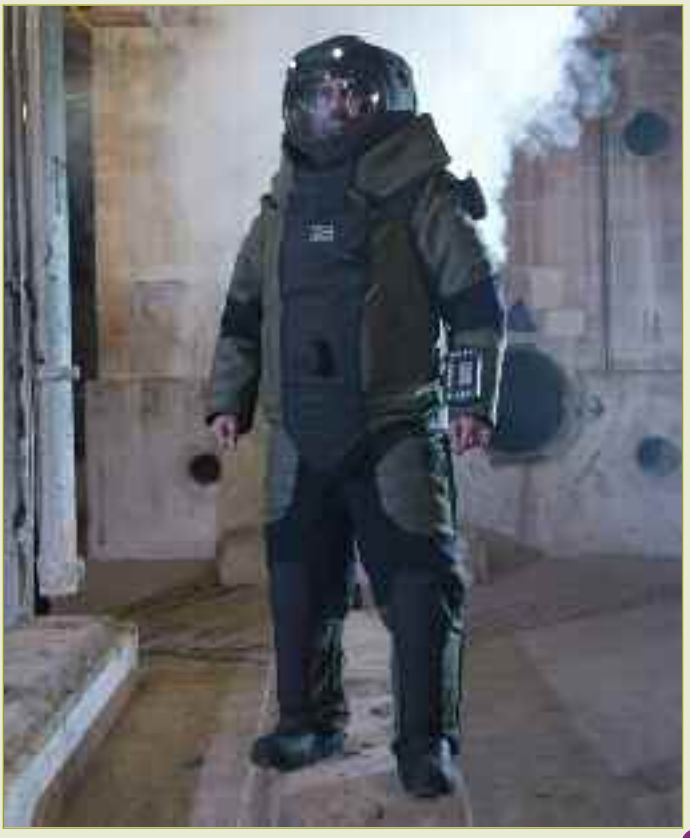
Mine-resistant ambush protected (MRAP) vehicles have been through several phases of evolution and varying levels of success in affording protection. A new generation of MRAPs has a V-shaped undercarriage, which has helped to some degree to deflect blast impact. Enhanced seating designs also add protection.

