MINE DETECTION AND THE NEED FOR NEW TECHNOLOGY

Patrick Blagden

I am grateful for the opportunity to speak directly to American physicists by mean of this short article. I am not a physicist, so my article will be short on technical detail, and I can merely give a general outline of the problems encountered by various technologies used to date. In case any subscribers are interested in contributing to the fight against landmines, I have included some outline descriptions of what our equipment needs are, and how your ideas can be drawn in to our thinking. Right now, we need all the technological help we can get.

Like any industry, the mine action industry has many functions with as many definitions and titles. For brevity, I am expanding the word "mine" to cover all forms of explosive rubbish (sometimes known as unexploded ordnance or UXO), buried or on the surface, encountered by clearance teams during post-conflict mine action programmes. I am also abbreviating "mine clearance staff" to "deminers".

The post-conflict removal of unexploded landmines and other explosive materials is a continuing problem, which will plague many countries for some years to come. It is also an area where few major technological advances have been made since the 1940s. But why new technologies? Because mine detection and clearance is currently slow, dangerous and inefficient. It involves teams of men and women trying to detect the metallic components in a mine, which in some cases can be very small – indeed, some mines have been produced which have no metallic content at all. Otherwise, mines have to be detected by prodding the ground with sharpened rods like overgrown knitting needles, or by detecting the explosive vapour from the mines by the use of dogs. Prodding can be even more dangerous in hard or stony soil, when normal prodders have to be replaced by short bayonets for stiffness and strength. Many deminers have lost hands, faces and eyes during this process.

But why cannot you avoid the whole detection issue by destroying the mines in situ by rolling over them, hitting them flail weights, or crunching them up in some way? Because, alas, in practice these methods will not produce the accuracy of clearance required. Mines do not always explode first or second time they are pressured, especially if they have been in the ground for some time. Mines with bits knocked out of them are still effective if the firing system remains intact. Experience has shown that while machines can help to speed up the clearance process, the only truly accurate way of getting rid of all the mines is to detect and locate them first. Back to square one.

What do we want from new technologies? In the demining community we have analysed our actions to identify our most pressing needs, and these lie in two areas, both concerned with detection. Our studies have shown that we have two main detection needs – to identify reliably the location of each individual mine, and to locate where mines are not, a process called "area reduction".[1] Let us deal with the location of individual mines first.

Our desired detection tool is one that will give an accurate identification of a mine, as little as 4cm in width, buried up to 20cm in the soil. It must preferably give some idea of size, shape and depth under the soil, to allow better discrimination between mines and

[1] Mine Action Equipment: A Study of Global Operational Needs (GICHD Publication)

other battlefield debris. This identification must ideally be given in real time for ma-portable systems, and as nearly as possible in real-time for vehicle-mounted equipments. False alarms must be reduced to a sensible minimum, even in soils with metallic and other debris, metallic ores (such as laterites), roots and stones, at all conditions of soil humidity or water content. At least one version of this tool must be man-portable, robust, waterproof, light, easy and comfortable to carry and operate from standing, sitting, kneeling or lying positions. The size of the search head on man-portable units must not greatly exceed 12 inches or 30cm, for ease of operation in foliage, and no contact with the soil should be necessary during the detection process. It must preferably operate for an eight-hour day on an integral power source, and operate reliably at temperatures from $65^{o}C$ to - $20^{o}C$. The tool must have a clear and unambiguous man-machine interface, and be usable, maintainable and field-repair-able by local deminers, who, whilst astute and well trained, may not be able to read or write. If the tool uses some form of radiation to "interrogate" the target, such radiation must not be harmful to the operator. It must be easy to maintain and repair, and be affordable. This is quite a wish list.

Such a tool would cause great productivity improvements under some conditions. A 100% improvement in false alarm readings can generate improvements of over 47% in productivity in areas where there are large numbers of metal fragments from artillery, mortars or rockets, or other battlefield debris[2].

Another version of this tool can be carried on a mine-protected vehicle, and used for the detection of anti-personnel and anti-vehicle mines on roads and tracks. Anti-vehicle mines are larger (some over 30cm in diameter), but may also have almost no metallic content. They may also be dug in deeper than 20cm. The vehicle-mounted detector will have no power consumption limitations, but will have to either respond almost immediately to the presence of a mine by stopping the vehicle, or to be fitted to an ultra-light vehicle, fitted with a target marking system which can roll over anti-vehicle mines without activating them. A clearance speed of 12kph or more is desirable. The other environmental and operating constraints for the man-portable systems will also apply, although there is less requirement for real-time detecion.

Now to detecting where mines are not. As early as 1996 we were concerned that too much time and expense were being wasted by clearing suspected mined areas, of which most of the area concerned was mine-free, with the mined area being a small proportion of the total. When mine clearance began in Bosnia, there were some 16,000 reports of mined areas, of which the majority had few, if any mines, but all had to be investigated. We therefore need a survey process, which can identify which parts of a suspect area are in fact mined. This requires "stand-off" identification of mined areas, a technological target very much more challenging. Attempts have been made to use satellite imagery, both radar and visible spectrum, but these lack the necessary resolution. Aerial imagery from airships has shown some potential, but identifying small 4cm plastic anti-personnel mine targets under 30 cm of grass, sometimes with trees or shrubs providing a further canopy, makes the challenge a truly daunting one. At present the job is done using sampling techniques, vapour-detecting dogs or rollers, but the technological challenge has not been met. Yet our studies have shown that an improvement of 100% in this area

[2] ibid p51

will result of an overall improvement in productivity of over 42% across almost every operating terrain scenario[3].

