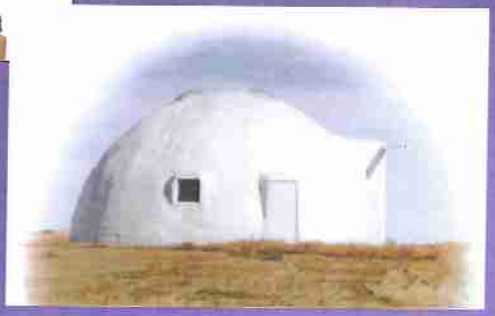
International Pilot Project for Technology Co-operation

Final Report

A multi-national technical evaluation of performance of commercial off the shelf metal detectors in the context of humanitarian demining



International Pilot Project for Technology Co-operation Final Report

A multi-national technical evaluation of performance of commercial off the shelf metal detectors in the context of humanitarian demining

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European Commission	*EC Joint Research Centre, Ispra*
The Netherlands	*Royal Netherlands Army, The Hague; TNO FEL, The Hague*
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United States of America	*U.S. Department of Defense, Washington DC*

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Abstract

The results of an evaluation of the detection performance for 29 commercial off the shelf (COTS) metal detectors, against a range of low-metal-content anti-personnel mines and some simulant targets, are described in this report. This work was undertaken by organizations from four nations together with the European Commission, in the International Pilot Project for Technology Co-operation (IPPTC) in the Humanitarian Demining R&D environment.

This report gives a summary of the methodologies and results. Detectors were assessed for performance in air; in a range of soils; and in realistic demining scenarios in Cambodia and Croatia. In addition, the human factors aspect relating to the use of each detector was assessed.

The in-air tests included measurement of sensitivity, drift with time, effect of moisture on the detector head, the assessment of the possibility to set-up the detector consistently and measurement of the sensitivity volume relative to the sensor head. In-soil tests provide comparison of performance in four different soil types under carefully controlled conditions. The measurements in Cambodia and Croatia allow comparison of performance measured under laboratory conditions with that achieved by deminers in field conditions.

A two-page summary of performance is provided for each detector.

A strong correlation was observed between the values for the magnetic susceptibility of the soil and the performance achieved by operational metal detectors. This suggests that such measurements should be a part of Level Two Surveys of suspected mined areas.

References are given to the reports of the full assessments made by the participants and to relevant test protocol documents.

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Glossary

AP	Anti-personnel (landmines)
CHS	Centre for Human Sciences (Department within DERA)
cm	Centimeters
COTS	Commercial off the shelf
CMAC	Cambodian Mine Action Center
CroMAC	Croatian Mine Action Center
DERA	Defence Evaluation and Research Agency
DRES	Defence Research Establishment Suffield
EC	European Commission
IPPTC	International Pilot Project for Technical Co-operation
ITEP	International Test and Evaluation Program
JRC	Joint Research Centre
Lab.	Laboratory
m	Meters
Max	Maximum
Min	Minimum
NATO	North Atlantic Treaty Organization
SME	Subject Matter Expert
SOP	Standard Operating Procedure
TNO-FEL	TNO Physics and Electronics Laboratory

1. Introduction

Background

The concept for the International Pilot Project for Technology Cooperation (IPPTC) originated in the United States Department of Defense in an effort to help answer one of the most frequently asked questions in humanitarian demining, "Which is the best metal detector to use?".

The project, although conceived in October 1997, did not actually become reality until December 1998, when voluntary participants from Canada, the Netherlands, the United Kingdom and the European Commission's JRC teamed with the United States to lay the groundwork. The pilot project took 21 months to complete, with actual testing being conducted in several phases. Laboratory testing took place in the Netherlands and Canada, followed by field-testing in both Cambodia and Croatia.

Purpose

The purpose of the pilot project was to conduct a coordinated, multi-national, technical evaluation of metal detectors suitable for use in humanitarian demining. The project sought to demonstrate, through a "consumer reports" type of evaluation, the mine detection capabilities of commercial-off-the-shelf (COTS) metal detectors. The report is available in the public domain. The background information is available to governments and organizations and individuals involved in the global humanitarian demining effort at the discretion of the holder of the detailed report on that aspect of the results.

It is hoped that this document will assist organizations in selecting the detector(s) most suitable for their particular environment or unique operational conditions. The pilot project also served as a test vehicle to identify and resolve problems in demining technology cooperation as the lead effort for the International Test and Evaluation Program (ITEP).

Project Overview

The detectors involved in the evaluation were purchased after soliciting the recommendations of all manufacturers known to the IPPTC team as to which detectors were suitable for humanitarian demining applications (see Annex C Invitations to participants). No model recommended by a manufacturer was excluded. Some manufacturers did not respond, while others offered prototype models still under development, which were not evaluated. Since the initiation of the project, several new detector models have entered the market and are currently being offered to the humanitarian demining community. Finally, some models currently available may be different from the equivalent models utilized in the pilot project. Readers interested in purchasing detectors are encouraged to contact manufacturers about implications of actual and potential changes prior to acquisition.

The solicitation resulted in the purchase of three copies of each of 25 different detector models from 13 manufacturers. Some detectors had more than one type of search head, resulting in a total of 29 different sensors for evaluation. The detectors finally included in the IPPTC tests were the following:

Adams AD2500 and AD2600S
Ebinger EBEX 420 GC and EBEX 535
Fisher 1235-X, 1266-XB, and Impulse
Foerster MINEX 2FD 4.400.01
Giat Model F1 (DHPM-1A)
Guartel MD4, MD8, MD2000
LG Precision PRS-17K
Minelab F1A4 CMAC and F1A4 MIM
Pro-Scan Mark 2 VLF
Reutech Midas PIMD
Schiebel AN-19/2, ATMID, MIMID
Vallon ML 1620C and VMH2
White's AF-108, DI-PRO 5900 and Spectrum XLT

The project established the following timeline and locations for the various phases of testing:

Phase I, Acquisition of Detectors and Targets	March - May 1999	United States
Phase II, Training and Entrance Test	May - June 1999	The Netherlands
Phase III, In-Soil Tests	June - September 1999	The Netherlands
Phase IV, In-Air Tests/Human Factors	October 1999 - January 2000	Canada
Phase V, Field Tests:	March 2000	Cambodia
	June 2000	Croatia

Project engineers, as well as indigenous deminers, evaluated the detectors against the following inert anti-personnel (AP) landmines: PMN, PMN-2, PMA-2, PMA-3, Type 72, R2M2, PMD-6, and simulants: G_0, I_0, M_0 (see page 126 for full description of test targets).

Project Methodology

The overall approach in designing the pilot project evaluation was progressive in that the detectors would be evaluated from the more controlled conditions (the laboratory tests in Canada and The Netherlands), to the less controlled (the field tests in Cambodia and Croatia).

The evaluation included assessments of detector sensitivity in air, in a variety of soil conditions, and environmental effects such as moisture on the sensor head. 'Human Factors' such as weight and ease of use were also evaluated, along with other aspects such as cost and ruggedness.

In designing the field tests, 5 and 10 cm were chosen as the two depths at which targets would be buried. It is recognized that the United Nations has established a 20-cm clearance standard for landmines and unexploded ordnance. However, in practice AP mines are mostly found at substantially less than 20 cm, and realistically not many detectors could be expected to find low-metal content mines at that depth. This performance assumption was validated during the conduct of the pilot project.

Inert target mines were utilized in as realistic a manner as possible. For example, all mines were set in the firing position with their detonating mechanisms blocked. This ensured that all metallic components were in the position that would generally be encountered during field conditions. Although all mines were buried in a level manner, in the field tests no systematic records were kept on the orientation of their firing mechanisms to the direction of mine detection.

The lanes chosen for the In-Soil Test are believed to be representative of many humanitarian demining scenarios throughout the world. Specifically, lanes consisting of sand, clay, peat and ferruginous soils were chosen. In Cambodia, test mines were placed in both clay and laterite soils. In Croatia, mines were placed in the soil predominantly available, which was highly metallic. In both field locations, host nation requests to test detectors against typical mine target configurations were also honored.

Although the testing covered many technical and environmental factors, some elements could not be evaluated due to time and budgetary constraints. These included: sustainability, the effects of electromagnetic interference and the use of multiple field test locations.

How to use this report

The body of this report contains summaries of the full technical reports from the In-Air Tests, In-Soil Tests, In-Country Field Tests and the Human Factors assessment. Copies of the comprehensive test results can be requested from the responsible agencies found in the References Section of this report. The respective agencies have agreed to evaluate each request on a case-by-case basis, with the desire to share the full details of the pilot project as much as possible.

This report should be of interest to a variety of readers including deminers and other operational users, donors, manufacturers of equipment and researchers. The report discusses results from basic laboratory tests through to field tests. Readers are encouraged to consider the relevance and value of each phase of testing to their particular situation.

The section describing the In Air Test results should provide the reader an understanding of the basic variables that affect the detector's performance, as well as the capability of the detector unencumbered by human factors or environment. As such, these results should not be used as the sole indicator of the detector's operational capability but will give an indication of the factors that may cause degradation of performance in the field.

The In-Soil Test, conducted in the Netherlands, was intended to approximate a number of representative soil types that deminers are likely to contend with. To achieve a certain degree of scientific rigor, the soil

test lanes were in a controlled environment. These results should help the reader to understand the effect of various soil types on detector performance.

In the section pertaining to field tests, the reader will find test results that may have more bearing on real-world demining applications. However, the results contained in this section may not be applicable to other regions of the world. These results were achieved in the less controlled field environment.

The Human Factors Assessment provides users with a subjective analysis of detector characteristics that do not lend themselves to scientific measurement. Many of these factors have significant bearing on the safety, usefulness and acceptability of equipment in the field. For example, an incomplete understanding on the part of the user of how the demining equipment functions, or the adjustment of the wrong control could easily lead to failure to detect an anti-personnel mine by the deminer - possibly resulting in severe or even fatal injury.

The results from both the In-Air Tests and the Human Factors Assessment can be used to improve training and operating procedures. In an effort to provide readers with specific test details pertaining to each detector evaluated, the report also contains individual detector data sheets (see Annex A). This section shows the individual detector performance from various tests relative to the performance of all other detectors evaluated. The results are depicted graphically for easy reference. Additionally, each data sheet includes information from the detector manufacturer related to cost, weight, and dimensions. Selected strengths and weaknesses of each detector are listed, based upon the Human Factors Assessment. The intent of this section is to provide readers more detailed information on a specific detector's performance and specifications, as well as comparative performance charts to aid the reader in selecting appropriate detectors for his situation.

A rating system (similar to ones used in some consumer reports) to rank the overall performance of the detectors was considered. However, in keeping with the original commitment not to convey a bias, no such rating is provided. Instead the results are presented in an objective manner. The data allows the reader, if he so chooses, to devise his own rating system to match his particular requirement.

The results as presented will allow the reader to identify groups of detectors with above average performance capabilities for a variety of demining environments. Therefore, it should be possible for the reader to focus his investigations on a few appropriate detectors in order to answer the question, "Which detector is the best for my needs?".

2. Training and Entrance Test

Objective

The objective of the Training and Entrance Test was to unpack and register the detectors and to train the personnel involved. Within this phase was a simple entrance test to identify any shortcomings and to ensure that all detector types met a minimum detection distance of 5 cm in air using the standard test object M_0. The training and entrance test took place at the Miner Training Centre of the Dutch Royal Engineers in Reek (the Netherlands). The test team consisted mainly of the same people that were involved during the other phases of the IPPTC.

Registration and training

Three copies of each detector type were purchased. The test team unpacked each detector type, registered it, and familiarised themselves with its operation. In order to keep all parts of the same detector together and to keep track of all the events a detector would go through during the IPPTC tests, each detector was given a unique code. This code – designated the IPPTC code - is used interchangeably with the detector name, and can be found on pages 5 and 127. It was put on all detector parts and casings. All information (including test incident reports) was noted in a logbook, which went with the detectors through all phases of the IPPTC.

In most cases, a short self-administered training session was conducted by studying the manual or instruction video and by using the detector outside the building. Some manufacturers took up the opportunity to provide a short on-site training session (Giat, Minelab, and Vallon). A questionnaire was filled-in to support the assessment of human factors in a later phase of the IPPTC.

Entrance test

To make sure that each copy of a certain detector type worked properly, a simple entrance test was defined. As part of this test a single operator determined the maximum (open-air) detection distance.

The detector was placed in a fixed position in a metal-free environment. A minimum warm-up time of three minutes was applied, unless the manual required otherwise. In general, the detectors were tested at the most sensitive settings. The M_0 test piece was moved manually across the detector head to stimulate a detector response. The distance from target to sensor head was raised in increments of one centimetre up to the distance that no signal was heard when the M_0 test piece was moved across the sensor head. This was repeated for all three copies of each detector. Table 2-1 shows the results of this test.

Detector Type	IPPTC ID	Maximum detection distance in open air (cm)			Maximum Difference	Remark
		Copy 1	Copy 2	Copy 3		
Adams AD2500	AD25	12	10	9	3	
Adams AD2600S	AD26	6	6	7	1	
Ebinger EBEX 420 GC	EB42	20	18	12	8	1)
Ebinger EBEX 535	EB53	15	16	15	1	
Fisher 1235-X	FI12	8	8	9	1	
Fisher Impulse	FIIM	27	27	29	2	
Fisher 1266-XB	FIXB	18	17	16	2	
Foerster MINEX 2FD	FOMI	22	22	21	1	
Giat Model F-1 (DHPM-1A)	GIAT	11	10	9	2	
Guartel MD2000 (round search head)	GUA2a	23	24	23	1	
Guartel MD2000 (long probe)	GUA2b	13	14	15	2	
Guartel MD2000 (short probe)	GUA2c	13	14	10	4	
Guartel MD4	GUA4	16	15	13	3	
Guartel MD8 (round search head)	GUA8a	16	17	17	1	
Guartel MD8 (oval search head)	GUA8b	16	16	16	0	
Guartel MD8 (probe)	GUA8c	x	12	13	1	2)
LG Precision PRS-17K	LGPR	18	18	15	3	
Minelab F1A4 CMAC	MICM	23	24	24	1	
Minelab F1A4 MIM	MIMI	24	25	23	2	
Pro-Scan Mark 2 VLF	PRMA	23	25	25	2	
Reutech Midas PIMD	REMI	12	11	12	1	
Schiebel AN-19/2	SCAN	24	26	25	2	
Schiebel ATMID	SCAT	27	27	x	0	3)
Schiebel MIMID	SCMI	20	16	18	4	
Vallon ML 1620C	VA16	28	28	28	0	
Vallon VMH2	VAVMa	30	29	29	1	
White's DI-PRO 5900	WH59	16	18	18	2	
White's AF-108	WHAF	20	23	20	3	
White's Spectrum XLT	WHSP	25	24	27	3	

1) Later in the project it was determined that copy 3 of the Ebinger EBEX 420 GC was malfunctioning.
2) The test of copy 1 of the Guartel MD8 (probe) was not completed, due to electromagnetic interference.
3) Copy 3 of the Schiebel ATMID had not been delivered in time for the test.

Table 2.1 *- Detection performance in air for the detectors in the Entrance Test.*

Summary of the Training and Entrance Test

Besides some small technical and logistic problems during the training, all detectors passed the entrance test and were deemed suitable for further testing with no significant differences found among samples of each detector.

3. In-Air Tests

This section summarizes the results of the In-Air Test conducted during the International Pilot Project for Technology Cooperation. It is derived from the full technical report [1,2].