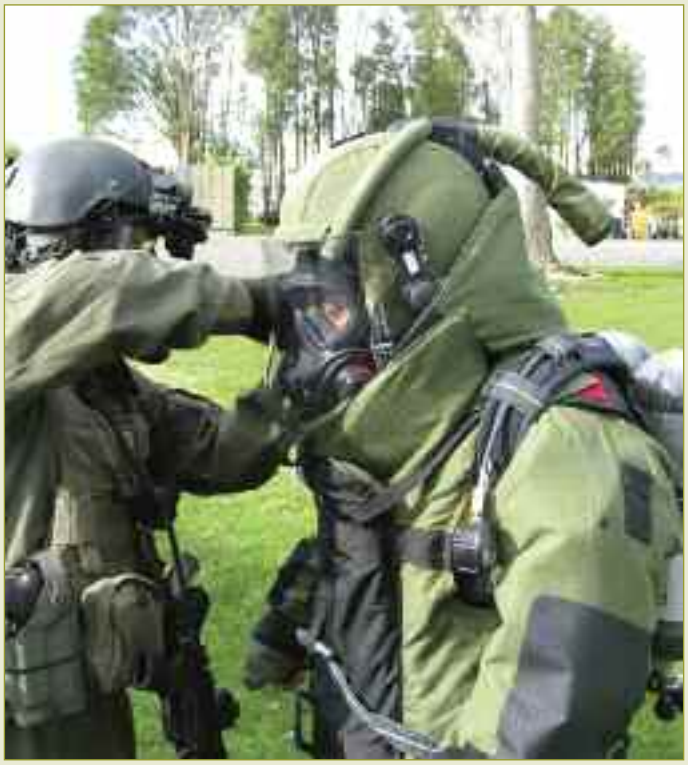
PPE for bomb techs

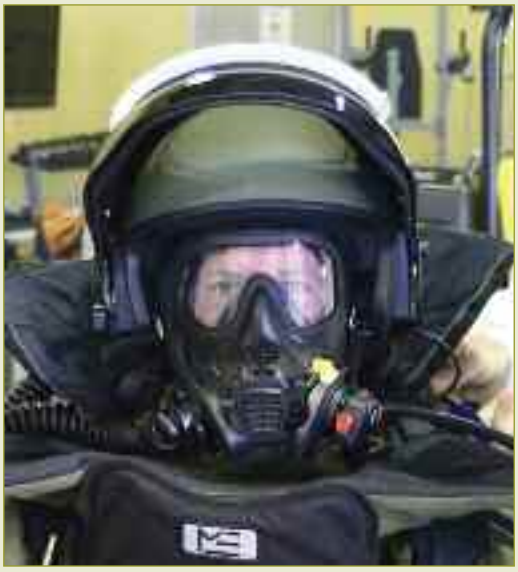
Of ultimate importance is personal protective equipment (PPE). The most commonly used EOD PPE in military operations, the advanced bomb suit (ABS), is made with layered low-weight, high-strength materials such as Nomex, Kevlar, foams and multiple plastic composites to provide maximum protection. Blast panels are fitted on the outside of the suit to help protect the neck, arms, upper torso and legs from fragments and other high-speed projectiles flying as fast as 1,667 metres per second. Rigid composite ballistic panels offer reinforced protection to the chest, lower abdomen and groin and a spine protector and raised supportive neck collar overlaps the helmet may help to curb the blast effect. Variations depend on weather conditions and the theatre of operation.

New designs of the bomb suit aim to make it lighter while affording maximum blast protection; the standard suit weighs more than 35 kg. The next-generation Med-Eng EOD-10 bomb suit is a substantial step forward in having lighter and more agile protective layers to reduce the overall physiological burden - and provide greater mobility and dexterity. The Med-Eng BCS 4 cooling system reduces the debilitating effects of heat on the body and redesigned jacket, trousers and EOD 10 helmet reduce weight and fatigue to improve situational awareness, protection and fit. There is an integrated Voice Command system to provide enhanced warning and confirmation.

The next-generation Med-Eng EOD-10 bomb suit has been completely redesigned to reduce weight and fatigue while giving enhanced protection against overpressure, fragmentation, impact and heat. ©Med-Eng







The Med-Eng EOD-9 bomb suit and helmet with the Scott First Responder Respirator (FRR): a platform mask that supports multiple breathing options that can be prepared in advance for specific scenarios, and adapted during operations. ©RMC

The Scott Safety General Service Respirator evolution Specialist (GSReS) is integrated with the Med-Eng EOD-9 bomb suit. ©Scott Safety

Training in conflict areas

What if troops and techs are not equipped with protective gear, stand-off detection, and training? Despite examples of great heroism and an infusion of equipment and training, Afghan and Iraqi soldiers still lack robots and protective suits and resort to "jerry-rigged tactics" to locate and defuse IEDs. In July 2013 an Afghan bomb tech risked his life to defuse a suicide vest after a failed bombing in Jalalabad. He managed to disarm the would-be bomber - who was hog-tied to prevent him from blowing the device up and was wearing an ANA (Afghan National Army) uniform - with just a wire-cutter.

In February 2012 a bomb squad officer approached a suspect plastic bag in the Nigerian city of Kaduna. Wearing no protective gear, he looked inside the bag, which exploded, killing him. His death could have been prevented through better training. Consequently, the Africa Defence Forum issued the following basic precautions to soldiers confronting the plague of IEDs deployed by Boko Haram:

Training of soldiers in high-risk areas would emphasise that they wear flak jackets and helmets at all times. As well as being taught first aid, especially in basic treatment of shock, they would need to know how injuries are caused by the pressure wave of the primary blast, the multiple types of wounds caused by the secondary blast, and injuries resulting from being thrown by the blast.

