Oh Blast!

A Nato NC3A scanning system at work to detect makeshift bombs in vehicles

Although Coalition partners in Afghanistan are busy countering the IED threat, the number of these roadside bombs is still rising, according to the Joint IED Defeat Organisation (Jieddo). Inasmuch as these threats remain quite unsophisticated and are produced with homemade explosives, their lack of metallic content makes them difficult to find with conventional mine-detection equipment.

Paolo Valpolini

No explosively-formed projectiles have yet been used in the Afghan theatre of operations for this purpose and vehicle-borne IEDs are relatively rare, unlike suicide vest-type IEDs. Compared to Iraq, Afghanistan is therefore a less sophisticated but equally dangerous country from that standpoint – and detection remains a crucial problem.

The Joint IED Defeat Organisation follows three lines of operations: attack the network, defeat the device and train the force. The first bullet aims at finding and eliminating bomb makers and their supply sources before the bombs are made and emplaced. Tracing components is thus of paramount importance; the right assets, together with a command structure that allows tracking the network and thus reaches the higher levels of the organisation, is the answer, which involves airborne change detection, airborne radars and analytical support.

On the other hand, defeating the devices, which means neutralising them prior to detonation, involves their detection, the jamming of their triggering system and their early detonation. However, detection often allows disposal teams to neutralise the system and study it to acquire further knowledge on the opponent's skills and thereby find clues on how to trace the network. This is something that jammers (which mostly leave the devices undetected) and early detonation devices do not, of course, allow.

Within the Atlantic Alliance the Nato Consultation, Command and Control Agency (NC3A) started in 2005 to deal with the C-IED topic. The agency is responsible for taking the military requirement, elaborate a technical solution that meets the requirements, issuing the bid, installing the equipment downrange and providing support up to the end of the warranty. The NC3A is currently providing direct support to three locations in Afghanistan, namely at Isaf headquarters, Kaia and the Kandahar airfield, and its first task was to install standoff detection sensors against vehicle-borne and suicide bomber devices (see title illustration above). This involves vehicle and body scanners with multi-scan capability combining high-energy transmission and backscatter imaging that allows the identification of organic material (such as explosive precursors) and shape recognition. These systems are not only used on base sites: being mobile they can be used to set up vehicle checkpoints. The scanning time for a vehicle is less than ten seconds, a speed compensation system (Doppler radar) allows the vehicle to move through the gate at about five km/h.

A typical checkpoint consists of a scanning area, followed by a staging area where the vehicle remains until the analysis clears it and, in case of necessity, a search area. The layout is, of course, configured to reduce risks for Isaf soldiers to a bare minimum. The next research and development programme for the NC3A concerns ground-penetrating radars. The work is to focus on vehicle-mounted systems. The system should be able to detect metallic elements, such as command wires and non-metallic systems such as pressure plates (in which metal is no longer much used).

Persistent ISR is yet another alley. Nato is aiming at computer-assisted analysis of video footage, including from infrared cameras. The idea is to be able to exploit the imagery of an itinerary over a period of at least 24 hours (and more if needed) before the passage of a major convoy. In September 2009 the NC3A awarded Lockheed Martin UK a contract for the development and delivery of a Full Motion Video (FMV) system allowing for real-time (HD) video distribution, storage, archival and retrieval. This asset will be used to recognise and plan for unusual or suspicious events, track individuals, identify insurgents among civilians and also improve the detection of devices placed along Afghanistan's roads. In 2011 the NC3A intends, if tasked, to start a programme involving the use of hyperspectral sensors.

Another agency that is active in countering the IED threat is the European Defence Agency (EDA). In 2009 the EDA embarked on a project aimed at identifying which detection technologies could contribute to this capability in the short, medium and long term. Terifiec, an EDA Operational Budget study launched in January 2009, has provided insight into the pros and cons of terahertz technology, giving advice on how it could fit into the device detection algorithm. EDA is not limiting its initiatives to terahertz technology but is adopting a scenario-based approach aimed at defining the contexts in which devices must be detected, assessing for each of them what systems or technologies can best meet the needs, as there is no one technology that can serve as a panacea to save lives.