Objective

The tests conducted in a controlled laboratory environment focus on a detector's ability to detect objects in air (also referred to as its in-air sensitivity) and assess how this sensitivity is affected by various parameters that reflect real-world conditions. In-Air tests are conducted in a controlled environment in which the only variable is the detector with its operator. While a detector's ability to detect objects in air does not directly indicate its ability to detect objects buried in the ground, such controlled tests are essential for an objective comparison of basic performance factors.

Test Facility at DRES

All In-Air testing at Defence Research Establishment Suffield (DRES) was conducted in the Foam Dome (Figure 3.1), an all weather foam building that, due to its non-conductive, non-magnetic construction, can be used to make very low noise magnetic and low frequency electromagnetic measurements.

An apparatus consisting of a scanner and a target holder, built of non-metallic materials, was specially developed to provide accurate mechanical control over sweep speed and target location (Figures 3.2 and 3.3). This device is capable of providing a linear or area scan. The electric motor, which was selected for its low electromagnetic interference, was positioned far enough away to not adversely affect the metal detector.

General Procedure

The process inherent in all of the In-Air tests is the determination of the maximum distance that a target can be detected from the detector sensor head. This is defined as the "maximum detection distance" and taken as a measure of the sensitivity of the detector. This distance was measured by placing a target on a platform that was moved up and down (Figure 3.3) to control target distance from the detector head. The

Figure 3.2. An Overall View of the Apparatus.

Figure 3.1. *The Foam Dome.*

Figure 3.3. Close-up View of Target Holder.

detector head was scanned on a horizontal plane above the target. The target distance from the sensor head was increased in one-centimeter increments until the operator judged that the detection signal disappeared. Although a number of operators were used during the tests, to the extent possible the same operator carried out all the tests for a given detector sample.

Because of mechanical limitations early in the tests, maximum detection distance of some detector/target combinations could not be achieved. An arrow is placed at the top of the chart bar(s) to indicate where this occurred.
Six tests were conducted: Calibration; Drift; Sweep Speed; Moisture; Sensitivity and Scan Profile. Descriptions and results for each test follow.

Calibration Test

For consistent results users should avoid using detectors whose performance changes significantly each time the detector is adjusted or set up for use. The purpose of this test was to determine the repeatability of the initial set-up. The test measures the maximum detection distance, using the mine surrogate target M_0 in vertical orientation, for five consecutive set-ups of a detector after an initial warm up period. The results are presented in Figure 3.4.

The sensitivity of some detectors remained essentially constant. In others it changed resulting in differences of up to 10 cm in the maximum detection distance, which represents a significant variation. Two samples of each detector were tested. In Figure 3.4, orange bars represent results from the sample with the lower maximum detection distance while the blue bars show the results for the other sample.

Drift Test

A reduction in sensitivity with time without warning to the operator could be potentially dangerous. The purpose of this test was to determine the extent of the change in the sensitivity of a detector over a 30-minute period. Practically, the results are important because if a detector's sensitivity suffers significantly from such short-term drift, the operator will have to adjust the detector frequently.

After an initial warm-up period of three minutes (in the absence of a manufacturer's requirement for longer periods), the detector was set up according to the manufacturer's recommended procedures and the maximum detection distance for the M_0 target was measured. This measurement was repeated, without readjusting the detector, every three minutes over a period of about a half-hour. The temperature of the laboratory was essentially constant during the tests for all detectors. Two samples of each detector were tested. The results showing the ranges of variation of the maximum detection distance are shown in Figure 3.5. In this figure, orange bars represent results from the sample with the lower maximum detection distance while the blue bars show the results for the other sample.
There was a wide variation in the drift performance among the detectors. The sensitivity of some detectors remained essentially constant. In others it changed resulting in differences of up to 10 cm in the maximum detection distance, which represents a significant variation.

Moisture Test

A reduction in sensitivity, without warning to the operator, when the search head comes in contact with water could be potentially dangerous. The purpose of this test was to determine the extent that moisture on the sensor head affected the sensitivity of a detector.

One sample of each detector was tested. The results show how much a detector's sensitivity will change if the search head comes in contact with water-such as occurs when operating in dew-covered vegetation or in light rain.

The test consisted of measuring the maximum detection distance of the M_0 target, after an initial warm up period and calibration, as an increasing amount of water was sprayed (in the form of tiny droplets of water as a mist) on the search head. The amount of water was controlled such that the range of wetness (from dry to completely wet) was achieved incrementally. Figure 3.6 shows the total variation in maximum detection distance for all the detectors over the entire range of wetness. Due to the time taken to complete a Moisture test (typically 20-30 minutes) the results from this test included some effect of drift that is difficult to separate. However, if a detector is found to have a much larger variation in the Moisture test than in the Drift test, the effect of moisture can be inferred.

There was a wide range of variations in sensitivity among the detectors with increasing amounts of moisture on the sensor head. The sensitivity of some detectors remained essentially constant. In others it resulted in differences of more than 10 cm in the maximum detection distance. One detector, the Schiebel ATMID (SCAT-1), stopped operating properly after some amount of moisture had accumulated on the sensor head. The detector produced continuous detection tones despite repeated attempts at initial set-up adjustments. It functioned properly the following day.

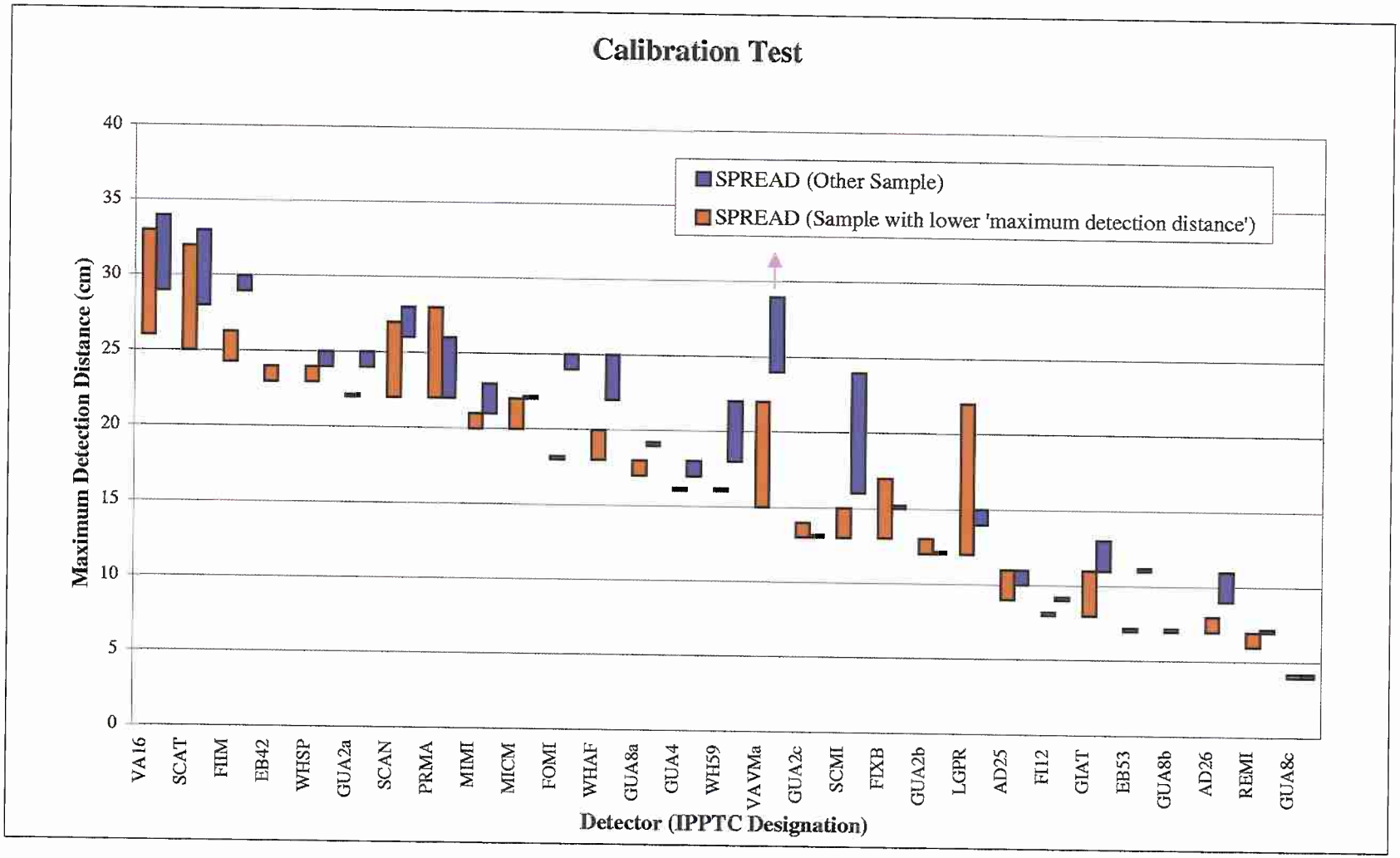


Figure 3.4. *Variation of maximum detection distance for five consecutive set-ups. Arrow explained in 2.3 General Procedures.*

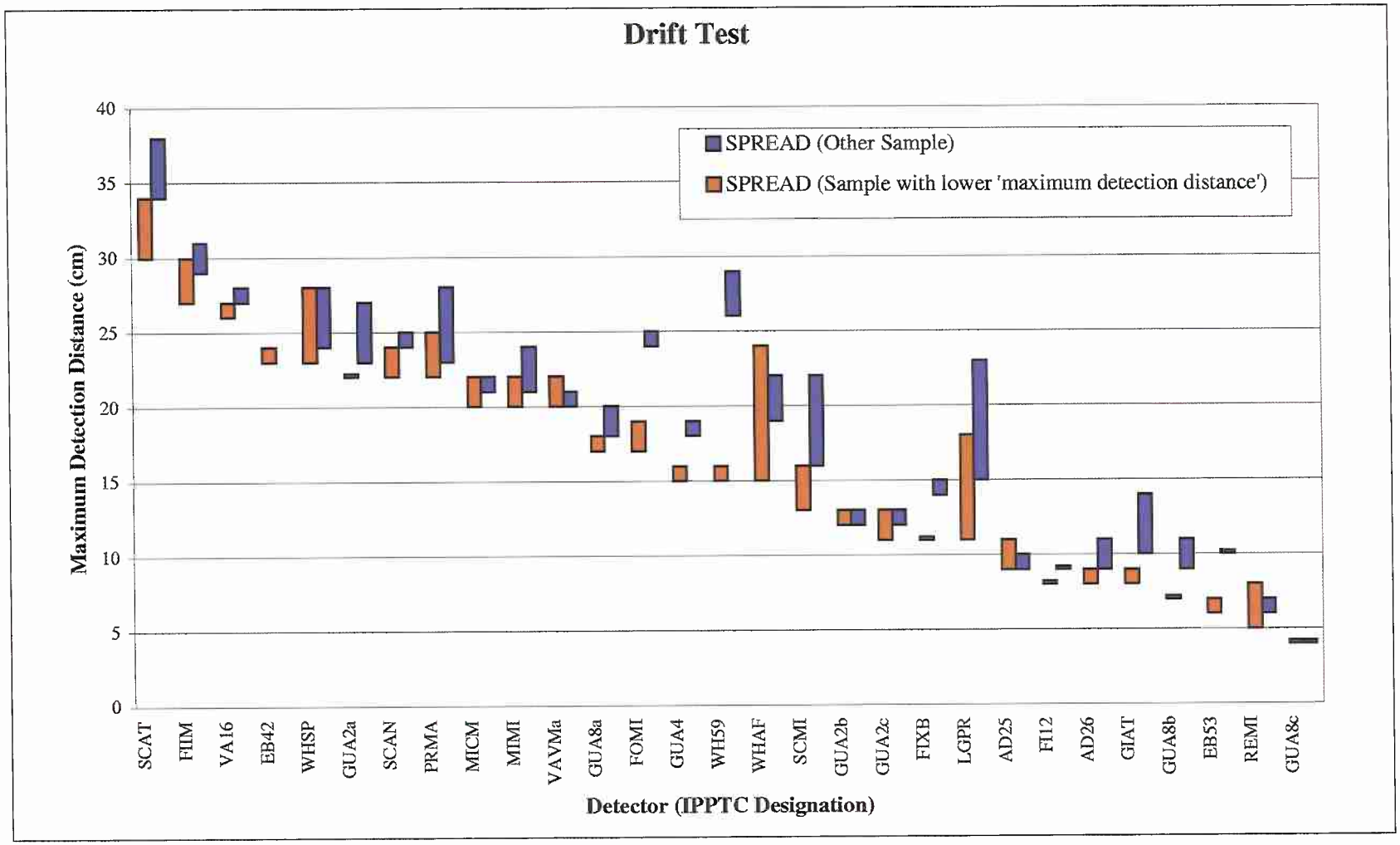


Figure 3.5. *Variation of maximum detection distance over 30 minutes.*

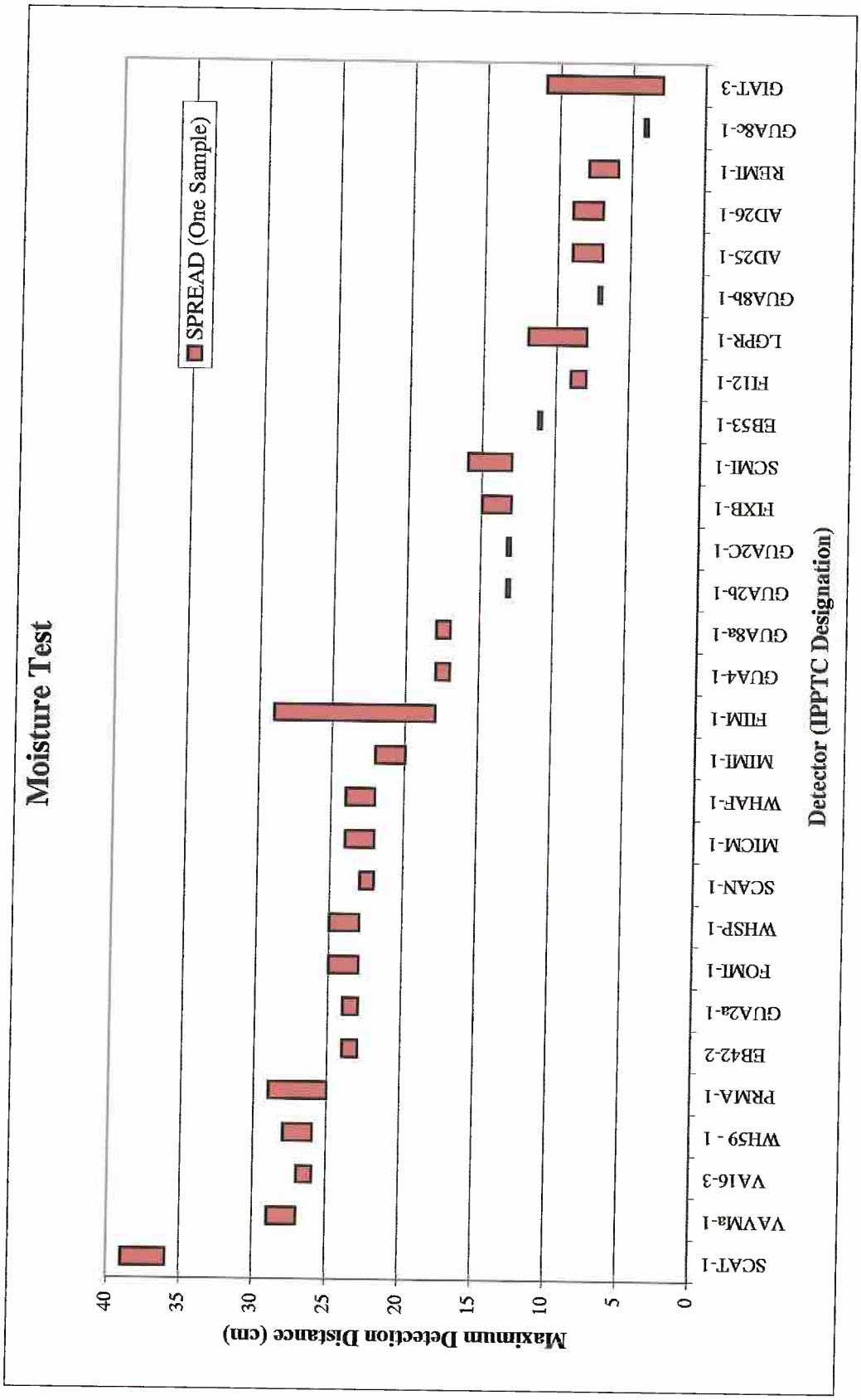


Figure 3.6. Variations of maximum detection distance due to sensor head wetness (dry to completely wet).