Vehicles employed in high-risk areas should be equipped with bags of fine sand on their floors as protection. Any material larger than fine sand becomes a missile in the event of an explosion. Passengers in armoured vehicles should ride on top, rather than inside (although this may render them vulnerable to snipers). Hatches on armoured vehicles should be left cracked open, with the latch pin still in place, to permit the dispersion of the concussion of an IED explosion.

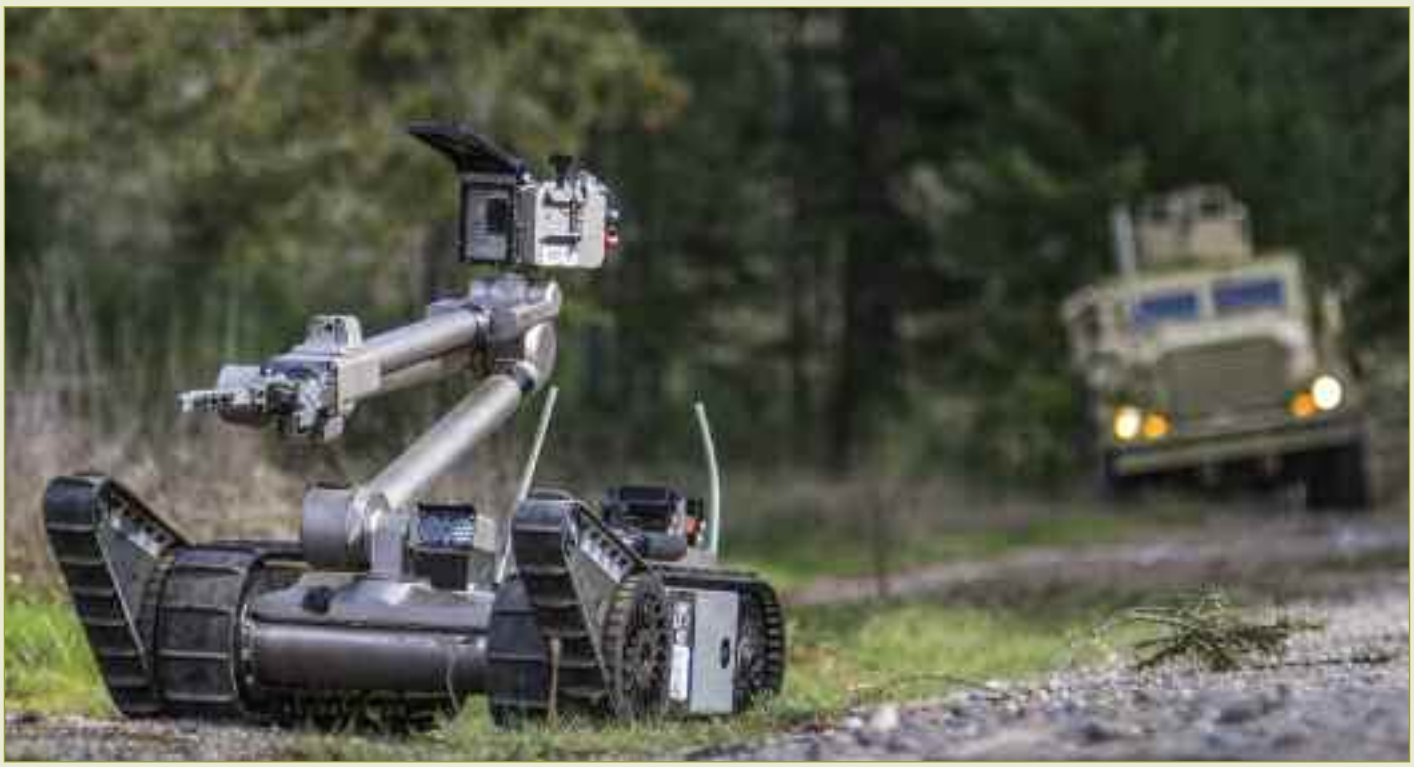
A footpath through an otherwise difficult-to-negotiate street or field is an obvious place for IEDs; footprints may end abruptly and other signs are disturbed soil or sand, isolated boxes along a trail, abandoned vehicles and military equipment, and street trash that include wires, strings, and bits of steel. When occupying an empty building, it should be assumed that the building has been rigged with IEDs. This clearly also applies to the hundreds of booby-trapped devices encountered by Iraqi and Kurdish forces fighting to retake ISIS-held territory.