The combined Capability/R&T Workshop of July 2009 kick-started the scenario-based approach and paved the way for the launch of the Counter-IED Detection Expert Group, a government-only group for the moment, with representation from around ten participating member states. The group is to provide

A vehicle scanner, produced by American Science and Engineering installed in Afghanistan, through which vehicles are typically driven at the speed of a man on foot. (Nato Consultation, Command and Control Agency)

thorough recommendations by October 2010 for where research and technology is needed before bringing industry on board in order to translate the recommendations into the launch of projects – a phase tentatively scheduled for 2011. Several of the joint investment programmes currently ongoing at the EDA are related to IED detection. It is to note that Nato and EDA efforts are well co-ordinated as many members of the working groups are the same.

This panoramic picture allows viewing the whole processing area, which includes the scanning area, a waiting area where the vehicle awaits the results of the scan, and a containment area where the vehicle is directed if something suspicious is detected. (NC3A)

Foliage- and Ground-penetrating Radars

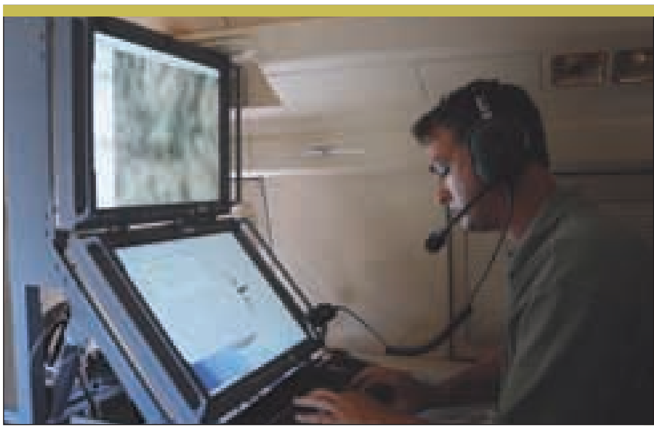
The capability to penetrate the ground with electromagnetic impulses and obtain a picture of what is buried underneath is certainly one of the most interesting. Foliage-penetrating radars (Fopen) and ground-penetrating radars are increasingly regarded as one of the key elements of mine and roadside bomb detection.

In 2005 America deployed to Iraq a C-12 aircraft equipped with a Penrad 6 synthetic aperture, continuous-wave radar developed by SRI International. In addition to this primary sensor, the aircraft carries an L-3 Communications Wescam 14 Skyball electro-optical turret. In the course of its deployment the radar was subjected to a series of software and hardware upgrades, including a two-fold output power increase. Known as the Horned Owl programme, what started as operational testing became an operational mission and the C-12 Horned Owl has flown over 680 combat sorties, finding 21 devices and 24 weapons caches totalling over 42 tonnes of buried ordnance. Mostly based on cots components, its limitations in hot desert conditions were obvious. In August 2008 SRI International obtained a $ seven million contract to complete a turn-key system using a King Air 200T aircraft with a Penrad 7 radar for a 90-day period to Iraq, as part of Desert Owl Phase Two. Not much is known about this improved ground- and foliage-penetration radar in its use for mine and IED detection.

In May 2007 Lockheed Martin was awarded a $ 40 million contract to provide a Tactical Reconnaissance and Counter-Concealment Enabled Radar (Tracer) capability to the army. The 32-month programme included the development, integration and testing of two VHF/UHF dual-band synthetic aperture radar systems, to be integrated into Extended Range/Multi Purpose and on the MQ-8 Reaper drones, although it is currently tested on board a conventional fixed-wing aircraft. When operating in the UHF band the system demonstrated its ability to locate devices with a resolution of about 0.75 metres, although the original Fopen was designed to detect vehicles, buildings and large metallic objects under broad areas of dense foliage, forested areas and wooded terrain. The reliability of the system was also vastly improved, power consumption slashed by two-thirds and size and weight cut by 50%. In August 2009 the company deployed its new Airborne Multi-Intelligence Laboratory, based on a Gulfstream III bizjet, which should give further impulse to the system development.