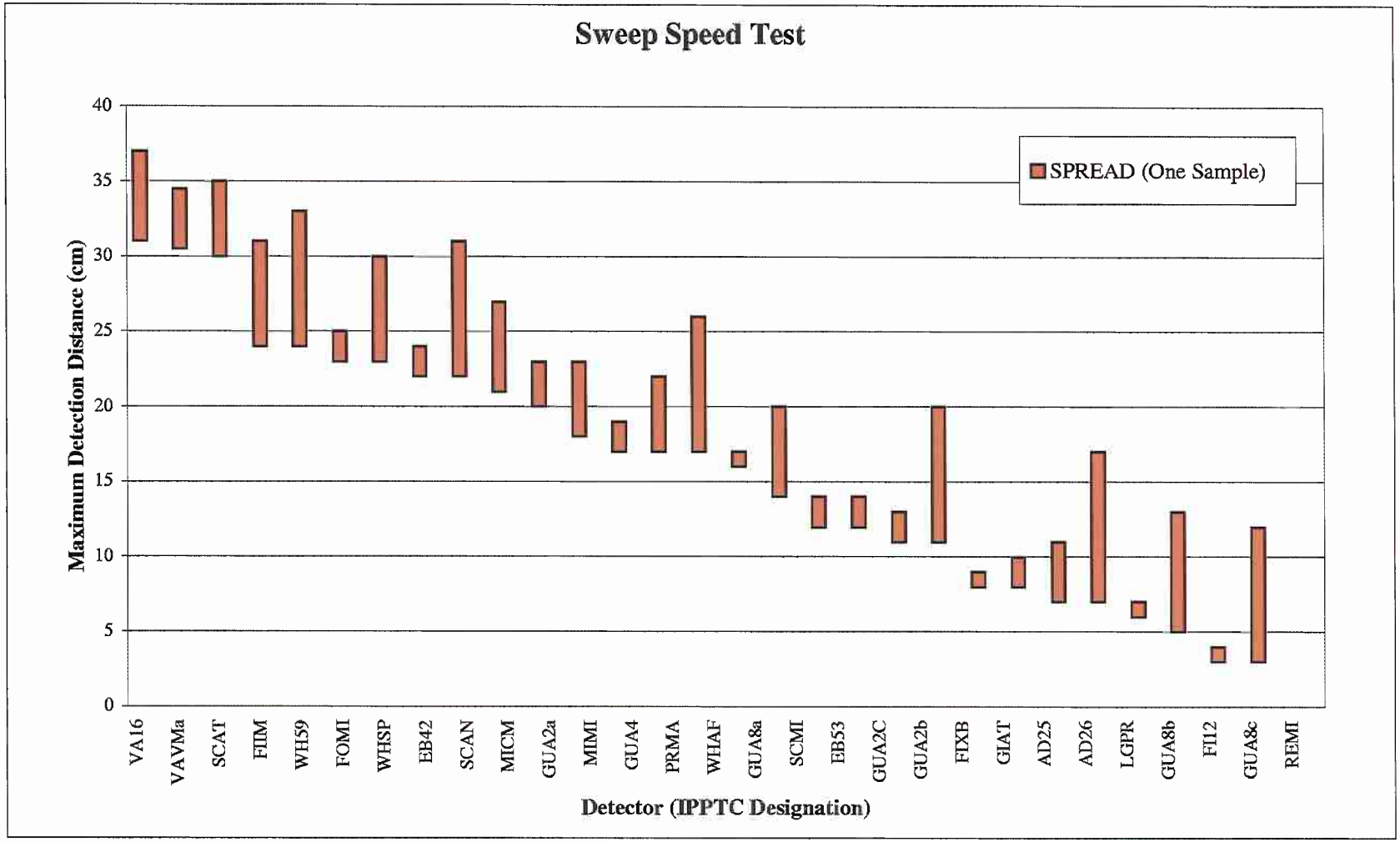


Figure 3.7. *Variations in maximum detection distance for a range of sweep speeds (0.12 to 1 m/s).*

All tests were conducted at the laboratory ambient temperature (20 – 22°C).

Sweep Speed Test

A reduction in sensitivity due to a change in sweep speed could be potentially dangerous since no current detectors give a warning to the operator if this were to happen. The purpose of this test was to determine how the sensitivity changes as a function of the speed with which the detector head is swept over a target. Results show what effect different sweep speeds had on sensitivity.

The test measured the maximum detection distance for the M_0 target, after an initial warm up period and calibration, for sweep speeds varying from 0.12 to 1 m/s. One sample of each detector was tested. Figure 3.7 shows the total variation in maximum detection distance recorded for all the detectors over the sweep speed range. The details of this variation as a function of sweep speed for each detector are shown in Figures 3.8 to 3.13. Although we did not test for it, we noted that some detectors would not detect targets when stationary. The user should make a particular point of knowing if this is the case for a chosen detector in order to develop a proper operating procedure.

There was a wide range of variation in sensitivity as a function of sweep speed among the detectors. The sensitivity of some detectors remained essentially constant. In others it resulted in differences of more than 10 cm in the maximum detection distance. In some models, sensitivity decreased as sweep speed increased while in others sensitivity increased with speed. In still other detectors, sensitivity initially increased and then decreased as the speed increased. End users should be made aware of this behavior whenever such detectors are employed.

Sensitivity Test

The purpose of this test was to determine the maximum distance at which a detector can detect each of the IPPTC targets. The test measured the maximum detection after an initial warm up period and calibration. The results show the maximum distances at which a given target was detected by the various detectors and are presented in Table 3.1 for the mines with significant metal content, namely, PMN, PMN-2, and PMD-6. Figures 3.14 to 3.20 show the results for the low-metal content mines and the simulant targets M_0, I_0, G_0. Two targets (PMN-2 and M_0) were measured with two samples of the detectors while all others were measured with only one sample of the detectors.

These figures illustrate the relative ability of the detectors to detect a specific target. **The potential users of the data presented in this section are warned against interpreting the detection distances of the various targets as distances at which they may be detected under operational conditions**. The results obtained with targets in air in a controlled laboratory environment should be used only as guidelines to assess relative performance of the

IPPTC Detector No.	TARGETS			
	PMN First Sample	PMD-6 First Sample	PMN-2	
			First Sample	Second Sample
AD25	23	11	13	9
AD26	23	9	10	15
EB42	61	30	34	no data
EB53	25	12	13	13
FI12	26	11	14	16
FIIM	**26**	**25**	**26**	44
FIXB	39	20	22	24
FOMI	58	29	35	25
GIAT	30	15	17	22
GUA2a	61	30	36	39
GUA2b	36	16	19	18
GUA2c	37	18	20	20
GUA4	**32**	22	28	23
GUA8a	46	22	27	29
GUA8b	22	8	11	no data
GUA8c	15	5	6	6
LGPR	43	18	20	21
MICM	46	23	26	28
MIMI	40	23	29	30
PRMA	**33**	28	**33**	36
REMI	28	10	13	13
SCAN	46.2	32	38	34
SCAT	**47**	41	**47**	46
SCMI	**34**	21	29	18
VA16	**39**	**39**	**40**	40
VAVMa	38	30	35	31
WH59	**44**	27	33	23
WHAF	**45**	28	37	34
WHSP	**44**	29	35	36
LEGEND		Maximum detection distance was not obtained due to mechanical limitations of early target holders. Consider these values as 'greater than'.		

Table 3.1 - Maximum detection distance for PMN, PMD-6 and PMN-2.