Protecting against CBRN (Chemical, biological, radiological and nuclear)

The growing use of improvised chemical devices in some theatres, disposal of legacy chemical munitions, and the threat of radiological dispersal devices means response to such situations and incidents requires enhanced physical protection. Operating in any environment that poses a CBRN threat has a substantial physiological burden due to the PPE that must be worn and its debilitating effects, particularly in very hot conditions.

The CBRN risk is primarily through attack on the nervous system, the respiratory system, contamination of the blood and exposed surfaces of the body. An IED close by that releases or leaks a blister or thickened nerve agent could cause penetrative contamination of the body as well as of protective equipment and robotics. An example arose in an UXO mission in Wales in 2009, when the detonation to dispose of a legacy munition washed up on a beach on the Gower Peninsula released sulphur mustard with unexpected after-effects for two EOD operatives.

New designs set out to reduce the physical burden to the bomb tech along with lessening risks to internal injury caused by blast and fragmentation - as well as providing physical protection against CBRN and novel explosives. As described by Brian Clesham and Richard Mead in the June 2016 issue of CBNW Xplosive, Scott Safety's General Service Respirator (GSR) and First Responder Respirator (FRR) has been included in systems integration trials with a Chemical Protection Undergarment from the German company Blücher, being trialled as a chemical protective layer for the Med-Eng EOD-9 bomb suit and helmet. Integration of the EOD helmet and respiratory protection are also critically important in CBRN conditions.



A PackBot robot leads a convoy. ©Endeavor Robotics

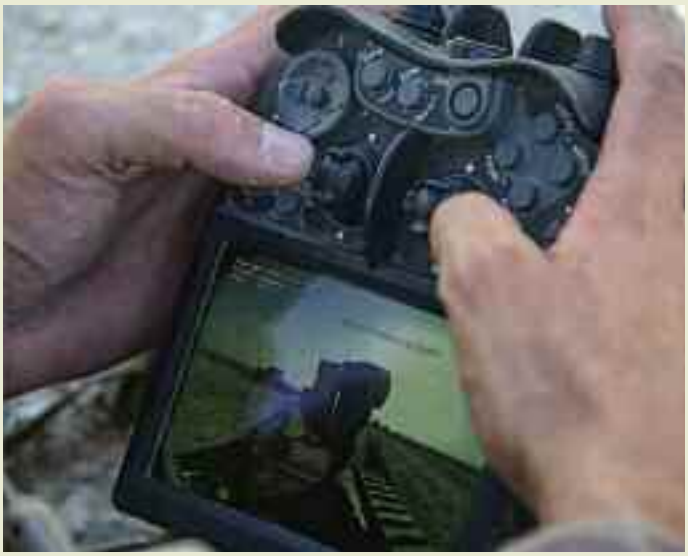
Both the Scott General Service Respirator evolution Specialist (GSReS) and the FRR are platform masks enabling respiratory options to suit varied scenarios. This means that an approach movement could be undertaken using the Powered Air Purifying Respirator (PAPR), with a simple lever enabling the switch to Self-Contained Breathing Apparatus (SCBA) at the incident site if required at any time due to the nature of the threat, which can change. SCBA also becomes essential if there is a poor air atmosphere such as in a confined space.

