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ITEP Test Trials for Detection Reliability Assessment of Metal Detectors

Christina Mueller  
*BAM Berlin*

Mate Gaal  
*Federal Institute for Materials Research and Testing*

Martina Scharmach  
*BAM Berlin*

Sylke Bär  
*BAM Berlin*

A.M. Lewis  
*European Commission*

See next page for additional authors

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ITEP Test Trials for Detection Reliability Assessment of Metal Detectors

Authors
Christina Mueller, Mate Gaal, Martina Scharmach, Sylke Bär, A.M. Lewis, T.J. Bloodworth, Dieter Guelle, and Peter-Th Wilrich

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Abstract

The test detection reliability of a mine-searching system is governed by the following three elements:

- Intrinsic capability, which describes the basic physical-technical capability of the method.
- Application factors, which include those due to environment.
- Human factor, which is the effect of human operators on the detection reliability.

Some of these can be determined in simple laboratory measurements in which the effect on detection capability of individual parameters is measured. However, the human factor and some aspects of the effect of environmental conditions on the system need to be treated statistically.

By far the most common "mine-searching system" is the use of a metal detector. The test and evaluation procedures for metal detectors described in European Committee for Standardisation (CEN) Workshop Agreement (CWA) 12474:1999 (PMA-II) include those above. This is why, in addition to parameter tests, they include detection reliability or blind field tests under local conditions with local personnel.

A series of three field trials was performed in the International Test and Evaluation Program for Humanitarian Demining (ITEP) project 2.1.1.2, "Reliability Model for Test and Evaluation of Metal Detectors," in order to specify the optimal conditions to obtain reliable trial results with affordable effort. Each set of specific working conditions is characterized in terms of a combination of mine type and soil type with standard deviation determined by local personnel. For each set of conditions, the searching system will deliver a warning, a false alarm, or no alarm according to the detection rate as a function of mine depth, and a certain overall false alarm rate. During the ITEP trials in Horkow and Oberjegenberg, the authors learned to determine this function separately for each mine type in each soil. This is especially important for low-metal mines in soil that can influence metal detectors, as will be illustrated for the case of the PMA-II. Two discussion points still remain. How representative are the trials of field conditions, and how statistical setup is required if we are to distinguish between the capabilities of individual detectors.

Introduction and Background

The CEN Working Group 07 began the process of standardizing test and evaluation methods for metal detectors in humanitarian demining, including both laboratory measurements of detection capability and blind field trials (reliability tests). In reliability tests, the probability of detection (PDI) and recovery operating characteristics (ROCs) help to summarize the performance results. Under the umbrella of ITEP, a number of test trials with metal detectors have been conducted. The aim was to specify the trial setup and the statistical rules necessary to achieve true, repeatable and reproducible results.

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Overview of the Parameter Matrix of the Trials

The main aim of the trials was to investigate how the detection performance matrices itself in different application circumstances. The authors compared three sets of trials for which the parameter setup could be seen in Figure 3. The first trial took place in Obernettersberg, WTD 52 on the testing ground of the German army.

The conditions for the first trial in May 2003 were representative of four circumstances likely to yield poor performance: inexperienced operators with a short training period and not lines with significant metal contamination. Three neutral soil were used and a fourth lane was artificially made "uncooperative" by adding a layer of magnetic blast-furnace slag. (With the benefit of hindsight, one would naturally recommend this technique because the slag was found to contain metallic particles, creating additional metal contamination). The burial mines were characterized by a median to large metal content. Some generic International Test Operations Procedure (ITOP) targets were also used, irregularly distributed over a predefined depth range.

The second trial set was organized in Benkovac, Croatia, with eight experienced Croatian operators, three of whom were active deminers at the time of the trials. A brief training period (half a day for each person) was given. There were three types of soil on eight lanes: neutral soil, homogeneous uncooperative soil and heterogeneous uncooperative soil. The last soil had frequency-dependent susceptibility. The mines had large, medium or small metal content and were randomly distributed over a depth range ranging from zero to 20 cm to allow statistical analysis. For testing roadside detectors, the normal target depth should be to the limits of the physical detection capability in the soil. The depth of 20 cm was chosen because it is the required depth for mine clearance under Croatian law. The lanes were "almost ideal" of metallic pieces.