What new mine detection technologies have we tried so far? To date, we have examined most areas of the energy spectrum, in the hope of finding something that will generate some response from a hidden mine. The ones offering most promise have been variations on metal detectors (which threaten to be useless against totally non-metallic mines and are generally slow to operate), ground-penetrating radars (GPR), Infra-red detection, various types of neutron energy bombardment, acoustic detection (a sort of land-based sonar), radio-frequency (RF) bombardment, other types of electrical energy bombardment, and explosive vapour detection. At a ground-breaking meeting in Stockholm in 1994, scientists and engineers met with deminers for the first time, and from this meeting, a chart was drawn up showing the most likely areas of technology to provide the advances the deminers were calling for. Unfortunately, the prediction of having new technology in field service in five years, ie by 1999, was never fulfilled. We are still about five years away from a fieldable new technology.

The technology showing the most chance of reaching the field has so far been GPR, but GPR has had difficulties in achieving the necessary soil penetration with a reasonable target resolution, although broad-band radars may be overcome this limitation. Fieldable man-portable GPR sets have been used in trials in Cambodia and Thailand.

Infra-red detection has not proved effective, again due the lack of resolution. In addition, the thermal difference induced by a small plastic mine laid just below surface level under a 30cm crop of grass is a daunting target for any detector, even given wide swings in daily temperature. Initial trials were better at showing recently dug holes where mines had been laid, but even these faded after 12 months, and in many cases deminers have to deal with minefields many years old. Pre-heating the target area might improve the signal, but at a considerable energy cost and administrative effort.

Various forms of active neutron interrogation have been explored[4], which can identify the presence of large concentration of Nitrogen by activation with thermal neutrons to achieve the generation of gamma rays. This area has been examined for some years, but no trial sets have been fielded.

In the field of RF detection, Nuclear Quadrupole Resonance is reputed to have the highest detection potential[5], but at the moment this technique works better for some of the more exotic explosives like RDX (cyclotrimethylenetrinitramine), rather than the cheaper TNT (trinitrotoluene), the more common explosive filling for mines. Some development is taking place in the military world, but this has not fed across to the humanitarian mine clearance community.

Acoustic sensors have apparently had some success, but no equipments have yet been sent for trials in any mine action programmes. It is possibly very difficult to detect small targets in dry stony or root-filled soil.

The detection of explosive vapours is another area where great advances have been made, but at present the sensitivity of such detectors still lags some orders of magnitude

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[3] ibid p51 and 52

[4] Forensic and Environmental Detection of Explosives; Jehuda Yinon, John Wiley & Sons Ltd p. 136 et seq

[5] ibid p. 118

behind the dog, which can apparently detect low vapour concentration levels down to 1 in 10^{-18}, which is better than current vapour detectors. It may be that other animals such as rats, bees or flies can also do so, but field trials have only been carried out with dogs and rats. The man-bee or man-fly interface will need some examination, as will the logistics of carrying out insect detection in places like Central Angola. Dogs and rats continue to show great potential, especially as there are now methods of bringing the vapours to the animals. The vapour sampling techniques and technologies used in this process will become even more vital if chemical or electronic vapour detectors become available with the right levels of detection and discrimination. This is in fact one area where new technologies can be said to used in the field, and where Research and Development are closely integrated with field operations.

You will note that in this article I have concentrated on detectors, and not on platforms. Over the last few years, the demining community have been offered robots (wheeled, tracked and legged), balloons, helicopters and other exotic vehicles. In most cases the designers seem convinced that all minefields are constructed on golf course greens and fairways – few even venture into the rough, let alone the bunkers. In my opinion, we must get the detection sensors right first, and then concentrate on the platforms that carry them. In practice, we have versatile, sustainable, low-cost two-legged platforms, which can get into every corner of a mined area in almost any terrain, which many vehicle-mounted machines cannot.

If the physics community have ideas on how we could improve our stand-off or close-in detection techniques, please let us know. We are not searching for "silver bullets", merely an incremental increase in our capability. Our overall aim is to speed up the demining process, and make it more reliable and cost-effective. We will do what we can to help your efforts: most of the GICHD staff have good contact with deminers world-wide. So how to approach the problem? Start by getting to know the mine detection situation as well as possible, attend demining syposia, visit some minefields (I recommend conducted visits only, please!) or look at photographs of suspected minefields on the GICHD website, http//www.gichd.ch/.

Paddy Blagden, Brigadier (retd), British Army
Technical Director, Geneva International Centre for Humanitarian Demining
Ave de la Paix 7 bis,
CP 1300
CH-1211-Geneva 1
Switzerland
Phone 0041-22-906-1674 or 1622, fax 1690
e-mail p.blagden@gichd.ch, web http.//www.gichd.ch/