



MINETECT TRIALS



The MINETECT combined MD and GPR mine detector was sponsored by the UK Department for International Development and developed by ERA Technology. Using a radically different patented approach from conventional GPR designs, in terms of the man machine interface, MINETECT offers simplicity of use and affordability, both key factors in humanitarian demining operations. The ground penetrating radar employs novel operator and audio interface; techniques embodied in European patent number 99306164.7.

The design combines the output from a Guartel MD8 metal detector and an ERA ground probing radar based on the ERA SPRscan technology, with the design aim to offer considerable improvements in detection performance and a significant reduction in false alarms. A key element in the design philosophy is the need to avoid expensive and complex image display and to implement a GPR design that mimics the operation of a conventional metal detector.

The technical goal of this project is to develop a more effective and affordable hand-held mine detector for use by indigenous deminers. Taking into account the need for robust, simple and easy to use equipment, the design minimises the need for changes to the established standard operating procedures for mine clearance, which are currently used by demining organisations. Four phases of trials were conducted to determine the performance of the detector. These trials were carried out in the UK, in the US under an ITEP programme, in Bosnia in conjunction with Norwegian Peoples Aid and also in Southern Lebanon with Bactec International.

The two MINETECT prototypes that were built have been tested on a wide variety of soils. These include London clay, English topsoil, ballast, UK DoT road sub-base material, gravel, sand, ferrous loaded sand, US soil, Bosnia soil and Southern Lebanese soil.

Figure 1 MINETECT system under trial in Bosnia





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The audio output from the radar system has two degrees of freedom: frequency and amplitude. The frequency of the audio output is proportional to the range of the buried object, whilst the amplitude of the radar signal is proportional to the radar cross section of the target. Shallow targets sound high in frequency, whilst deep targets sound low in frequency. The relationship between target depth and MMI output frequency is illustrated in figure 2. It can be seen that the typical hyperbolic target response in a GPR B-scan is heard as a variation in the audio frequency output. The ground surface reflection would be heard as a continuous tone. This ground surface reflection is removed through the algorithms applied to the radar data, without affecting the capability of detecting flush buried mines.

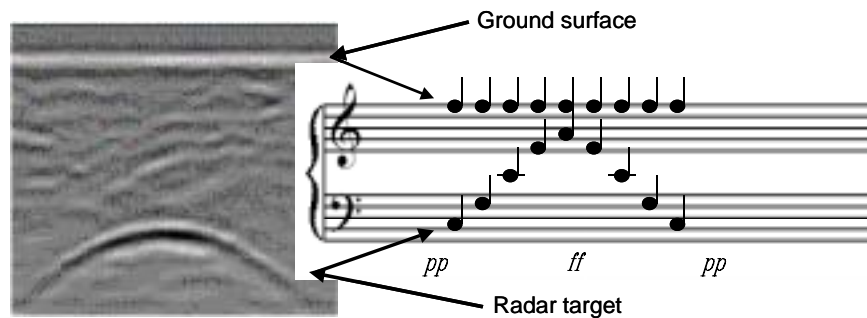


Figure 2 Conversion of radar signal to audio output

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All data reported describes the detection performance of the combined sensor and the operator. That is, the MD is regarded as the prime detection and the GPR is used to discriminate between small and large metallic objects classifying them as mines or clutter. Evidently if the MD fails to detect a target then the combined system fails to detect. The results do not define the detection rate of the GPR, which proved to have a better detection capability than the metal detector.