The lessons learned from the first two trials were applied to the third trial set in Obernettersberg in November 2003, with the intention of creating conditions likely to yield better performance. Three new lanes were set up (in addition to the ones available from the previous trial in May) and carefully cleaned of any metal fragments. Mines with large to medium and small metal content were selected and distributed systematically at a depth ranging from 0 to 20 cm. The operators, who were inexperienced, were trained carefully in open and blind exercises until they were confident controlling the reaction of each detector to each mine in each soil at different depths. To avoid confusion among the different detector operating procedures, the operators were assigned detectors belonging to one class both during the training and during the first week of the trial only (double-D coil, static mode or single coil, dynamic mode). In the second week, they changed to the second class of detectors.

**Results of the Trials**

Figure 4 shows the overall results of each trial set. These diagrams illustrate the influence of the factors (application factor and human factor) degrading the performance of all the detectors, without distinguishing among individual detectors. The results of inexperienced operators with a short training on metal-contaminated ground shows a mean detection rate of 70 percent and 0.3 false alarms per square meter. The artificial uncooperativeness reduces the performance to a 60-percent detection rate and almost one false alarm per square meter, which is surprisingly poor.

Even more surprising are the total overall results for Benkovac in June 2003, where the operators consisted of eight experienced Croatian deminers. The detection rate is about 65 percent in neutral soil and decreases to almost 50 percent in a local, neutral, uncooperative soil with frequency-dependent susceptibility. The false alarm rate grows from 0.5 false alarms per square meter to almost 0.6. Possible reasons for this extremely poor result are as follows:

1. Many of the targets were deeply buried and in some cases beyond the physical capability of some of the detectors.
2. Minimum metal mines, which are inherently difficult to detect, were buried according to a systematic depth distribution, ranging from zero to 20 cm in order to evaluate the detection rate as a function of depth. The maximum depth of 20 cm was chosen because it is the requirement of the Croatian demining law. A more realistic mean value of detection rate for the region could be determined if the real depth distribution of mines is known by using the PCD as a function of depth measured in the trial. Usually, anti-personnel mines are mainly buried at a depth ranging from zero to 5 cm, which is much shallower than the range laid in the trial and would be detected with a higher average PCD than measured in the trial.
3. Only three of the detectors are currently active.

It has been suggested that experienced deminers may need a longer training phase because they are generally accustomed to using a particular detector model and cannot handle too many different device types at the same time. In the trial, the deminers are not in depth distribution of mines is known by using the PCD as a function of depth measured in the trial. Usually, anti-personnel mines are mainly buried at a depth ranging from zero to 5 cm, which is much shallower than the range laid in the trial and would be detected with a higher average PCD than measured in the trial. Only three of the detectors are currently active.

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danger and are less motivated to be careful than they would be in a real minefield.

5. The sea schedule required the deminers to work more quickly and for longer hours than they would normally.

6. The test courses were synchronized with metal.

Heterogeneous soil with strong frequency-dependent magnetic susceptibility is a challenge for all detectors, especially in combination with minimum metal mines, since the soil signal often masks the mine signal.

The performance in the third trial is much better than in the first two, as expected from the conditions of the test with respect to the human factors and application factors. In Figure 4c, the left upper corner of the ROC point is 90 percent detection rate and false alarms below 0.1 percent square meter. The "score" is in carefully controlled and longterm training, reduced workload, neural and very clean soil, and targets that are easier to detect. If we want to estimate a realistic POD, it is therefore necessary to ask: "What is the appropriate scenario of application and human factors for the situation we want to investigate?"