Another company involved in Fopen is SRC, formerly Syracuse Research Corporation. Its Foliage Penetration Reconnaissance, Surveillance, Tracking and Engagement Radar (Forester) is at the end of the developmental phase and two prototypes are flying on board Boeing A160T Hummingbird verti-lift drones. In 2009 the company was contracted by the US Army to provide one more radar followed by another in early 2010, the latter being scheduled for delivery in June 2011.

Ground penetrating radars can also be used for route clearance purposes. This is the case of the Niitek modular Visor 2500 GPR, which can be installed on different categories of vehicles as a single module weighs less than 50 kg. The system provides 2D and 3D subsurface visualisation



The working area of Lockheed Martin's Airborne Multi-Intelligence Laboratory. Ground and foliage-penetrating radars and change detection technologies are among the most promising methods to detect roadside bombs. (Lockheed Martin)

Lockheed Martin's Airborne Multi-Intelligence Laboratory will also be used to develop airborne sensors able to spot hidden explosive devices at long range. (Lockheed Martin)

and features an automatic detection system working in conjunction with a regularly updated database. Not only does the latter ease the operator task, but it also considerably reduces the false alarm rate. It has been mounted on different vehicles such as the Husky, adopted by the US Army, where four panels form a 3.2-metre-wide array. Target marking is provided by four front-mounted jet-marking bars with a one-metre resolution and twelve centre-body-mounted marking bars with 14-centimetre resolution. The system normally operates at twelve km/h and the on-board computer records up to 100 km of scanned data. The Visor 2500 has also been installed on smaller vehicles such as the Minestalker II 6 x 6 bobcat, which is equipped with only three modules, and the Foster-Miller Talon tracked robot which is equipped with a single module. According to the company, the operational speed can be increased up to 50 km/h, allowing clearing in two days what in the past took over a week.

Norway-based 3d-Radar, a Curtiss-Wright Controls company, developed a step-frequency GPR (SF GPR) system that uses a digital frequency source instead of traditional, phase-locked-loop technology. The system operates in the 100 MHz to 3 GHz band providing as many as 1160 frequencies with waveform lengths of 0.5 to ten milliseconds. Its coherent receiver enables the use of the whole waveform length (typically a few milliseconds) as 100% efficient integration time. 3d-Radar's GPR is designed to operate with an electronically scanned antenna array containing up to 31 antennas, which covers a width of 3.2 metres. The radar unit scans the antennas sequentially. The unique antenna system consists of air-coupled, bow-tie monopole pairs that provide a quasi-monostatic antenna configuration with practically zero offset distance. For route clearance purposes the antenna attachment is designed to be vehicle agnostic and, due to the design of the integration, it is also very easy to field-mount or dismount the antenna array. The antenna's optimal distance from the ground is 50 cm or more, which provides a significant advantage when surveying rough terrain. When the GPR is coupled with advanced automated detection software developed by Exponent and combined with quick vehicle installation and removal, the solution becomes well suited for counter-IED missions. This integrated system, known as the Duracrete, is currently being used in theatre by a large US Defense Department agency. The 3d-Radar system allows the user to program and optimise the frequency range for each measurement problem. Raw data can be stored in time-domain or frequency-domain form for further analysis.