United Kingdom

The initial tests at the ERA test site were designed to determine initial operator values for probability of detection (PD) and false alarm rate (FAR) in different soils. The trial was also aimed at establishing the detection performance range that a variety of users could achieve from initial exposure to the MINETECT concept. The operators ranged from those with considerable GPR surveying experience to those with no previous experience of search equipment. The mines were buried and the test was conducted blind. A short AV clip of MINETECT under test is provided

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United States





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The quantified trials were conducted at a US test facility. The trial was aimed at establishing the actual false alarm rate of the combined detector when compared with the false alarm rate of a metal detector alone. The trial site is a performance benchmarking facility for metal detectors, which allows comparison with the detection characteristics of other demining tools. The trial facility is comprised of a calibration grid and a blind test area. Information on the contents of the calibration grid was available to the trials team, but the operators were only informed of the target characteristic after they had recorded the result. The blind grid results were assessed by the host organisation and ROC (Receiver Operating Curves) were produced for both areas.

Bosnia

The in-country trials were conducted at Norwegian Peoples Aid's facility in Sarajevo, Bosnia and Herzegovina. The trial was aimed at determining an accurate figure for the probability of detection when used by deminers. The trial also introduced the concept of a live audio GPR system to the demining end user. Quintec human factors conducted an exhaustive survey of the space model for the second-generation prototype.

Lebanon

Further trials were conducted in Southern Lebanon to assess the performance of the MINETECT prototype in realistic Middle Eastern site conditions. Various test sites were visited and results obtained to define the likely reduction in FAR compared with a Minelab metal detector.

RESULTS

United States trials

As part of an ITEP programme, MINETECT was evaluated at a US test site. This site was subdivided into two zones; a calibration area and a blind area. In the calibration area a total of 223 cells of area 1 m² were measured and a performance rating for the combined detector was produced.

The operators were asked to classify the target over a range -5 to +5 expressing their confidence that the target was a mine or clutter. Minus 5 indicates clutter, zero is a no target or blank and plus 5 is a mine. Unit 2 of the two prototypes was used to gather data on the calibration area while both Unit 1 and Unit 2 were used to gather data on the 1008 cells comprising the blind area. Unit 1 was used on about 65% of the blind area.





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Calibration area

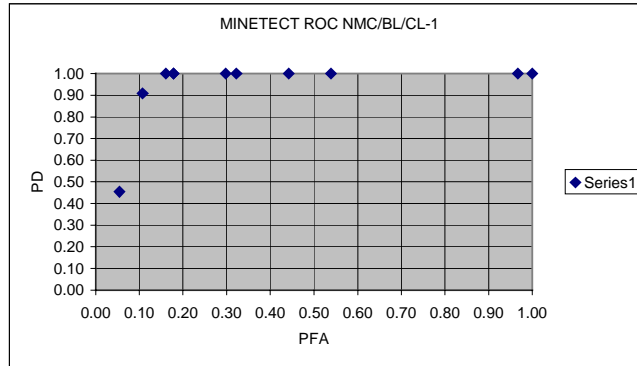


Figure 3 ROC curve for mines versus blanks, non-metallic clutter and small metallic clutter for the calibration cells

The calibration area was measured and the following ROC curves were generated. MINETECT was designed to discriminate against small items of metallic clutter, therefore it is appropriate to evaluate its performance against this type of target. This is shown in figure 3. For comparison it is useful to evaluate the performance against all clutter in the calibration site as shown in figure 4. This includes very large metallic clutter, which MINETECT was not designed to classify.

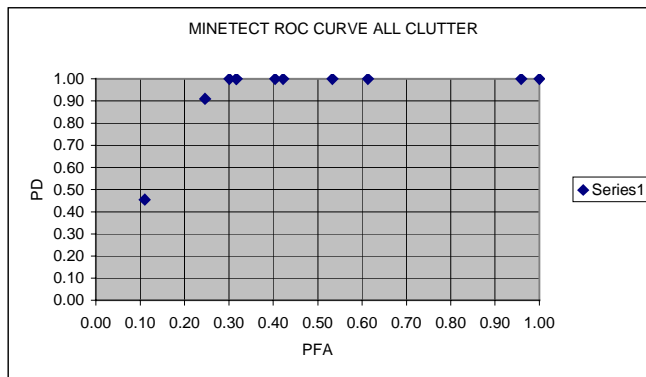


Figure 4 ROC curve for mines versus all clutter and blanks, for the calibration cells

Results for the blind site show that there was a difference in performance of the two metal detectors one of which was 20% less sensitive. This reduced the combined Pd to 92% and the FAR to 0.4. However, it is considered that the results from the calibration lane are more representative of the achievable performance of the system.