Full Process Simulation

In Obergurgl in November, one additional test was conducted, on the advice of Dietmar Gaier.7 The test simulated the full manual demining process, including peddling and excavation. Since the statistical basis was too small to be representative, results of this test must be considered indicative only and any conclusions provisional. The detection rate of the manual clearance process appeared to be higher than that of the detection process without excavation, probably due to conditions where a minimum metal mine was hidden by a larger false-alarm item. Indications that could be assigned to identifiably metal fragments were excluded (according to a "threshold-free" approach), so the false alarm rate is lower. The latter is, of course, a mandatory condition, rather than performance. A more detailed investigation is planned within the GCCHD program for improvement of the manual demining methods mentioned above.

Figure 5 gives an overview of the soils in the three trials. In Figures 6 and 7, the individual detector results are illustrated for the FMA I minimum metal mine under ideal conditions (i.e., neutral soil without metal contamination, well-trained operators and optimized working hours). Figure 6a shows the detection rates as a function of the burial depth for each device separately and Figure 6b shows the ROC points of all devices together.

Figure 7a-d and Figure 7f present the same results for the more difficult soil. The anomalous results for detector Y is due to a high FAR in the unscreened soil, up to one false alarm per square meter and the sparsely higher detection rate at large depth. The latter phenomenon can be explained by the fact that some of the "true" positive indications appear to be signals from the soil that happened to fall within the hole of a target, so that the apparent POD does not approach zero at large depth. To avoid this type of anomaly, the soil compensation and sensitivity of the detectors should be adjusted to produce an acceptable low FAR prior to starting the blind trial, CWA 14747: 2003 section 8.3.5 specifies a procedure for checking the adjustment of a metal detector to the soil under test. The test is only to be considered valid if the detector is adjusted in a representative one-meter by one-meter setup area so that no false alarms are given when it is placed on the soil surface and then raised 30 mm above it. It seems likely that detector Y was not adjusted (or not adjustable) according to this procedure.

Figure 7e: This soil sample is heterogeneous and loose, non-cooperative. Being that it has real bonuses with neutral stones it has frequency-dependent susceptibility. Its detection rate as a function of mine depth (FMA I only) has four different devices with 95 percent confidence limits.

Data Fusion for Mine Action Decision Support: An Example From Lebanon

Why Data Fusion?

Within humanitarian mine action, progress in integrating information is manifestly clear by the way the traditional array of survey activities have been reformed. Following the 1997 Ottawa Treaty to ban anti-personnel mines, several mine action non-governmental organizations (NGOs) and the United Nations Mine Action Service (UNMAS) launched the Global Landmines Survey, a multi-country survey project. This initiative has helped to institutionalize the collection of social and economic data, along with contaminated area data, to enhance the overall management of mine action programs worldwide, and to that end has achieved a paradigm shift over the entrenched purely technical approach to mine clearance.

Socio-economic impact surveys have since been completed in several countries and have been certified by the United Nations. More are ongoing or in planning. In addition to establishing countrywide inventories of communities affected by landmines and/or UXOs, the surveys classify communities by the severity of socio-economic impacts. The classification relies on an internationally standardized scoring system that combines types of munitions and blocked resources as well as recent victims, using weights that national stakeholders may adjust within limits. Technical information as the contaminant area level and demographic data on incident survivors are also generated and are available to national mine action coordinators through the Information Man-

by Xiào Renzhi and Charles Conley, Wag
Working Towards a “Mine-Free” Hemisphere

The government of Ecuador served as the host of the Americas Regional Mine Action Conference “One More Step Toward a Mine-Free Hemisphere” held in Quito, Ecuador, on August 12–13, 2001. The government of Canada and the Organization of American States Mine Action Program (AICMA, for its initials in Spanish) co-sponsored the conference, the fourth in a series of annual meetings convened in the region since 2001.

The regional gatherings have promoted the exchange of information among members of the mine action community in the hemisphere and fostered a sense of common purpose as the countries strive to reach the goal of a hemisphere free of the negative effects of anti-personnel landmines. This year’s conference, like the one in Lima, Peru, in 2003, also served as a regional preparatory meeting for the Ottawa Convention Review Conference to take place in Nairobi, Kenya, from November 29–December 3, 2004. Over 100 participants from both within the Americas and beyond attended the Quito event.