Niitek's Visor 2500 ground penetrating radar mounted on a US Army Husky. The system is modular and while the Husky can carry four modules, as seen here, lighter configurations are also being used. (Niitek)

The Franco-German Institut Saint-Louis developed a change detection system that allows a vehicle operator to compare the video of a route itinerary with a recording taken earlier. (Institut Saint-Louis)

Surveillance Systems

In Iraq one of the key elements in the fight against roadside bombs has been Task Force Odin, an acronym for Observe, Detect, Identify and Neutralise. Observation and detection not only allow identification of where devices are emplaced, but can also help to attack the bomb-makers' network. Currently one of the capabilities being investigated and developed is change detection; which calls on airborne imagery. The ideal situation would be to have constant coverage of an area in order to record any possible movement and check to verify if any were linked to a bomb-related event. However, even image acquisition at certain intervals allows researching such events. What is needed is an automated system that continues the job under human surveillance, as the amount of imagery obtained by current surveillance systems is enormous. Therefore, military, industrial and academic communities are developing new algorithms that allow recognising differences between successive images in even the most difficult situations, different times of the day or night, different weather conditions, etc.

Change detection is also being studied as a ground application. The Franco-German research centre Institut Saint-Louis has developed a low-cost change detection system based on a GPS receiver, a three-axis magnetic compass and a video camera. Linked to an image processing and a computer vision scheme it allows the occupants of the vehicle to focus their attention on any visible changes occurring along their itinerary since a previous ride, which allows creation of a geo-referenced image database of the specific itinerary. The system works by coupling pairs of images according to the geographic grids and the estimated camera orientation, a homographic transformation takes into account translation, rotation, scale factor and perspective.

The system also considers different lighting situations, providing non-linear corrections to allow further algorithms to carry out the comparison. A vehicle was equipped with a camera operating at 7.5 frames/sec and with a GPS providing a ten-metre-accurate position report every second. The vehicle made a first pass in the morning at 40 km/h, followed by a second drive in the afternoon. Along the itinerary numerous targets had been dispersed and the system spotted objects as small as a soda can at a range of about 200 metres as well as otherwise unnoticeable vehicle

Two US soldiers equipped with an ICx Technologies Fido XT unit check vapours emanating from traces of explosive material. The system's sensitivity is said to be close to that of dogs. (US Army)

tracks on grass and scraped ground zones corresponding to buried mines.

Stand-off Search

Numerous standoff search systems have been developed to allow unobtrusive search and to avoid direct contact between troops and potential threats. Rapiscan, American Science and Engineering, and Smiths Detection, among others, provide static and mobile vehicle and body scanners used downrange by Nato and allied forces. Other companies and academic entities have produced interesting items in this domain.

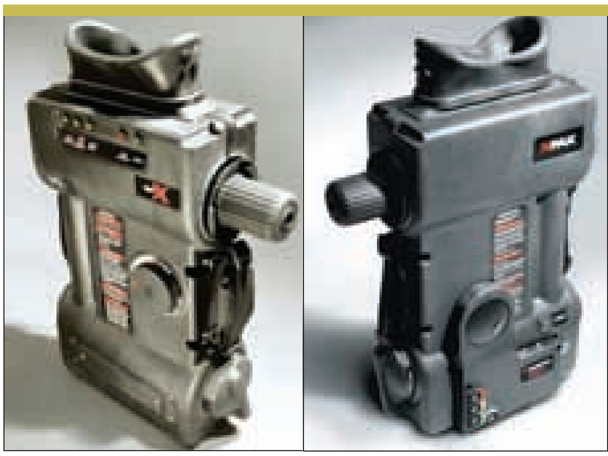
Migma Systems has developed two algorithm suites, one to detect roadside bombs and mines from land vehicles and the other via airborne platforms. The algorithms enhance images produced by existing hardware and sort the resulting data. For vehicle-based systems, the Migma Systems detection algorithm suite is able to cue at a safe standoff distance of 60 metres with a high detection and low false alarm rate.

For airborne-based systems, the developed algorithm suite is able to cue scattered and buried mines at a safe standoff distance of several hundred metres. The Thruvision T5000 is a tripod-mounted unit weighing 75 kg that provides detection of hidden objects under clothing at a distance of between six and 25 metres, in daylight as well as in low-light scenarios.