Bosnia

Three test sites were used. The first test site consisted of a gravel layer approximately 15 cm thick with a layer of clay type soil underneath the gravel. The test site was divided into 200 cells





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of 1 metre by 0.5 metre dimensions. The second test site was formed of minimal grass vegetation on native Balkan topsoil. The test site consisted of some 200 cells of 1 metre by 0.5 metre dimensions. The third site was constructed on native grass and topsoil in an area with many naturally occurring false alarms. The site consisted of a 3 metre by 1 metre lane with tapes marking the boundaries. Three mines were buried in the test lane with a number of naturally occurring false alarms. NATO SFOR (stabilisation force in Bosnia and Herzegovina) representatives from the British Army, the French Army and Australian Army were present.

On the gravel site MINETECT/operator detected 100% of the 33 mines, which were predominantly PMA2 and PMA3 AP mines. On the soil sites the GPR /operator achieved a 94% detection rate and the MD/ operator a 91% detection rate. The GPR / operator missed two mines in the soil test facility; the first target missed was a PMA3 at a depth of 10 cm, whilst the second target was a PMA2 at a depth of 10 cm. The MD / operator missed both these targets, plus a PMA2 at a depth of 5 cm with a 15° angle. On the third test site with many metallic false alarms, the MD detected 14 targets, 12 of which were false alarms. The MD missed a PMA2 without a metal fuse. The GPR detected four targets, one of which was a false alarm, the other three being mines. This demonstration showed that, with the GPR there were 10 fewer false alarms and proved that the GPR was capable of detecting completely non-metallic mines.



Figure 5 SFOR assessing MINETECT





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MINE CLASSIFICATION

Further off-line investigation of the capability of the GPR function to classify mines was carried out on a limited set of targets; these consisted of a VS50 mine, PMA3 mine, 10 cm diameter stone and an animal burrow. A correlation parameter matrix provided the following results:

Table 2
Mine classification rank order

PMA-PMA	9	VS50-VS50	10
PMA-VS50	8	VS50-PMA	8
PMA-burrow	5	VS50-burrow	5
PMA-stone	3	VS50-stone	4

It can be seen that, albeit from a small data set, it is possible to classify the type of mine. Further work on a much larger data set is needed to determine the robustness of the approach.

CONCLUSIONS

The prototype system has demonstrated that the combined sensor approach is a valid method of achieving the goal of a significant reduction in false alarms. The results from the US calibration lane for the MINETECT Unit 2 were, for all mines, blanks, non-metallic clutter and the following categories of metallic clutter:

PD=100% at FAR of 0.07 m^{-2} for small metallic clutter

PD=100% at FAR of 0.125 m^{-2} for all clutter

The false alarm rate was significantly reduced where the metal targets were small and an improvement of better than 5:1 was achieved. The GPR function was well able to discriminate against small pieces of metal and in some cases was more effective than the MD in detecting minimum or no-metal mines.

The MD function used in the prototype was not designed to remove ground conductivity effects and this deficiency degraded the overall system performance in two ways. It reduced the sensitivity of the MD in conductive soils and it increased the probability of false alarm of the MD. It therefore reduces the performance of the combined system. The MD function of a combined detector should have range sensitivity equivalent to detection of a 1 g metal mass at 20 cm. This is within the capability of current MD technology and is not seen as a limitation. [1],[2]

The overall system achieved the project objectives, but the performance needs to be uniform across all soils and surfaces. This should be achievable with an improved MD performance and GPR target classification.





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