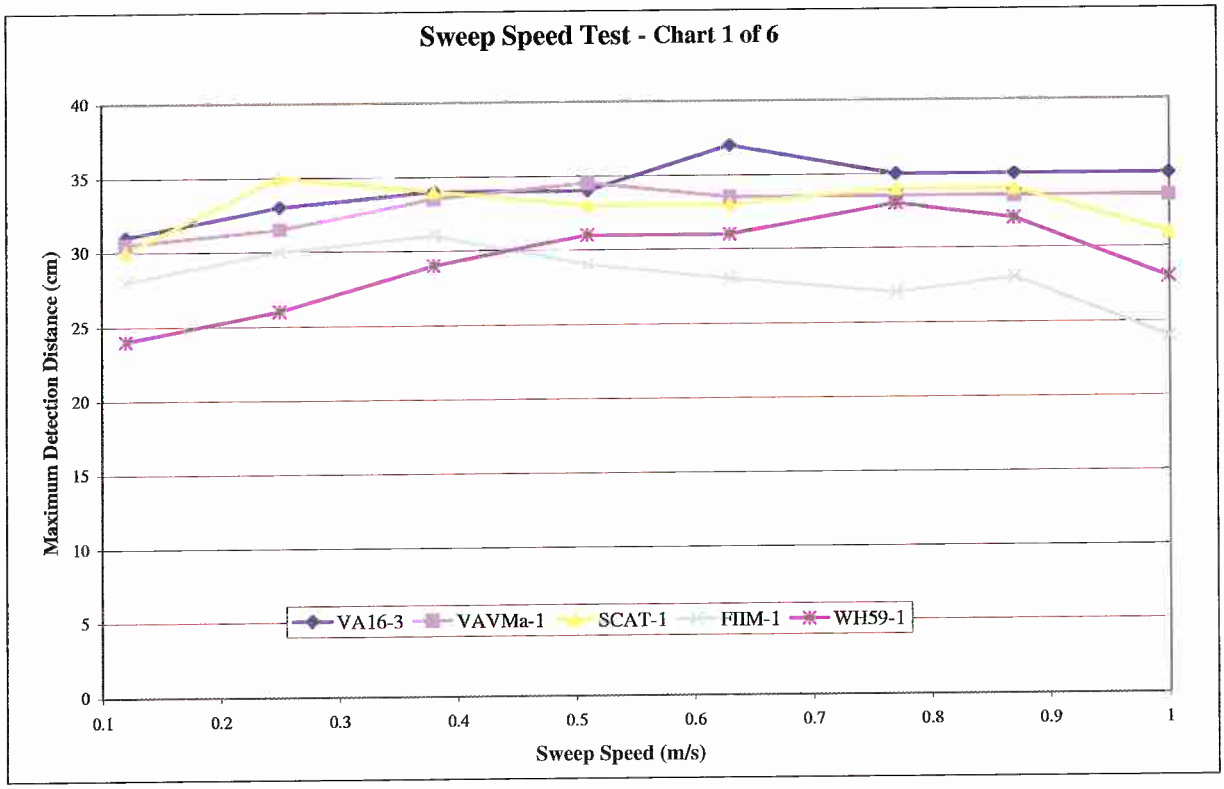


Figure 3.8. *Maximum detection distance vs. sweep speed of selected detectors.*

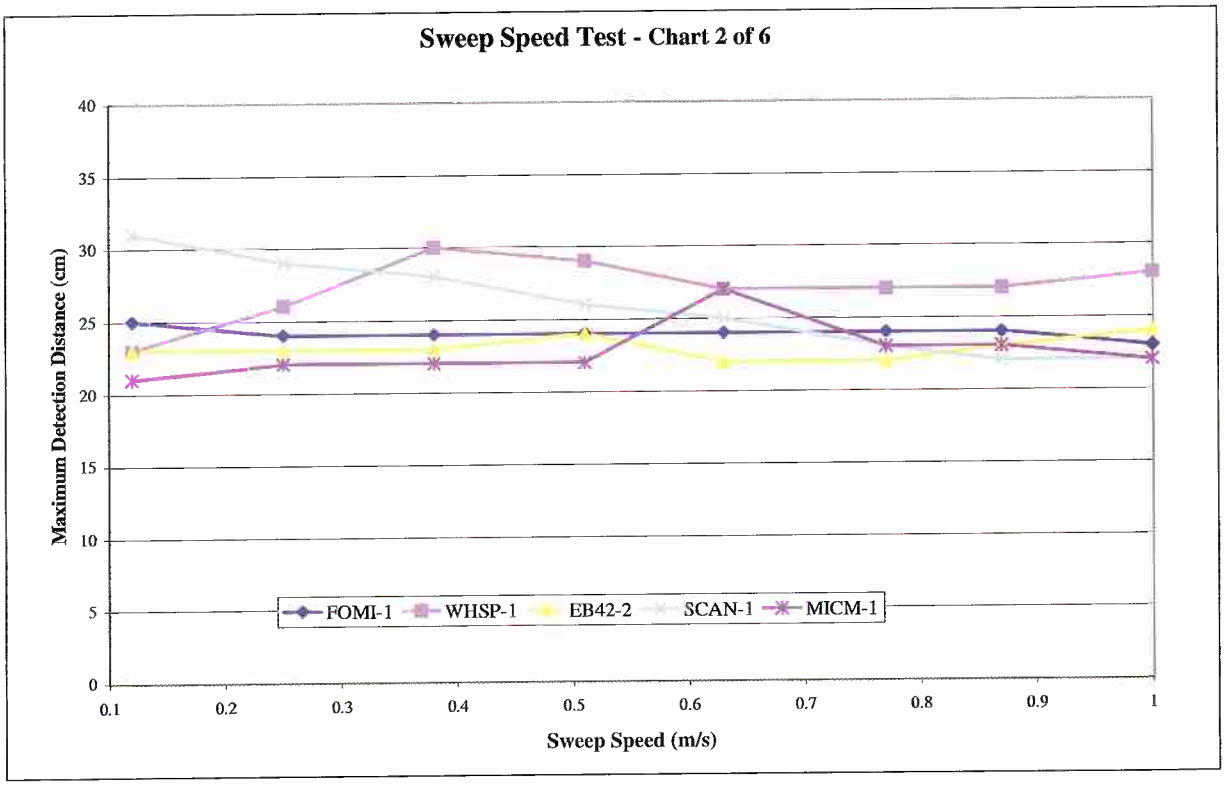


Figure 3.9. *Maximum detection distance vs. sweep speed of selected detectors.*

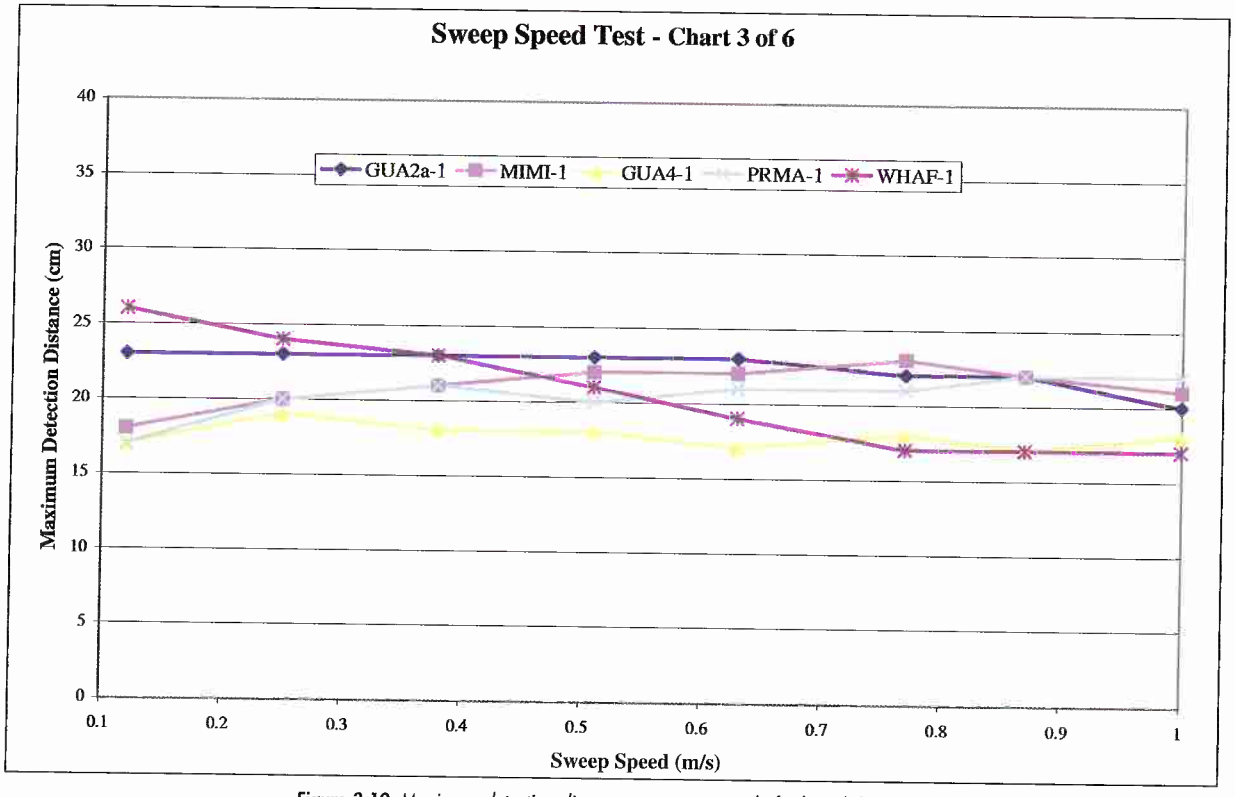


Figure 3.10. Maximum detection distance vs. sweep speed of selected detectors.

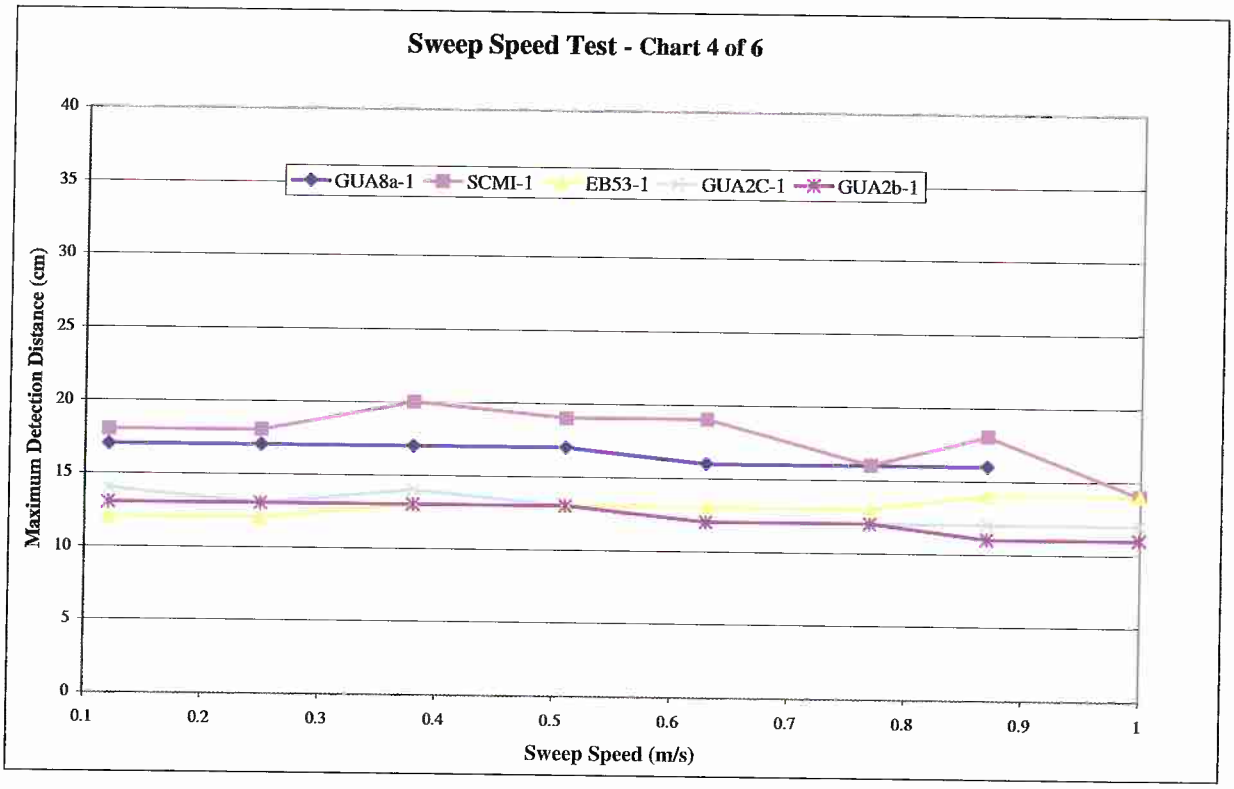


Figure 3.11. Maximum detection distance vs. sweep speed of selected detectors.

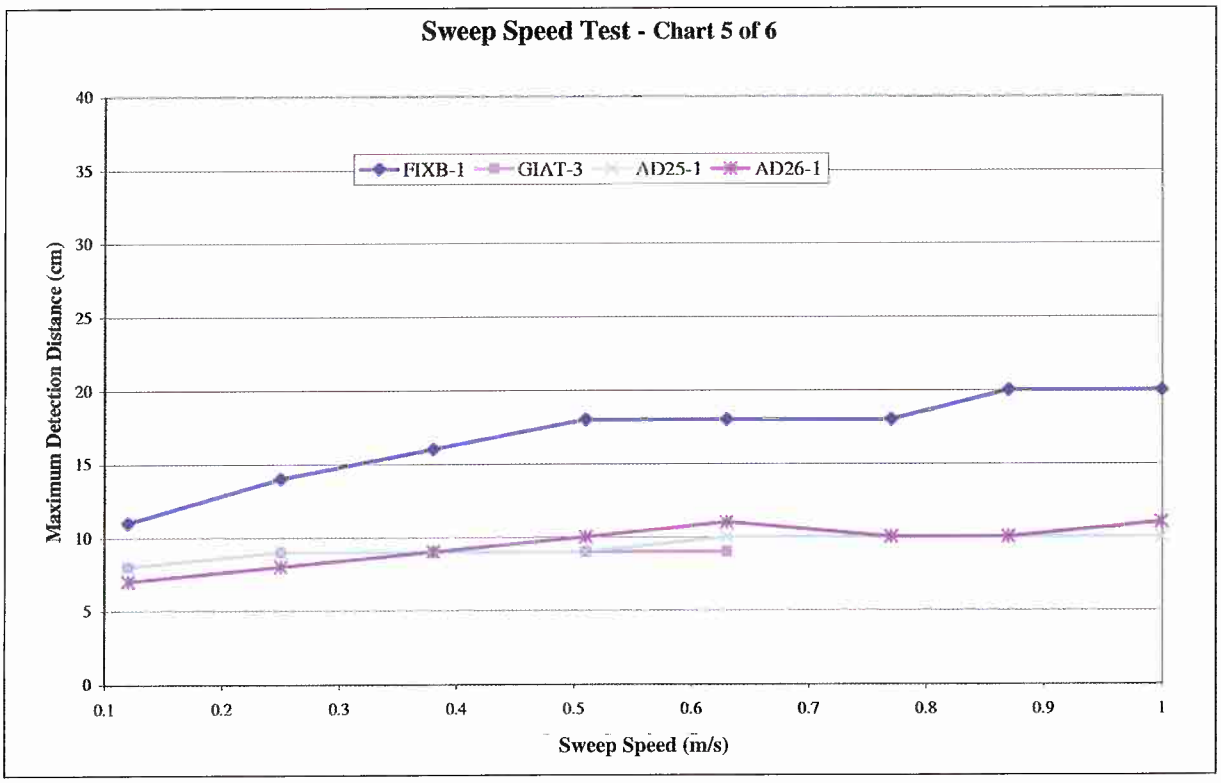


Figure 3.12. *Maximum detection distance vs. sweep speed of selected detectors.*

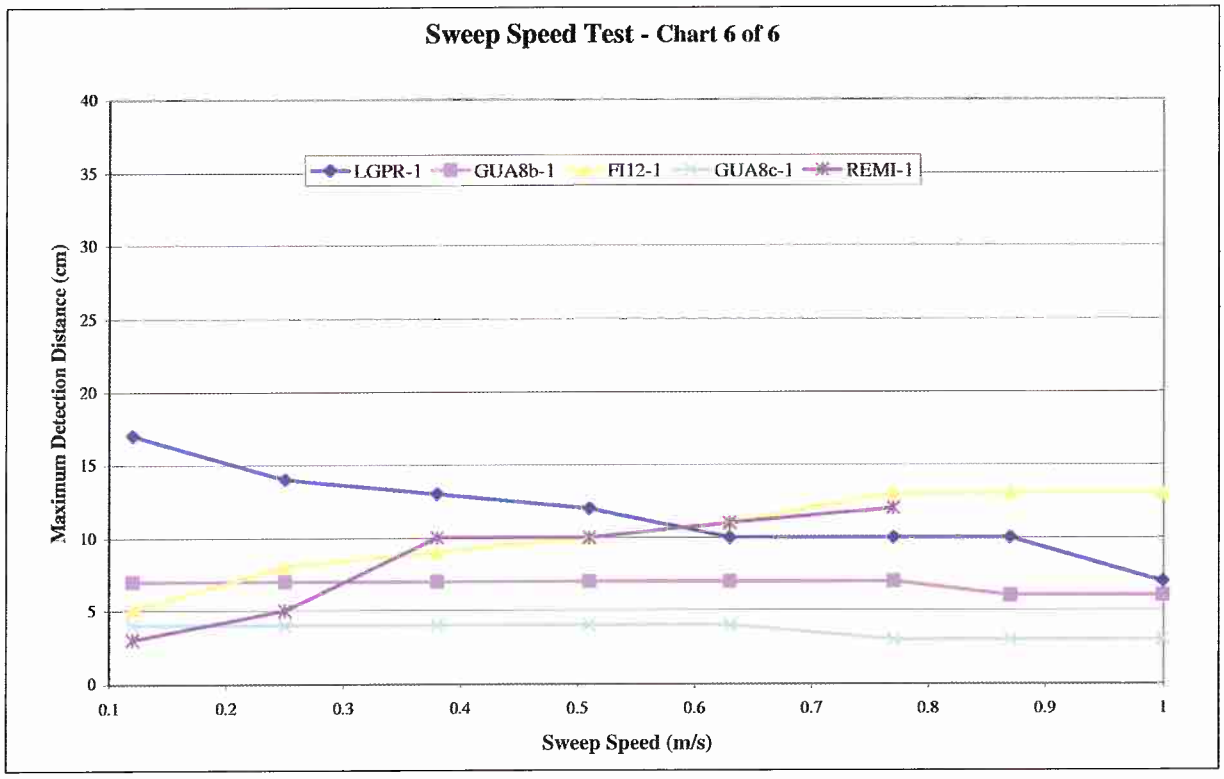


Figure 3.13. *Maximum detection distance vs. sweep speed of selected detectors.*

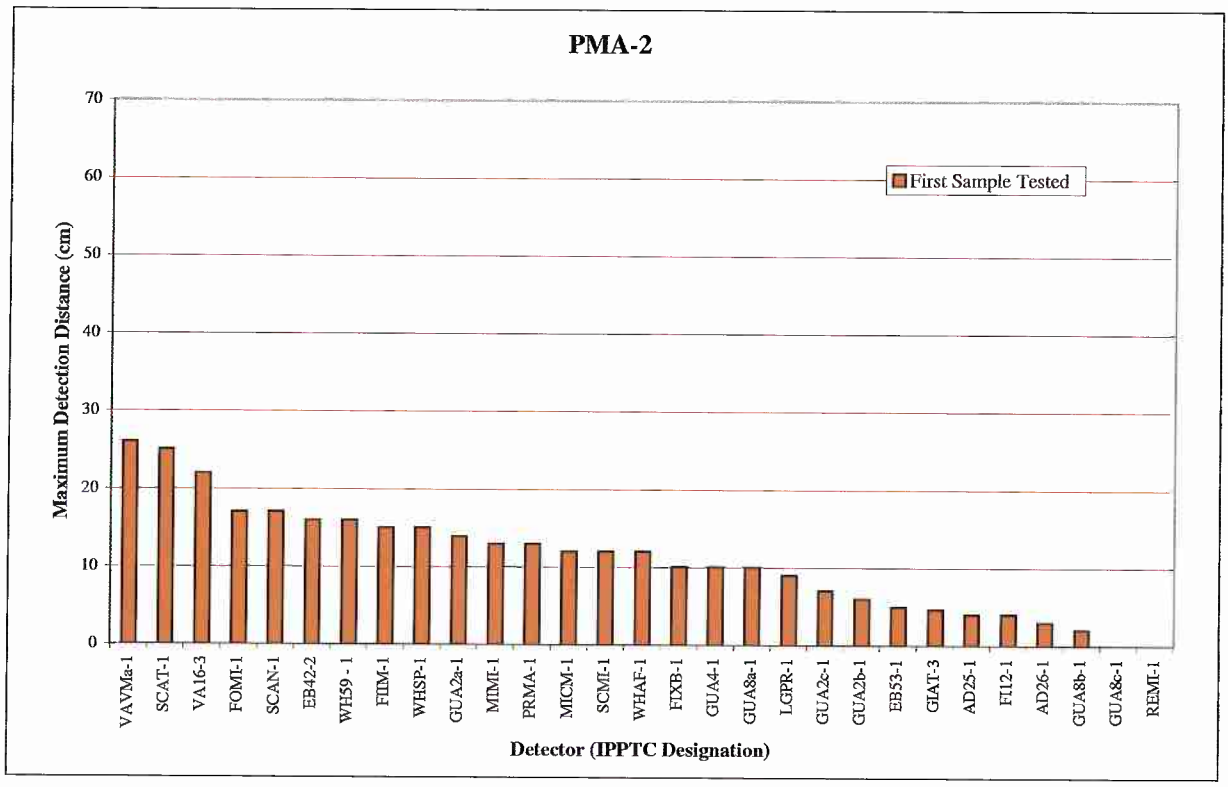


Figure 3.14. Maximum detection distance for PMA-2.