Qinetiq North America developed the SPO-7R Standoff Suicide Bomb Detector, which operates in the W and G bands, has a power output of less than 50 Watts, weighs some 24 kg without computer and has a minimum range of 4.5 metres and a maximum of 15. It allows the detection of metal, plastic and ceramic objects under clothing and features an automatic alert mode.

A group of University of Michigan engineering undergraduate students invented portable, palm-sized metal detectors of less than one kilo each, which form a wireless sensor network that conveys to a base station where suspicious objects are located and who might be carrying them. Cheap, low-power and long range, they can be hidden in the field and adapted to various situations. The Missouri University of Science and Technology developed a system that detects the electromagnetic energy radiated by electronic devices. Even so-called passive systems, such as receivers, generate unintentional electromagnetic emissions, and through electromagnetic stimulation the system can detect wireless receivers at several tens of meters in a noisy urban environment. Optimising equipment and refining algorithms should lead to considerable range improvements.

Another company working in this field is Nokomis, whose Advanced Electromagnetic Location of Electronic Devices (Aeled) successfully identified electronic triggering devices at a range of over 200 metres. Intelligent Automation developed a compact sensor system for explosive detection based on the Laser Induced Breakdown Spectroscopy technology; it exploits femtosecond (unit of time equal to 10-15 of a second) laser pulses and allows identification of the presence of ammonium nitrate and terahertz radiations.



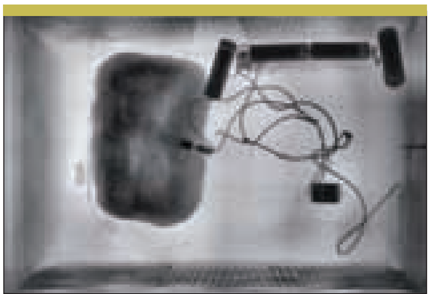
While the RedX Xpak analyser allows to quickly determine whether a person has been in contact with explosives, the Xpak-i has an add-on system that records data for subsequent analysis. (RedX)

Explosive Analysis Systems

During the construction and deployment of an explosive device, those involved become contaminated with trace amounts of explosive residue on their skin, clothing and personal effects, and the vehicles used to transport them. Although it is true that in certain theatres of operation, many people possess a weapon, and therefore can come in contact with some form of explosive. Systems that verify explosive contamination are easy to deploy and use, but require physical proximity to the target.

ICx Technologies developed the Fido XT, which uses a polymer-based technology to carry out vapour detection emanating from trace amounts of explosive materials. In laboratory tests the Fido XT has demonstrated a lower detection limit of one femtogram of TNT, while a further evolution has led to the detection of explosive compounds such as rDX, PeTn, nG and others. In side-by-side field tests the system has shown detection performance comparable to that of highly trained canines.

RedX Defense developed a system that uses an explosives particulate analysis kit called Xpak based on fluorimetric detection. It is part of a new conceptual framework for fighting terrorism focused on identifying the source of the explosive activity so that it can be disrupted and eliminated. The proposed concept of operation will use the Xpak for wide area explosives screening as a means of identifying individuals and facilities engaged in bomb-making activities.



Standoff detection of suspicious elements increases force protection by avoiding direct contact between soldiers and possible threats. (NC3A)

In operation, the user rolls the collection baton on the target surface, inserts it in the analyzer and in a few seconds any evidence of explosive is shown as a darkened area. Although the system does not allow standoff procedures, it is portable, rugged, and easy to use and therefore has been adopted by US and foreign military forces. The US Marine Corps deployed 50 systems in Afghanistan in March 2009. In May 2009 RedX introduced the Xpak-i module which is added to the sampler and allows operators to collect and analyse trace-explosive data over a wide target area, record samples with bar-code and GPS data and preserve them for further forensics. Using RedX's proprietary Xpak Spotlight software, it is possible to download data and a map to quickly identify patterns of activity or 'hot zones'.