Send in the robots

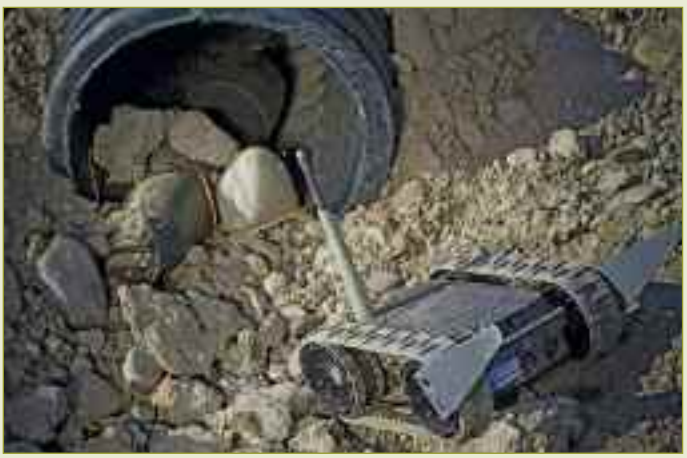
Unmanned ground vehicles (UGVs), also termed remotely operated vehicles (ROVs), have long been used for both military and civilian EOD missions, enabling operators to detect, analyse and disrupt the device at a safe distance. Equipment for an increasing number of users worldwide is also designed for smaller, lighter and less costly robotic platforms carrying less weight. Robotics greatly reduce 'the unknowns' and enable a more refined assessment from which to base threat mitigation measures without risk to life, and undertake functions which cannot be readily undertaken by an operator. Using a remotely operated vehicle as a mobile meteorological and CBRN detection platform is fully part of this process.

UGVs obtain visual information with advanced sensors as well as handling and placing objects with tools and weapons. They bring sensors up close to analyse and detect explosives. Of vital importance are camera systems that provide a live feed for data collection and information support.

UGVs can survey and analyse the device before and after the RSP (render-safe procedure) is applied. Portable X-ray systems on the UGV are used to radiograph the bomb before intervention to rapidly capture, collate and relay information on explosives, initiators, and booby traps back to the ICP (Incident Control Point) for it to be acted on swiftly. Multiple disruptors on the UGV precisely 'shoot' the innards of the IED and prevent the main charge from being detonated.



A US ordnance disposal craftsman controls the PackBot 310 robot to detect an IED during a training exercise.
©U.S. Air Force/Senior Airman Janelle Patiño



The 110 FirstLook robot is throwable, rugged, and expandable.
©Endeavor Robotics

Non-intrusive analytical X-ray equipment on the UGV can 'see' liquid or powder fill. Imaging systems such as the Pixium and Logos system can take high-resolution X-rays of the IED and produce a 16-bit picture in 10 seconds. The robot sends video footage back to the operator at a safe distance, thereby enabling a situation to be assessed prior to moving forward or entering a structure.

The surveillance camera can be mounted on the arm (low to the ground, high in the air, close or far from the gripper) or on an articulated boom. Modern robots have several cameras with multiple picture-in-picture views. Digital X-ray plates offer fast, one-click image acquisition and require only one image to be shot - at pixel sizes down to 50 microns. A very high dynamic range shows up fine wiring and circuitry detail.

ICOR Technology produces a lightweight live video X-ray imaging system, OpenVision Live Video X-Ray, to provide real-time video X-ray safely for hand held use without the need for evacuation of public areas, and also the SCANX SCOUT portable digital imaging systems. Vidisco Ltd makes portable digital X-ray systems for security inspections, such as for smuggled explosives. Each rugged system can be carried in rough terrain and operated in sub-zero or high temperatures, without cables on a battery, for at least five hours in the field. The system will provide high-resolution images for prolonged X-ray shooting within seconds, at a safe distance from the inspected object. Some UGVs also have detectors to survey and identify CBRN agents enclosed in the device, which may leak hazardous material.