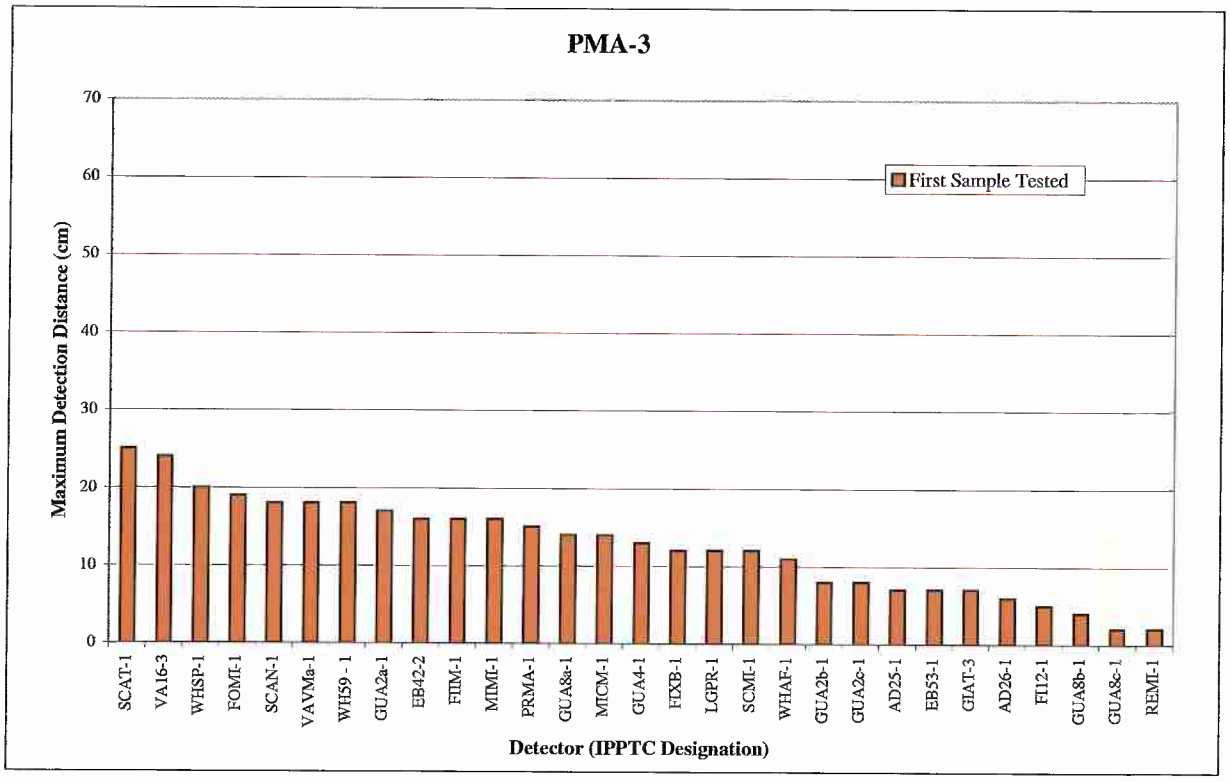


Figure 3.15. Maximum detection distance for PMA-3.

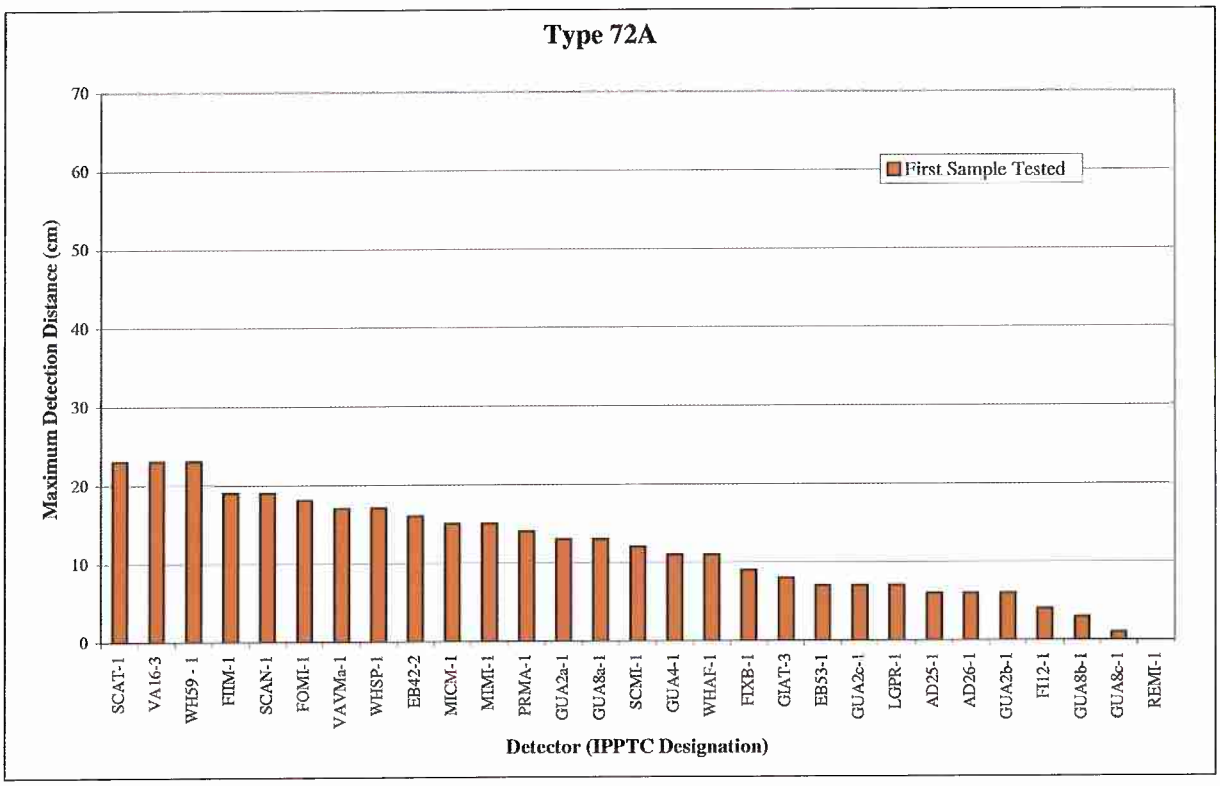


Figure 3.16. Maximum detection distance for Type 72.

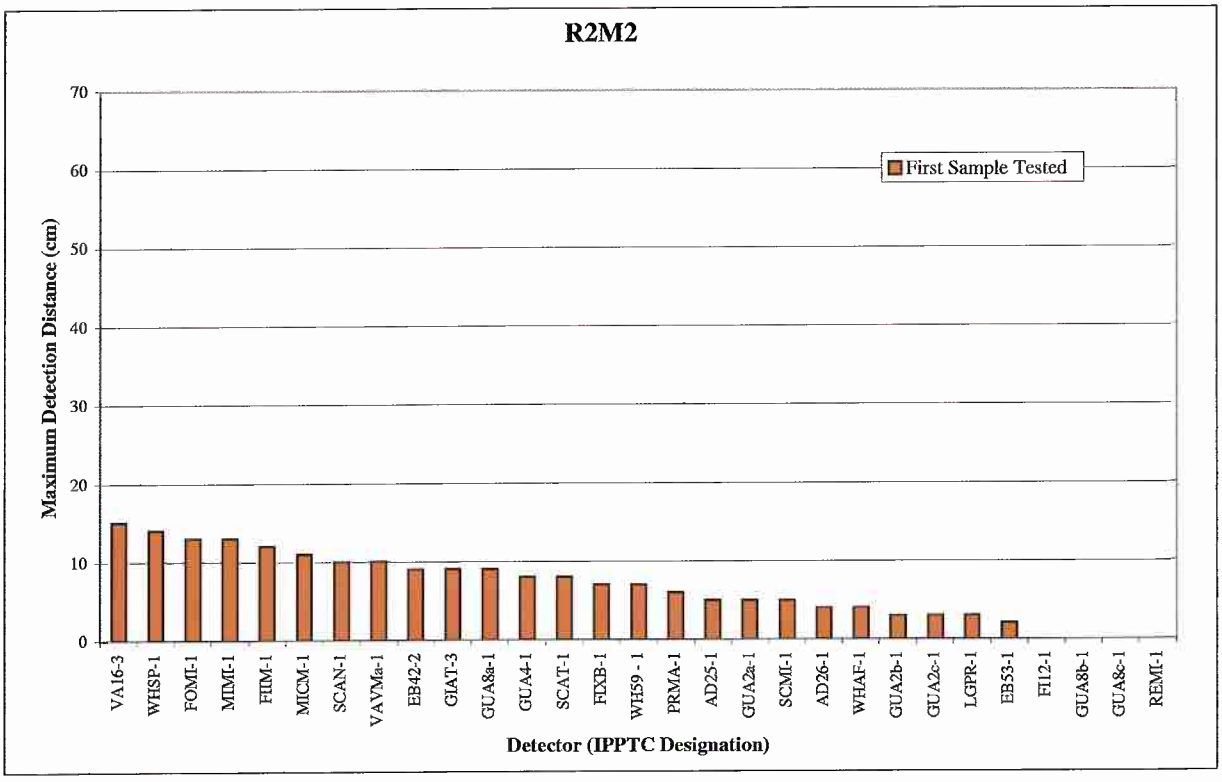


Figure 3.17. Maximum detection distance for R2M2.

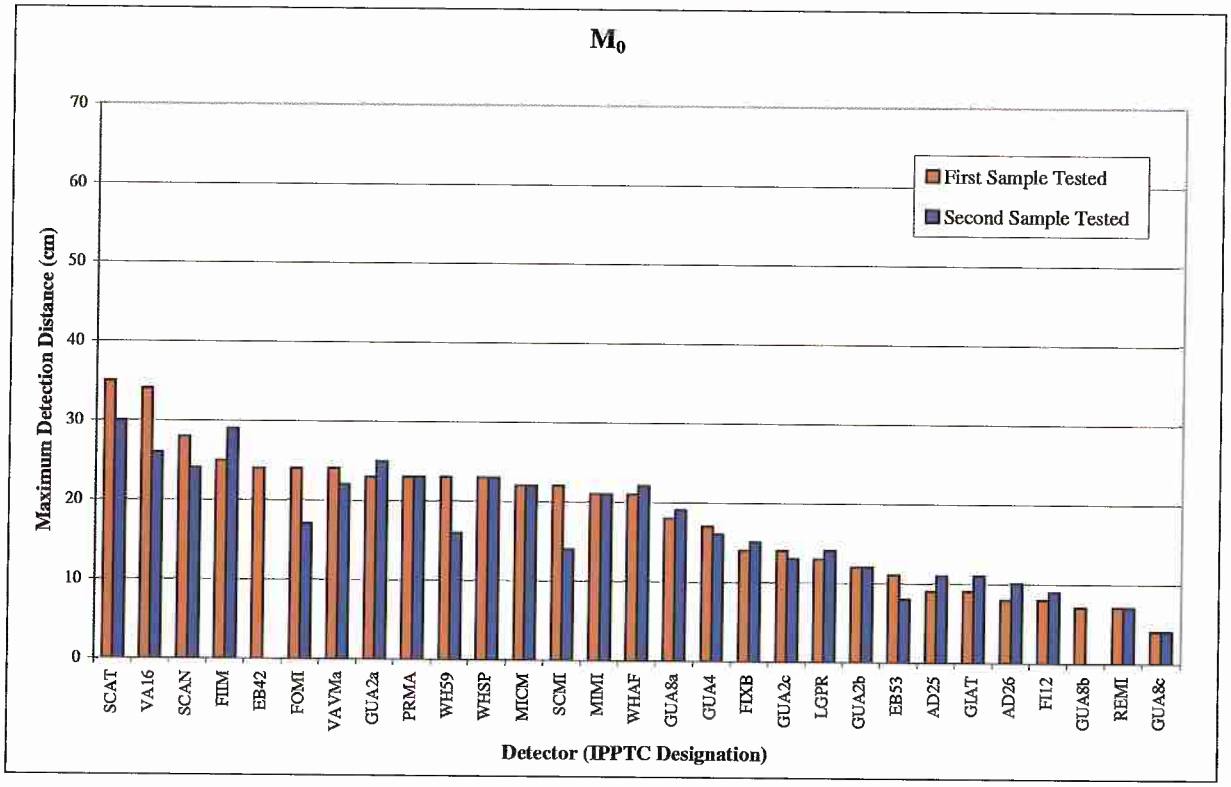


Figure 3.18. Maximum detection distance for M_0.

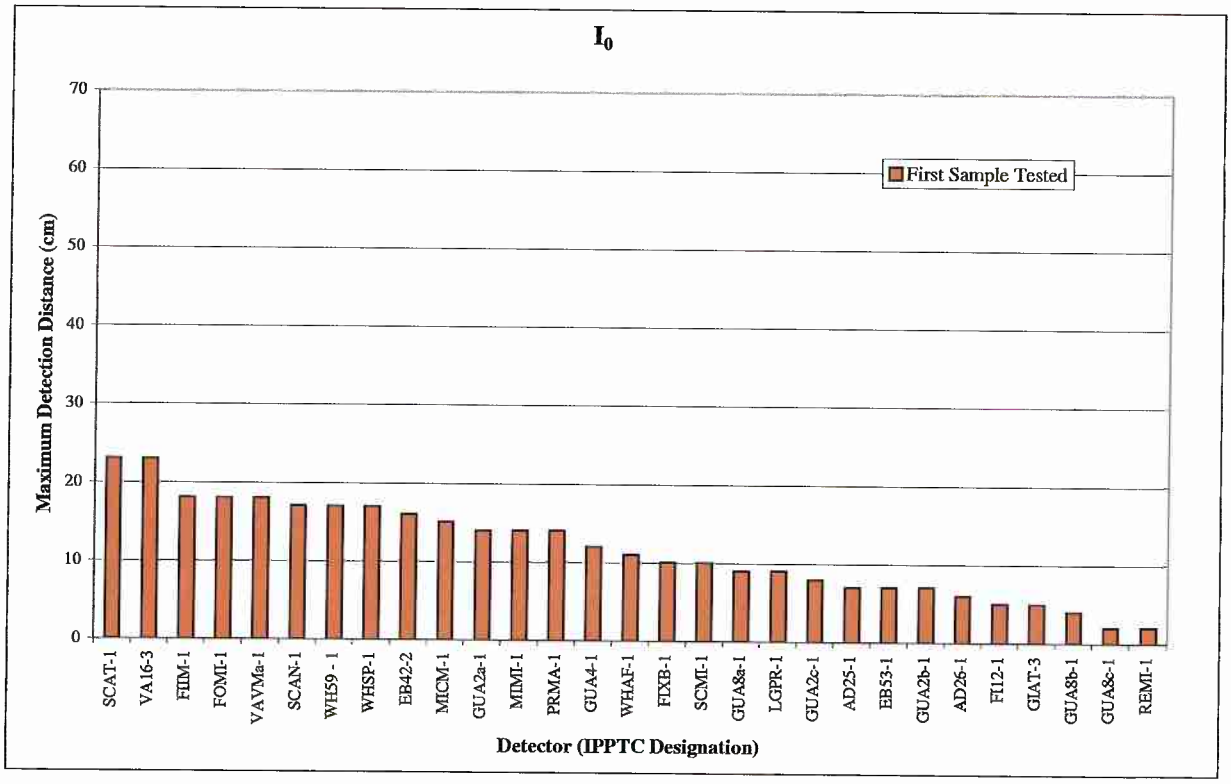


Figure 3.19. Maximum detection distance for I_0.