The meeting’s agenda included an opportunity for each country delegation to report on the status of its mine action program, as well as regional updates on the mine action pillars of mine clearance, mine risk education, victim assistance and mine-affected communities. Dr. Tyronn Tippins of the Geneva International Center for Humanitarian Demining (GICHED) provided an overview of the implementation of the Ottawa Convention in the Americas and other participants reported on preparations for the upcoming Naumburg Review Conference. A panel was included in this year’s conference that reported on the newly drafted (November 2005) Protocol V of the Convention on Certain Conventional Weapons (CCW) pertaining to Explosive Remnants of War (ERW). Conference proceedings are posted on the AICMA-Ecuador website at http://www. aicma-uc.org/conferencia REGIONAL.html.

Among the noteworthy announcements that emerged from the gathering was that all of the States Parties in the hemisphere should have met the requirement to destroy their stockpiled mines by the time they reach Nairobi. Furthermore, if all of them have launched a clearance program by that time, considering Chile’s commencement of demining operations this past August, with Costa Rica and El Salvador already having completed clearance and Honduras finishing in 2004, Colombia continues to work on developing its mine action program, even as internal conflict remains unresolved, it announced plans to clear its first minefiled in October. One remaining issue that arose on several occasions during the conference was the number of landmines the armies were retaining for development and training purposes under Article 3 of the Ottawa Convention. The countries agreed that transparency on this matter was essential.

The countries of the Americas aspire to achieve in Nairobi an example of regional success with lessons learned to share with others. Conference participants announced progress in furthering South-South Cooperation, including plans for Honduran mine clearance operators to assist in Guatemala and the aid provided by Argentina as well as Canada to Colombia in its stockpile destruction activities. These developments continue the pattern in the Americas of employing expertise within the region to support mine action programs, as with the use of International Supervisors drawn from a number of Central and South American countries to assist with clearance operations as part of the Mission of Assistance for the Removal of Mines in Central America (MARMINCA) program.

Ecuador and Peru took advantage of the regional conference to hold discussions concerning joint efforts to clear their common border, an initiative supported by the OAS Mine Action Program with technical assistance from the Inter-American Defense Board (IADB). Such joint efforts were cited as examples of how coordinated mine action projects between former belligerents can serve as important confidence-building measures. Guatemala presides an excellent case of the value of mine action programs that incorporate former combatants from different sides in an internal conflict.

Several United States government agencies sent representatives to the regional meeting, including the Department of State (DOS), the Defense Security Cooperation Agency (DSCA) and the Humanitarian Demining Training Center (HDT). Mr. Ed Trimble of the U.S. DOS, Office of Weapons Removal and Abatement (PM/R&A), in a keynote to the participants, reviewed the changes that had occurred in his DOS office in the past five years, the U.S. government’s humanitarian mine action goals and priorities, and its continuing commitment to addressing the mine/UCO problem.

* Photos by Nelson Castillo, QAS/MCHA/Observer

Contact Information

Dr. Suzanne L. Fiedlerlein, MARC
James Madison University
1 Court Square, MSC 8054
Harrisonburg, VA 22807
T: (540) 568-2715
E: muffie@jmu.edu
Website: http://make.jmu.edu

http://commons.lib.jmu.edu/cisr-journal/vol8/iss2/43

In the opinion of the authors, these combinations of ROC cases provide the information that the end-user ought to know about the device that he/she is going to operate in the field. It is therefore recommended that receiver operating characteristic curves with appropriate explanation and interpretation, be included in device catalogues for the main categories of landmines employed in mine-affected areas.

Conclusions and Outlook

For detection reliability field tests, the combined scenario of soil type, soil metal contamination and the human factor has to be set up with care and must be appropriate for the local field situation. The characteristics of one detector should be determined in terms of the detection rate as a function of depth in each soil for each mine type and complete with the information about the corresponding false alarm rate. An expected mean value of the performance of a detector in a certain region can then be determined from these basic curves, knowing the local mine distribution. The full demining process should be simulated to assess true clearance performance and might be introduced as a correction factor within a modular relabilty model.

* Figure 10 in text.

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