Endeavor Robotics (formerly iRobot) provides a family of integrated, modular UGVs ranging in size from 2-227 kg and has delivered more than 6,000 systems worldwide. These include the 2-kg FirstLook, the under 9-kg SUGV, the man-portable Packbot, and the heavy-duty Kobra. The 510 PackBot - 4,000 of which are in service - can perform EOD, surveillance and reconnaissance, CBRNE/HazMat detection and mapping and can climb and descend stairs and navigate narrow passages. PackBot relays real-time video, audio, and sensor data while the operator remains at a safer stand-off distance.

Handheld for dismounted detection

For dismounted detection, the equipment is man-portable with the hands left free for other search tools. Compact X-ray systems with flat imaging areas can be carried in a small backpack which can be pre-cabled, then deployment takes only the time needed to place the imaging equipment at the target end, and start up the laptop and X-ray program at the control area.

Specialised tools enable the bomb technician to perform handling and even disruption of devices remotely at a significant stand-off distance. A typical remote manipulator introduces a standoff of 3m, compared with 0.6 m for a manual approach, and has thereby reduced the incidence of blast injuries. For handheld mine detectors in military operations, electromagnetic spectrum properties are now being explored to detect IEDs with minimal metal content, based on the acoustics of mine casings or combined with GPR carried on blast-resistant vehicles.

The other challenge is to incorporate into handheld detectors the human ability to spot wires, disturbed ground, and power sources, as is lightening the load - as handheld detectors incorporating new technology to counter non-metallic, hybrid threats are heavier than conventional metal mine detectors.

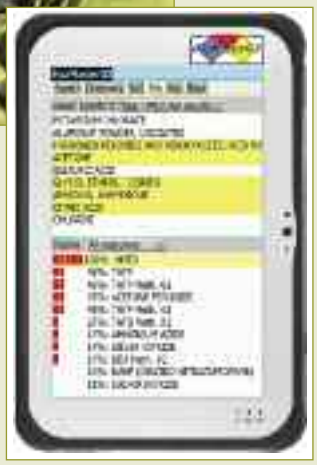
Chemical mixes

With over six billion chemicals in the world, added to which is the creation of HME and new chemical threats, first responders arriving on scene must consider themselves initially 'blind' - even if informed by prior intelligence. Questions arise over what key ingredients in an HME formulation are missing, what substitute ingredients could be used in a synthesis process if a preferred set of ingredients can't be obtained, and how much of a given formulation could be made from the identified source ingredients. Delay between observations to action jeopardizes the ability to effectively disrupt, dismantle and interdict across the entire network of HME, CWA and narcotics perpetrators.

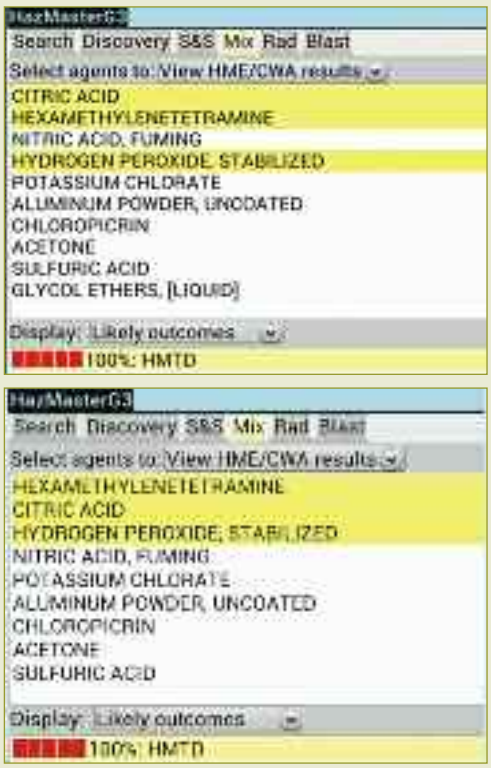
Helping to provide answers is the HazMasterG3 from Alluviam LLC - decision support software that can take identified samples from their detectors and virtually mix the chemicals to model what are the critical health, safety, and handling hazards being met by responders. By virtually mixing the chemicals identified by a detector, the HazMasterG3 can instantly model the specific formulation and quantity of the completed formulation being made – key actionable insights that may only become available later from subject matter experts (SMEs). The core database contains 167,000+ materials and trade names – a broad range of precursors that may be found in the field.