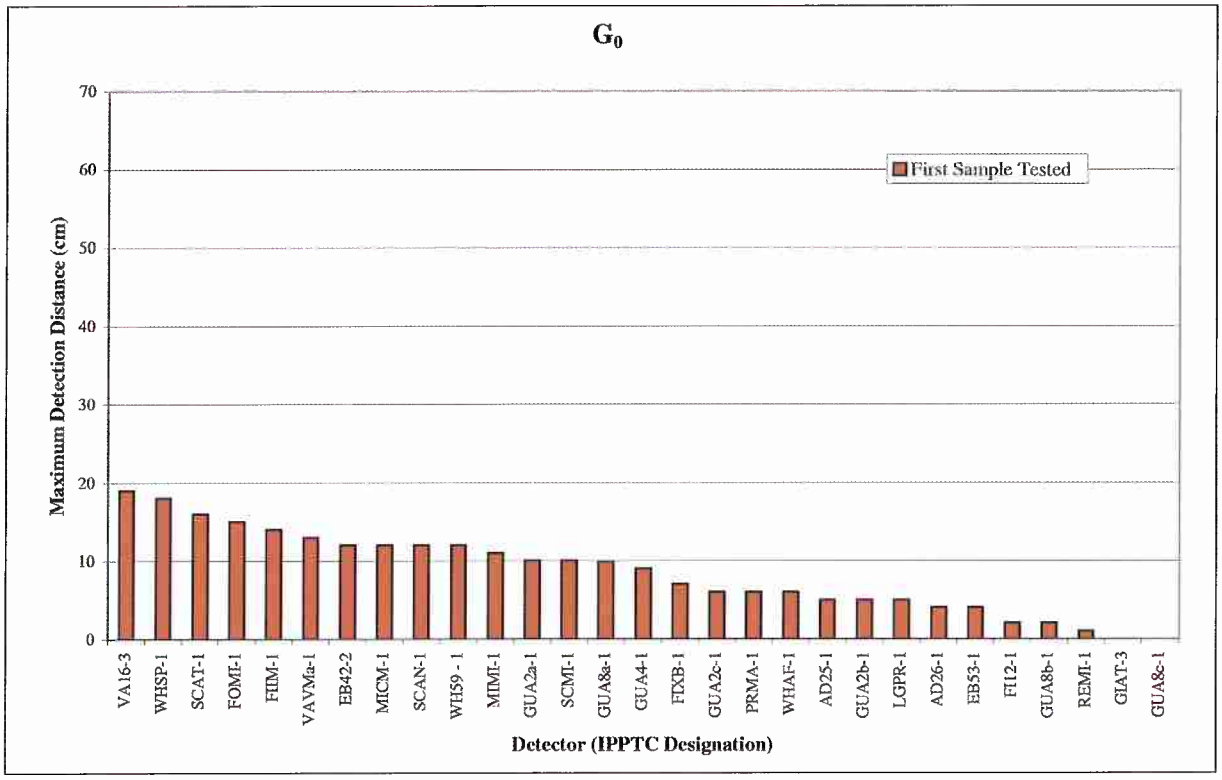


Figure 3.20. *Maximum detection distance for G_0.*

detectors and to compare results of similar tests done by others. The results also identified detectors that did not have the minimum required detection distance for targets of interest, since a target is not likely to be detected at a greater distance in soil than in air. In addition to factors such as calibration, drift, sweep speed and ambient noise that can affect the detection distance, the operators themselves could have a significant influence.

Scan Profile Test

The purpose of this test was to determine the scan profile or "footprint" of a detector. The footprint is defined as the variation of the detection area as a function of a target's location with respect to the sensor head. The test measures the area of this footprint at three distances after an initial warm-up and calibration. Results of this test give an indication to users of how closely to space consecutive sweeps to ensure desired coverage. The size and shape of this footprint may differ significantly dependent not only on the detector but also on the target, its size, orientation and depth.

The electrical signal that drives the headphone of the detector was recorded digitally for the scan profile, using the same system as used for the In-Soil tests. A value proportional to the strength of the audio signal was plotted as a function of two-dimensional position of the detector head over target M_0. To provide an indication of variation in the size of the footprint with distance, data was recorded corresponding to three different target distances:

(a) 2 cm closer to the sensor head than the maximum detection distance;

(b) 2 cm from the sensor head; and

(c) at a distance halfway between (a) and (b).

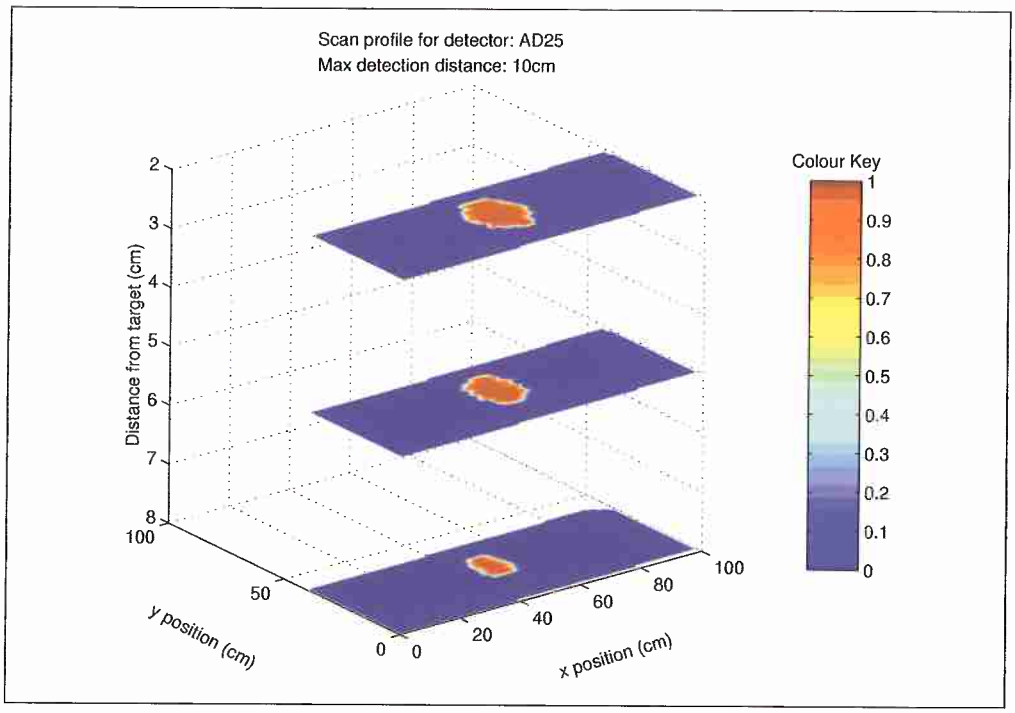
An example is shown in Figure 3.21.

The color key is representative of the signal from the detector where the "0" (dark blue) is minimum signal and the "1" (red) is maximum signal. The footprint becomes smaller as the target distance increases, resulting in a cone-shaped "detection volume". For the small target used, this general trend of shrinking footprint with distance was observed for all the detectors tested. The footprints for each detector are included in **Annex A. Detector Performance Summaries.**

Summary of In-Air Tests

The main purpose of the In-Air Tests was to understand certain basic operational parameters of the detectors in a controlled laboratory environment.

Figure 3.21. Variations in footprint with target distance.



Although it is difficult to draw statistically rigorous conclusions based on the amount of data available from the In-Air tests, the results provide practical and useful information to the reader. The In-Air Tests can be divided into three categories:
(a) Tests aimed at getting an indication of how much variation in sensitivity is to be expected due to various factors inherent in field use. The Calibration, Drift, Moisture and Sweep-Speed tests belong to this group;
(b) Sensitivity test, which measured the ability of a detector to detect a variety of targets of interest;
(c) Scan Profile test, which determined the variation of detectability of a target as a function of its location with respect to the detector head.
All tests were conducted at the laboratory ambient temperature (20 – 22°C).

The results of the tests in category (a) are summarized in Table 3.2, and presented in more detail in Figures 3.4 to 3.13. Table 3.2 shows the average of the maximum detection distances recorded during each test. The average gives an indication of the relative sensitivity of the different detectors. The column titled 'variation' is a representation of the variation in sensitivity found during that test. (The number in this column is an estimate of the standard deviation.)

Care must be exercised in using the results of the individual tests to derive their combined effect in the field. For example, due to the time taken to complete a Moisture test (typically 20-30 minutes) the results from this test include some effect of drift that is difficult to separate. However, if a detector is found to have a much smaller variation in the Drift Test than in the Moisture Test, the effect of moisture can be inferred.

The dependence of sensitivity on sweep speed is shown in Figure 3.8 to 3.13. For some detectors (White's DI-PRO 5900, for example) the sensitivity rapidly increased with speed, reaching a maximum, and then decreased at higher speeds. For some others (Schiebel AN-19/2, for example) sensitivity decreased linearly with sweep speed. In still others, the sensitivity stayed essentially constant. Although we did not test for it, we noted that some detectors would not detect targets when stationary. The user should make a particular point of knowing if this is the case for a chosen detector in order to develop a proper operating procedure.

The results of the category (a) tests should be used only in conjunction with the Sensitivity Test in choosing a detector. A detector with stable performance is not very useful if it cannot detect targets of interest at required distances. For example, the performance of the Adams AD2500 was found to vary very little due to the parameters tested. However, in air, its detection ranges for low-metal targets such as the PMA-2, PMA-3, Type 72 and R2M2 were well below 10 cm (Table 3.3), which would not be satisfactory for many demining situations.

TESTS	CALIBRATION				DRIFT				MOISTURE		SWEEP SPEED	
MODEL	First Sample	Second Sample	First Sample	Second Sample	First Sample	Second Sample	First Sample	Second Sample	First Sample		First Sample	
	Average	Variation +/-	Average	Variation +/-	Average	Variation +/-	Average	Variation +/-	Average	Variation +/-	Average	Variation +/-
AD25	10	1	10	1	10	1	10	1	8	1	9	1
AD26	8	1	10	1	9	0	10	1	8	1	10	1
EB42 (1)	24	1	No data		23	1	No data		24	1	23	1
EB53	7	0	11	0	10	0	7	0	11	0	13	1
FI12	8	0	9	0	8	0	9	0	9	1	10	3
FIIM	25	1	30	1	28	1	30	1	22	5	28	2
FIXB	15	2	15	0	11	0	14	1	14	1	17	3
FOMI	18	0	24	0	25	1	18	1	24	1	24	1
GIAT	10	1	12	1	9	1	12	1	6	3	9	0
GUA2a	22	0	25	1	22	0	25	1	23	0	22	1
GUA2b	12	1	12	0	13	0	12	0	13	0	12	1
GUA2c	13	0	13	0	13	0	11	1	13	0	13	1
GUA4	16	1	17	0	18	0	16	0	18	0	18	1
GUA8a	18	1	19	0	18	1	19	1	18	0	17	1
GUA8b(2)	7	0	No data		7	0	10	1	7	0	7	0
GUA8c	4	0	4	0	4	0	4	0	4	0	4	1
LGPR	18	0	15	4	13	2	18	2	10	2	12	3
MICM	21	0	22	1	21	1	21	1	23	1	23	2
MIMI	21	1	22	0	22	1	21	1	21	1	21	2
PRMA	26	2	24	2	26	1	24	1	27	2	21	2
REMI	7	1	7	0	7	1	7	0	7	1	9	4
SCAN	24	1	27	2	25	0	23	1	22	0	26	3
SCAT(3)	30	2	30	3	36	1	31	1	failed		33	2
SCMI	14	3	19	1	19	2	14	1	14	1	18	2
VA16	28	3	31	2	28	0	27	0	26	0	34	2
VAVMa	21	2	26	3	20	0	21	1	28	1	33	1
WH59	16	2	20	0	28	1	16	0	27	1	29	3
WHAF	19	1	23	1	21	1	21	3	23	1	21	4
WHSP	23	0	25	0	26	1	25	2	24	1	27	2
MAX	30	3	31	4	36	2	31	3	28	5	34	4
MIN	4	0	4	0	4	0	4	0	4	0	4	0

(1) All samples had failed. One working unit was made from modules of three detectors.
(2) The sensor head is a preliminary production model and is unreliable.
(3) This detector failed partway through the test. It recovered the following day after drying.

Key: Green (three shades) group average values of maximum detection distance into 0-10, 11-20 and >20 cm. Blue (three shades) group the variation into 1 or less, 2, and 3-5 cm respectively.
These groupings are arbitrary, intended only to assist the reader in finding detectors in low, medium and high performance categories. The lighter shades indicate more desirable performance.

***Table 3.2** – Summary table of Calibration, Drift, Moisture and Sweep Speed tests. The values are in cm.*

IPPTC Detector ID No.	TARGETS											
	PMN	PMN-2		PMD-6	PMA-2	PMA-3	Type 72	R2M2	M_0		I_0	G_0
	First Sample	First Sample	Second Sample	First Sample	First Sample	First Sample	First Sample	First Sample	First Sample	Second Sample	First Sample	First Sample
AD25	23	13	9	11	4	7	6	5	9	11	7	5
AD26	23	10	15	9	3	6	6	4	8	10	6	4
EB42	61	34	No data	30	16	16	16	9	24	No data	16	12
EB53	25	13	13	12	5	7	7	2	11	8	7	4
FI12	26	14	16	11	4	5	4	0	8	9	5	2
FIIM	**26**	**26**	44	**25**	15	16	19	12	25	29	18	14
FIXB	39	22	24	20	10	12	9	7	14	15	10	7
FOMI	58	35	25	29	17	19	18	13	24	17	18	15
GIAT	30	17	22	15	5	7	8	9	9	11	5	0
GUA2a	61	36	39	30	14	17	13	5	23	25	14	10
GUA2b	36	19	18	16	6	8	6	3	12	12	7	5
GUA2c	37	20	20	18	7	8	7	3	14	13	8	6
GUA4	**32**	28	23	22	10	13	11	8	17	16	12	9
GUA8a	46	27	29	22	10	14	13	9	18	19	9	10
GUA8b	22	11	No data	8	2	4	3	0	7	No data	4	2
GUA8c	15	6	6	5	0	2	1	0	4	4	2	0
LGPR	43	20	21	18	9	12	7	3	13	14	9	5
MICM	46	26	28	23	12	14	15	11	22	22	15	12
MIMI	40	29	30	23	13	16	15	13	21	21	14	11
PRMA	**33**	**33**	36	28	13	15	14	6	23	23	14	6
REMI	28	13	13	10	0	2	0	0	7	7	2	1
SCAN	46	38	34	32	17	18	19	10	28	24	17	12
SCAT	**47**	**47**	46	41	25	25	23	8	35	30	23	16
SCMI-	**34**	29	18	21	12	12	12	5	22	14	10	10
VA16	**39**	**40**	40	**39**	22	24	23	15	34	26	23	19
VAVMa	38	35	31	30	26	18	17	10	24	22	18	13
WH59	**44**	33	23	27	16	18	23	7	23	16	17	12
WHAF	**45**	37	34	28	12	11	11	4	21	22	11	6
WHSP	**44**	35	36	29	15	20	17	14	23	23	17	18
MAX	61	47	46	41	26	25	23	15	35	30	23	19
MIN	15	6	6	5	0	2	0	0	4	4	2	0

LEGEND	
	Detectors EB42 and GUA8b exhibited reliability problems on the second samples.
	Maximum detection distance was not obtained due to mechanical limitations of early target holders. Consider these values as 'greater than'.

Table 3.3 *– Summary of maximum detection distances (cm) of targets vs. detectors.*

4. In-Soil Tests

This section summarizes the results of the In-Soils Test conducted during the International Pilot project for Technology Cooperation. It is derived from the full technical report. [3,4]

Objective

The objective of In-Soil Tests was to determine the detection performance of the metal detectors when used for the detection of AP mines, buried in four different types of soil. To this end the detectors were tested against the defined IPPTC targets at the outdoor test lanes of TNO Physics and Electronics Laboratory (TNO-FEL) in the Netherlands.

Test facility at TNO-FEL

The outdoor test facility, which was used for the In-Soil Tests of the IPPTC, is situated on the Waalsdorp proving ground near TNO-FEL. It consists of six lanes with a different soil type in each lane, equipment to control the groundwater level in the lanes, a measurement platform and peripheral equipment. Figure 4.1 shows an overview of the six lanes and the measurement platform.

The dimensions of the test lanes are 10 m x 3 m x 1.5 m for length, width and depth, with a distance of 1 m between them. The distance between the lanes is to avoid interference in the measurements on one lane by objects situated in adjacent lanes. To avoid distortion of the metal detector measurements the lanes have been constructed of wood without the use of electrically conducting materials. During construction of the 6 lanes a zone 5 m wide and 1.5 m deep around the lanes was made free of metal.

Of the available six lanes only four lanes, containing sand, clay, peat and ferruginous soil, were used. While constructing the lanes, the natural layer structure of the soils was preserved. During the tests, the groundwater level was controlled and the moisture content was monitored. The magnetic susceptibility and the electric conductivity of the soils in the four lanes are given in **Annex B - Soil Measurements**.

Figure 4.1. *Overview test lanes and measurement platform.*

The measurement platform is made of non-conducting materials. It consists of a 17 m long glass-fiber reinforced polyester tube with a diameter of 0.9 m (Figure 4.2). A sensor platform moves automatically over the tube with a speed of approximately 0.18 m/s. The polyester tube can be moved manually along rails. The position of the sensor platform along the tube was measured continuously with a laser distance meter, and logged against time.

For the tests of the metal detectors on the test lanes a special mounting system was constructed out of

Figure 4.2. *Measurement platform.*

plastic. This mounting system was fixed to the sensor platform and adjusted to mount the different metal detectors.

The weather conditions during the In-Soil Tests were measured and recorded with two meteorological stations, one at 30 cm above ground level and one at a height of three metres. The standard meteorological observations were recorded: solar radiation, air temperature, relative humidity of the air, wind speed and direction, and precipitation.

Equipment and materials

Metal detectors

Two samples of each detector model were tested. In case of a detector failure, the third sample of the concerned detector model was used.

During the project the manufacturer indicated that the oval search head of the Guartel MD8 was a preliminary product with reliability concerns. Therefore, this detector head was not included in the analysis of the In-Soil Tests.

Data acquisition hardware and software

The main functions of the data acquisition system for the In-Soil Tests were:

Recording the audio signals of the detectors;
Recording the position of the detector;
Playing back the recorded detector audio signal.

To record the audio signals of the detectors, the original headphones (all detectors were provided with headphones or a headphone connector) were adapted with a T-connector to allow simultaneous recording by the computer system and monitoring by the test operator. The computer to record the signals was situated in a 'Portacabin' at the test facility.

Procedures

Test lane layout

For the In-Soil Tests two examples of each of ten different types of target, (i.e. 20 targets), were buried in each lane. One of each target type was buried at a depth of 5 cm, the other at 10 cm. The depth was defined as the distance from the surface of the ground to the top of the target. The four test lanes each had an identical layout. The 20 targets that were buried in each lane were located on two tracks. In the plan in Figure 4.3 the locations of the 20 targets are indicated. The distance between any two-test targets for the In-Soil Tests and between each target and the other objects was in all cases not less than 50 cm.

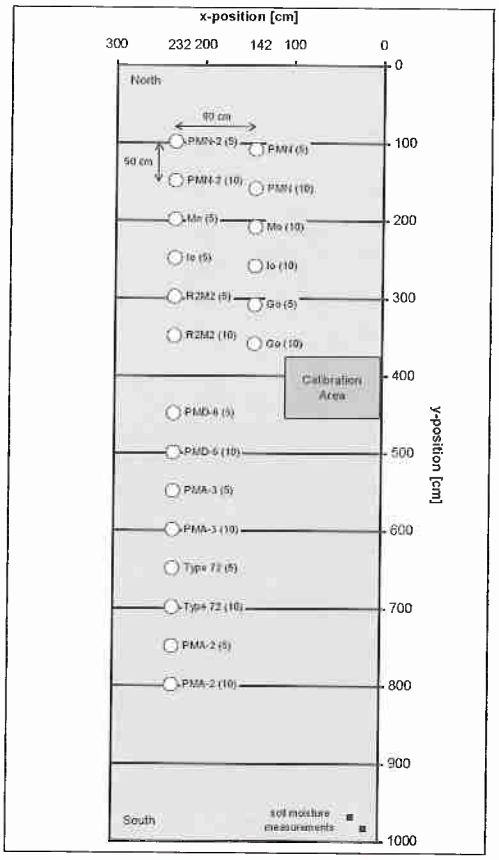


Figure 4.3. *Layout of targets in the test lanes*

Positioning of detectors

The detectors were tested at the minimum height possible above the test lanes (approximately 2.5 to 5 cm). The height of the detector search heads above the lane was adjusted with the help of a height indicator. This ensured that every detector was tested at the same height, although some minor differences (up to 2 cm) existed along the tracks.

All detector heads were placed parallel to the test lane surface. The detector heads were oriented as would normally be expected during field operations. The centre of the search head was positioned on the centre-line of the track concerned. When possible or desirable, the detector was mounted in such a way that the angle of the handle of the detector was 45° with the surface of the lane.

Test procedure

The main points of the test procedure are listed below:
Unless the manual required otherwise, a warm-up time of at least three minutes was used before the test was started and the working of the detector was checked.

The detectors were tested at the most sensitive setting for the specific soil type. When appropriate or necessary, the detectors were calibrated over the calibration part of each test lane before the start of the actual test on that lane.
During the test, the data was recorded in both directions (north to south and south to north).
All detectors were tested at the maximum velocity of the measurement platform (approximately 0.18 m/s).

Data analysis and results
The analysis of the In-Soil Test data gives an indication of the performance of the detectors. This analysis does not lead to a statistically rigorous statement on the detection probability of the detectors, because the number of targets in the test lanes is too small to obtain a reliable value for the detection probability. Instead the absolute number of detections is given. Due to the method of scoring, no statements can be made on the false alarm rate of the detectors.

Scoring methodology
The detector audio output recorded during the In-Soil Test was used to obtain a score of the detections of the detectors. For this purpose the audio files from each detector-run were played back. The corresponding position data was graphically displayed at the same time, with markers indicating the location of the buried targets.

Each run was assessed for the detection of each target and the ability to distinguish each target from its predecessor. For the scores, signals from both directions were taken into account. If a signal was encountered in either direction that correlated with the position of a target, it was counted as a detection. Some signals were influenced by adjacent targets, which were spaced at 50 cm. This caused apparent masked signals. Such signals appeared to be a prolonged single indication, but were actually counted as a detection for each target.

Most detector models did not show large differences between the performances of the two samples tested. For that reason, only the sample with the highest number of detections was considered in the analysis.

Three detector models did exhibit significant differences between the two samples tested. Investigation of possible causes did not give a clear explanation. Because no re-testing of these detectors was possible, the sample with the highest number of signals above targets was considered in the analysis. Affected detectors are identified in the tables.

Detector performance per target depth
A copy of each of the ten different target types was buried at two depths in the four test lanes: one at 5 cm and one at 10 cm depth from the surface of the ground. Table 4.1 presents the number of targets detected by each detector. Figures 4.4 to 4.7 compare the performance of the detectors, sorted by the number of detections of targets buried at 10 cm.

Although only burial depths of 5 cm and 10 cm were used in the In-Soil Tests, it was observed that the detection performance of nearly all tested detectors decreased for deeper buried targets.

Detector performance against selected minimum metal targets
In this section the assessment concentrates on the detectors' performance against selected minimum metal small AP mines PMA-2, R2M2, and the simulants, I_0 and G_0. In each lane, 8 of these minimum metal targets were present; two of each type, buried at two different depths (5 and 10 cm). Results are shown in Table 4.2.

The charts in Figures 4.8 to 4.11 compare the performance of the individual detectors against these low metal targets per lane.

Overall detector performance
This section presents the results showing detector performance against all targets used in the test. Table 4.3 shows the total number of targets detected. The performance of each detector is compared in Figures 4.12 to 4.15 (ordered by total number of targets detected) for each of the four different soil types.
From these charts it is clear that the ferruginous soil imposes the most problems for the detectors under test and the sand the least.

Summary of the In-Soil Tests
The main purpose of the In-Soil Tests was to determine detection performance for targets buried in controlled soil environments. Tests were conducted in four soil types, namely, sand, clay, peat and ferruginous. The ferruginous soil imposed the most problems on detection performance and the sand imposed the least.
A summary of overall performance is given in Table 4.3, while the associated charts show the relative performance of the detectors. From the charts, which show the ranking for various circumstances, the user may make a preliminary selection of preferred detectors for a particular requirement or for further user evaluation.

Detector	Lane 1 Sand (10 targets per depth)		Lane 2 Clay (10 targets per depth)		Lane 3 Peat (10 targets per depth)		Lane 4 Ferruginous (10 targets per depth)	
	5 cm	10 cm	5 cm	10 cm	5 cm	10 cm	5 cm	10 cm
AD25	6	3	4	1	4	1	2	0
AD26	4	2	6	1	4	1	2	2
EB42	9	6	8	4	8	4	8	4
EB53	6	1	7	3	6	2	4	3
FI12	4	3	3	2	3	1	2	1
FIIM	10	8	10	7	8	7	8	7
FIXB	4	3	6	2	7	3	5	2
FOMI	9	6	9	6	8	7	9	8
GIAT	4	4	5	4	6	4	3	3
GUA2a*	9	8	10	7	9	8	8	6
GUA2b	8	4	8	4	7	6	5	3
GUA2c	7	4	8	4	7	3	6	3
GUA4	8	4	8	4	8	5	9	5
GUA8a	10	10	10	8	10	10	7	5
GUA8c	7	6	8	4	8	4	7	4
LGPR	9	4	9	4	9	6	5	3
MICM	10	7	10	6	10	6	10	6
MIMI	10	6	10	6	10	6	10	6
PRMA*	9	8	9	9	10	9	10	10
REMI	3	3	1	2	3	2	1	1
SCAN	9	8	10	8	8	7	9	8
SCAT	5	4	7	6	9	9	5	4
SCMI*	10	6	8	7	10	9	10	10
VA16	9	8	8	7	8	8	7	6
VAVMa	9	9	10	10	9	9	5	2
WH59	9	8	8	3	7	3	7	3
WHAF	8	4	7	4	7	4	7	4
WHSP	10	10	10	10	10	10	10	10

* Large differences in results between two samples tested. Only the sample with the highest score is reported

Table 4.1 *– Number of detections per depth of target burial.*

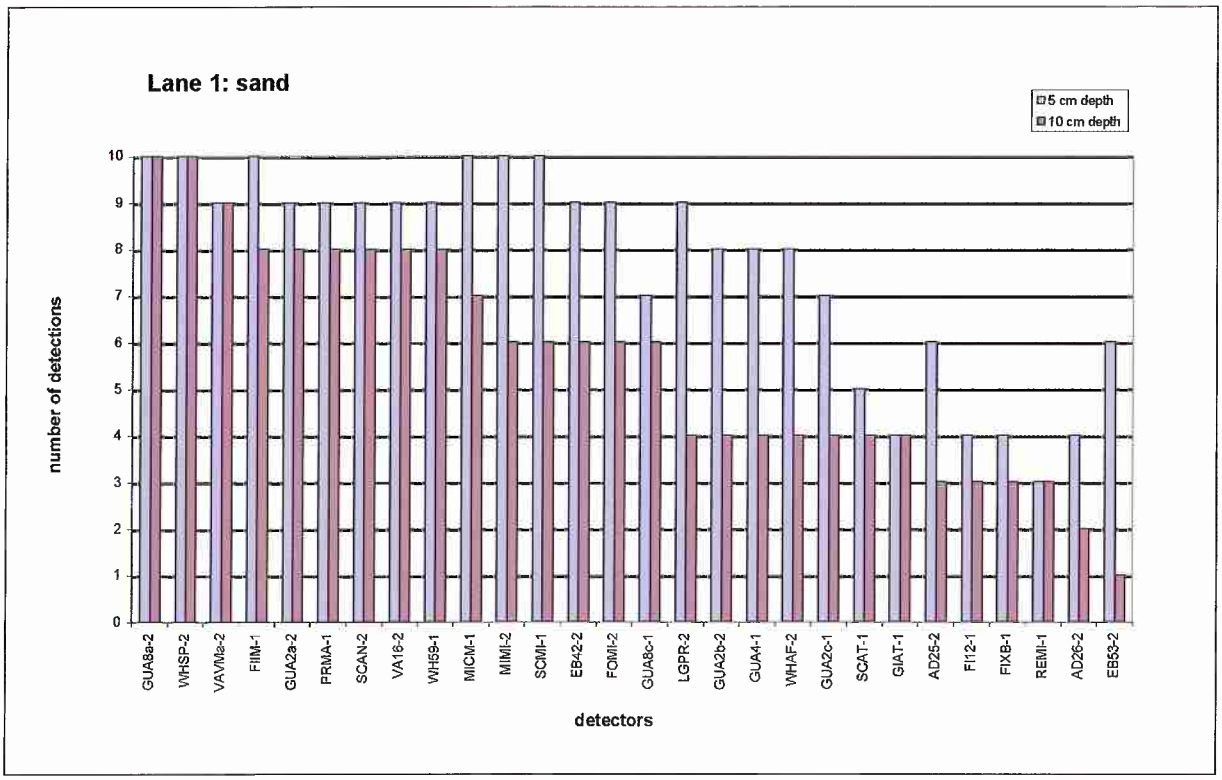


Figure 4.4. Number of detections of targets buried at 5 cm and 10 cm depth in the sand lane

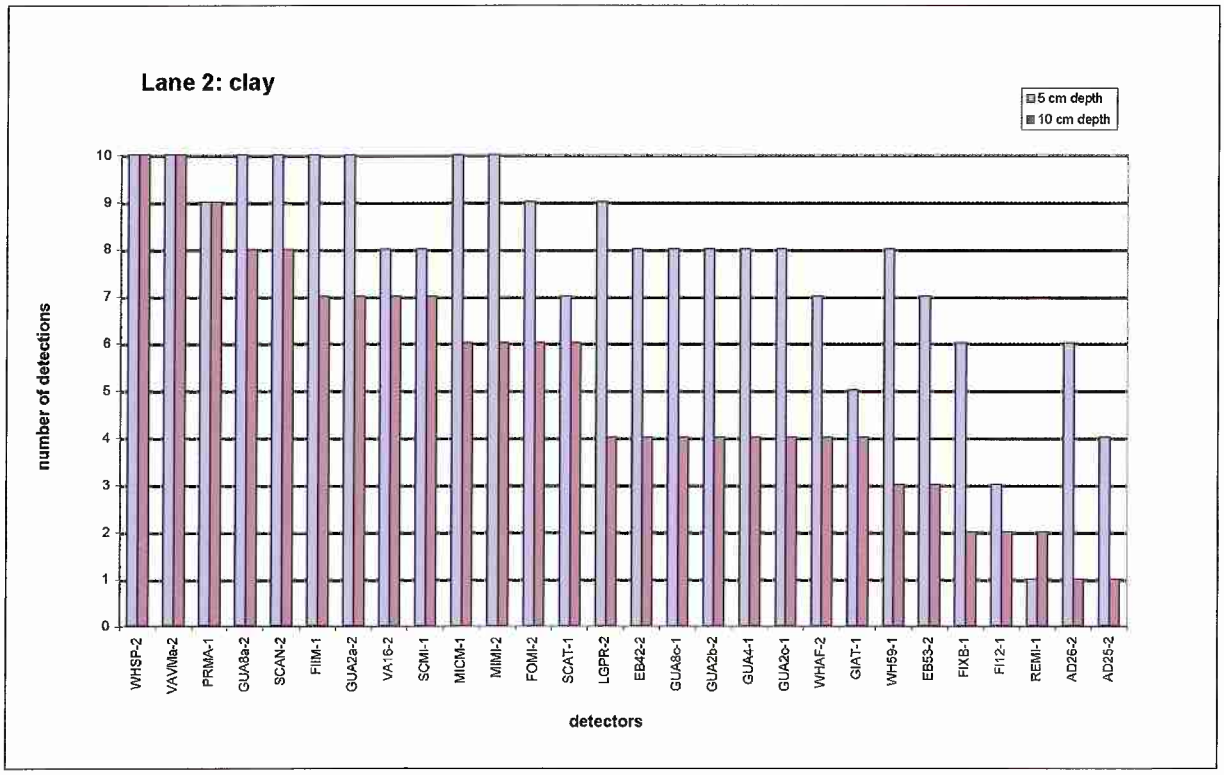


Figure 4.5. Number of detections of targets buried at 5 cm and 10 cm depth in the clay lane