The detection company 908 Devices has produced the M908 for first responder teams to test various materials at the scene, from surface residues to ambient and headspace gases. The M908 will alert the teams that a priority threat is present by using a powerful form of chemical analysis to determine whether or not, for example, a powder on a table is being used to make an IED or an improvised chemical device.

A soldier at a command post supporting operations provides guidance to the commander, indicating the operational significance of a set of chemicals found by a reconnaissance team using the HazMasterG3. ©Alluviam



HazMasterG3 on a ruggedized tablet: one popular mobile HazMasterG3 configuration is an 18-cm MILSPEC 810G Android tablet that can fit easily into a cargo pocket or rucksack. ©Alluviam



Mixing selected chemicals can model formulation outcomes. The HazMasterG3 Mixtures screen permits an operator in real time to virtually mix chemicals found on scene to indicate what is being made from the highlighted chemicals. ©Alluviam

Disrupt the device

Once defeat-the-device operations became increasingly civilian-based, the emphasis was on neutralisation rather than detonation on site. Disruption causes the charge in the IED to be separated from its means of initiation - before it has time to detonate. It involves an array of state-of-the-art equipment - water disruptors and de-armers, and mobile, recoilless and lightweight disrupters, such as miniature exploders and non-magnetic toolkits.

The aim is to detect IEDs from a safe distance and generate a pulse of directed high-power electromagnetic energy to prematurely detonate the device (sometimes called 'controlled explosions' in the media) or to destroy its circuitry. Robot-mounted water disruptors utilise a water-projectile shaped charge to destroy IEDs by severing any detonation cord inside the device.

Alford Technologies, a familiar name to the Institute, pioneered the water-projecting disruptor for deployment against a range of IEDs. Its founder, Dr Sidney Alford, lined a shaped charge with water, initially casting aqueous jellies on the wall of conical cavities in hollow cones of homemade sheet explosive –so that 10 g of plastic could shoot a jet of water through 20 mm of steel. The Alford HE BootBanger water disruptor against VBIEDs has been widely fielded around the world, especially in Iraq, and the MiniMod Mk2 is a lightweight system ideal for disrupting IEDs ranging in size from a briefcase up to a large suitcase or even an animal carcass.

The Allen Vanguard IED Disruptor Kit is designed to penetrate thin walled IEDs using an IED water jet disruptor with a low probability of causing detonation. This is a multi-shot device capable of many firings without sustaining distortion to the main body. Chemring produces the WASP lightweight multi-shot disruptor for dismounted EOD teams. Easily carried and operated by a single person, it is suitable for conventional EOD or Special Forces dismounted operations. The company's EOD range also comprises recoilless stand-off disruptors, available in small, medium and large options for the neutralisation of unexploded ordnance and IEDs.

A military WMD team sample in an industrial setting, with the detection results from the detector used in the HazMasterG3 to indicate which likely finished products are being synthesized. ©Alluviam

Where weight is not as issue, the company offers 'Pigstick' and 'Hotrod' disruptors for tackling medium and heavy IEDs.

Veteran US-based disrupter company Proparms produces a new range of high powered, recoilless and lightweight disrupters that can defeat metallic targets such as pipe bombs, pressure cookers and propane tanks with a water shot only, further reducing risk of detonation. Weighing 3kg with 3 component parts plus ammo, in most cases it is possible to eliminate the need to use a high-explosive-activated bottle charge for large suitcase-type targets, thereby simplifying user training and reducing the need to use a HE procedure in an urban area.

The technologies and instruments to defeat the device are rapidly coming on stream - along with the vital training in their use - to help save the maximum number of lives while protecting operators in their highly dangerous work.

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