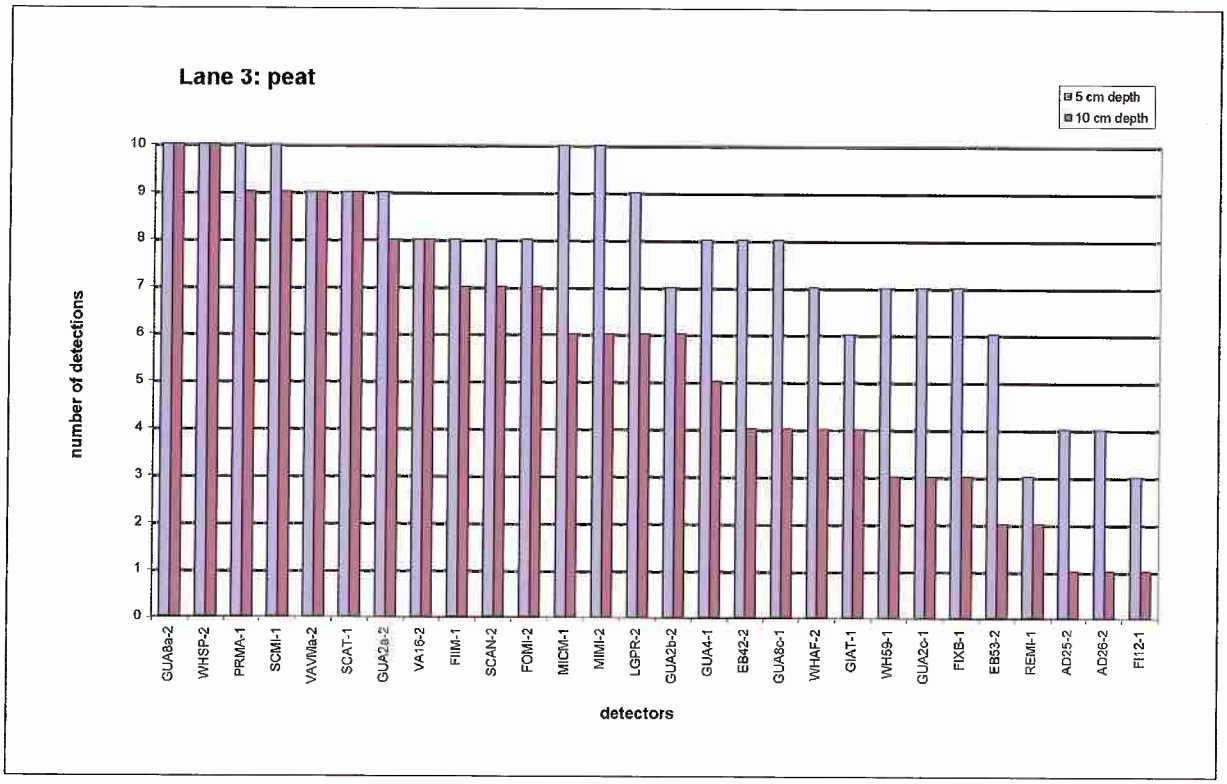


Figure 4.6. Number of detections of targets buried at 5 cm and 10 cm depth in the peat lane

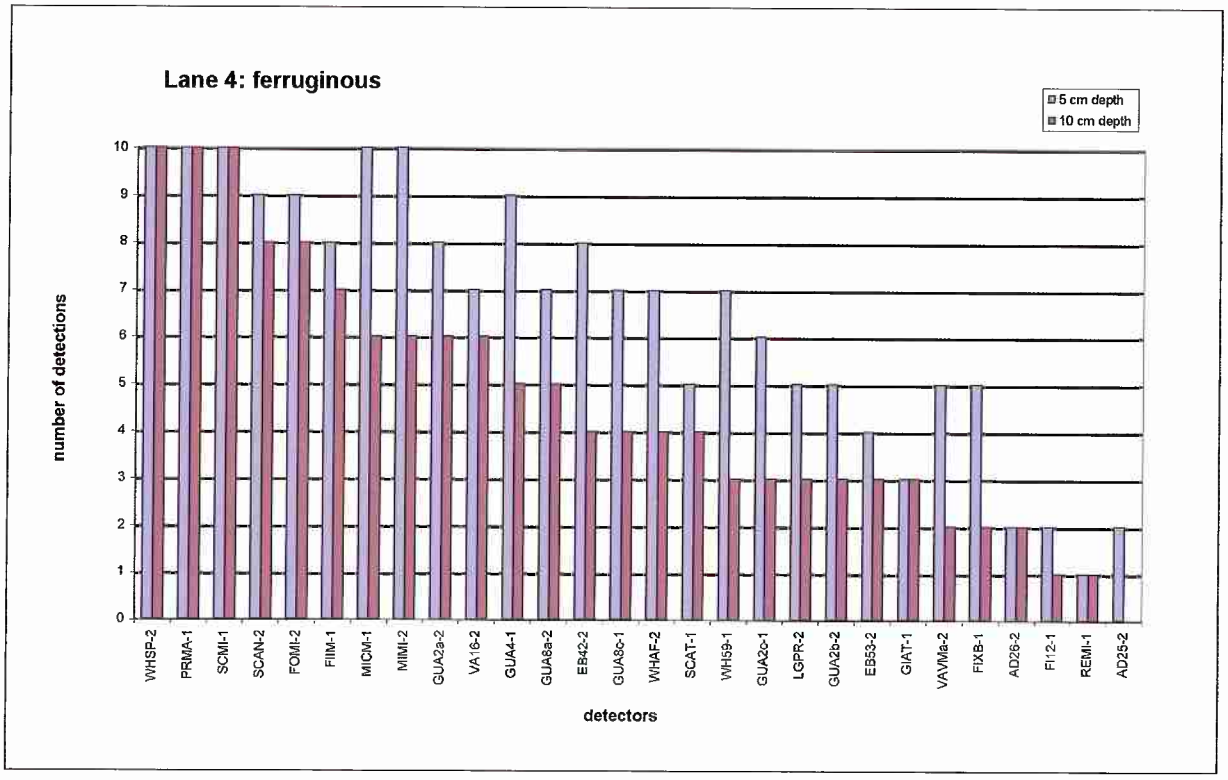


Figure 4.7. Number of detections of targets buried at 5 cm and 10 cm depth in the lane with ferruginous soil

Detector	*Lane 1 Sand (8 targets)*	*Lane 2 Clay (8 targets)*	*Lane 3 Peat (8 targets)*	*Lane 4 Ferruginous (8 targets)*
AD25	0	0	0	0
AD26	0	0	0	1
EB42	3	2	2	2
EB53	1	1	0	0
FI12	0	0	0	0
FIIM	6	5	3	3
FIXB	0	1	1	0
FOMI	3	3	3	5
GIAT	0	1	1	0
GUA2a*	5	5	5	3
GUA2b	2	2	2	0
GUA2c	1	2	1	0
GUA4	2	2	3	3
GUA8a	8	6	8	1
GUA8c	2	2	2	1
LGPR	3	3	5	0
MICM	5	4	4	4
MIMI	4	4	4	4
PRMA*	5	6	7	8
REMI	0	0	0	0
SCAN	5	6	3	5
SCAT	0	2	6	0
SCMI*	4	3	7	8
VA16	5	3	4	2
VAVMa	6	8	6	0
WH59	5	2	1	1
WHAF	2	1	1	1
WHSP	8	8	8	8

* Large differences in results between two samples tested. Only the sample with the highest score is reported

Table 4.2 *– Number of detections of minimum metal targets per lane.*

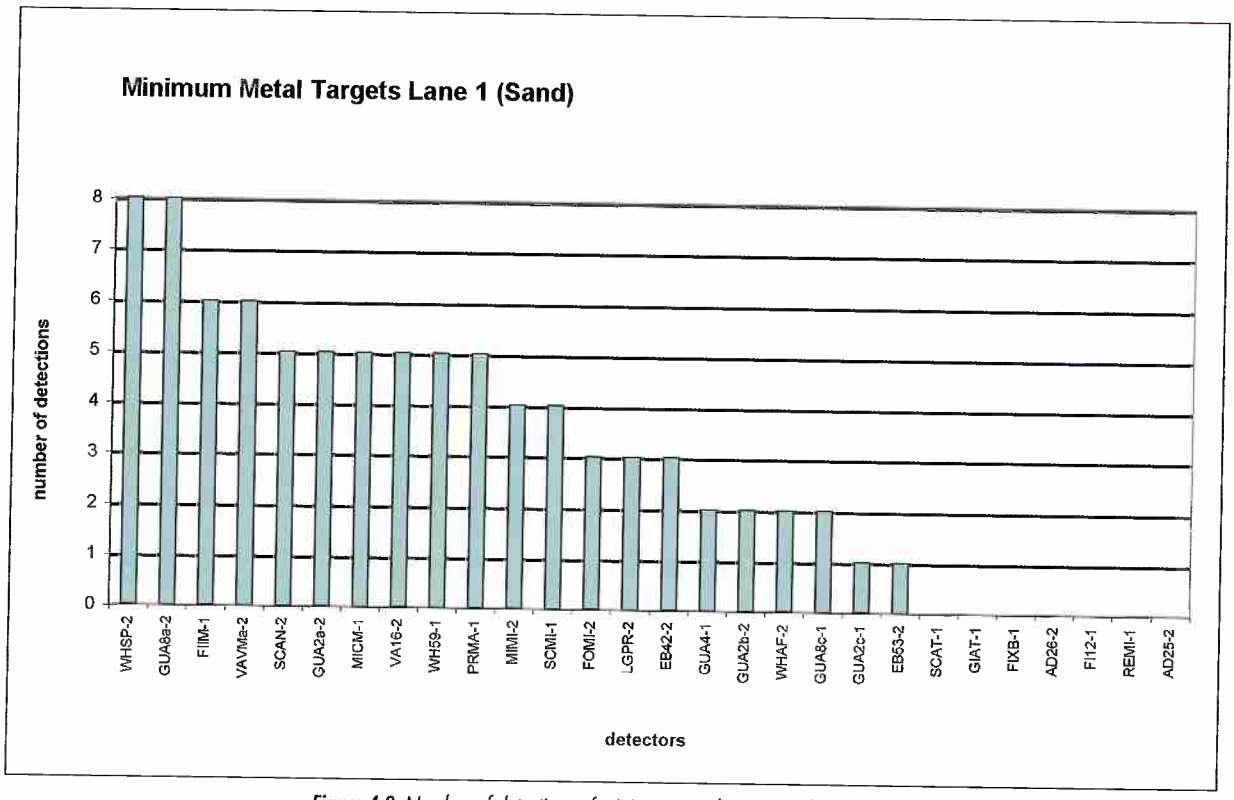


Figure 4.8. Number of detections of minimum metal targets in the sand lane

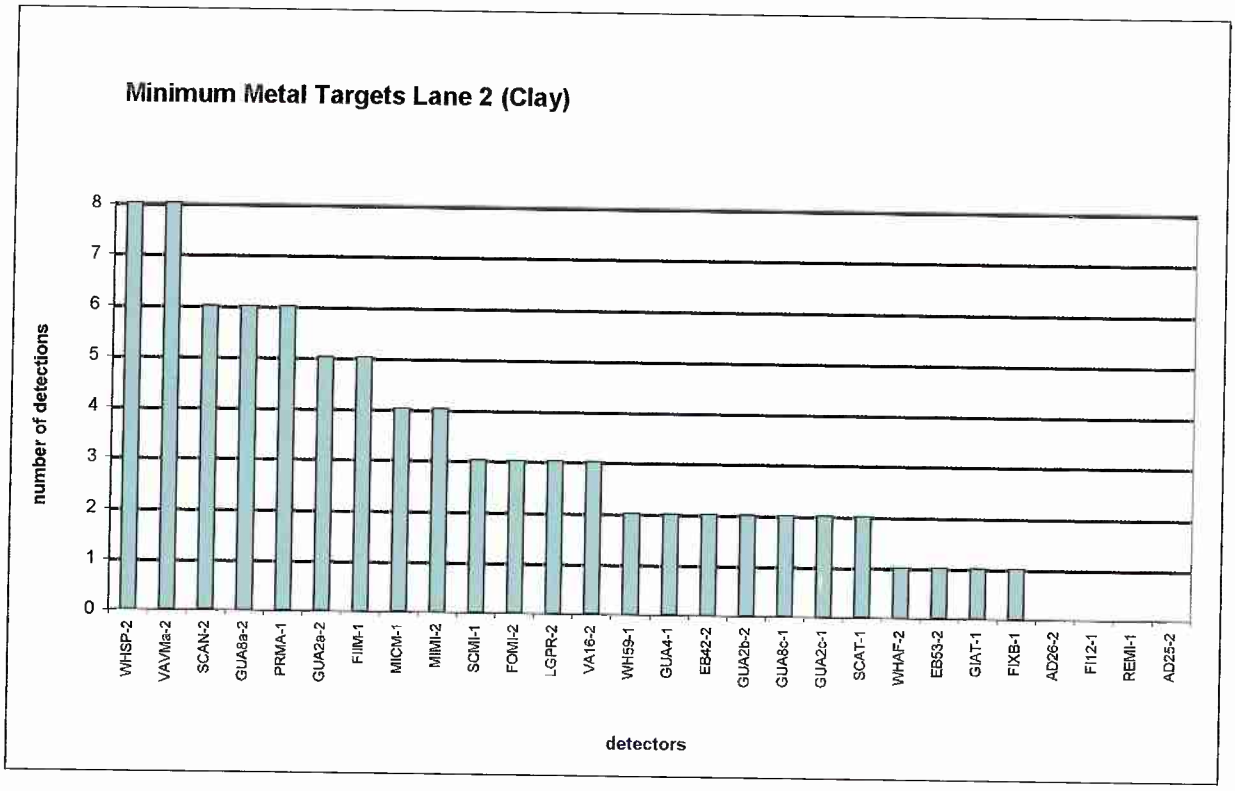


Figure 4.9. Number of detections of minimum metal targets in the clay lane

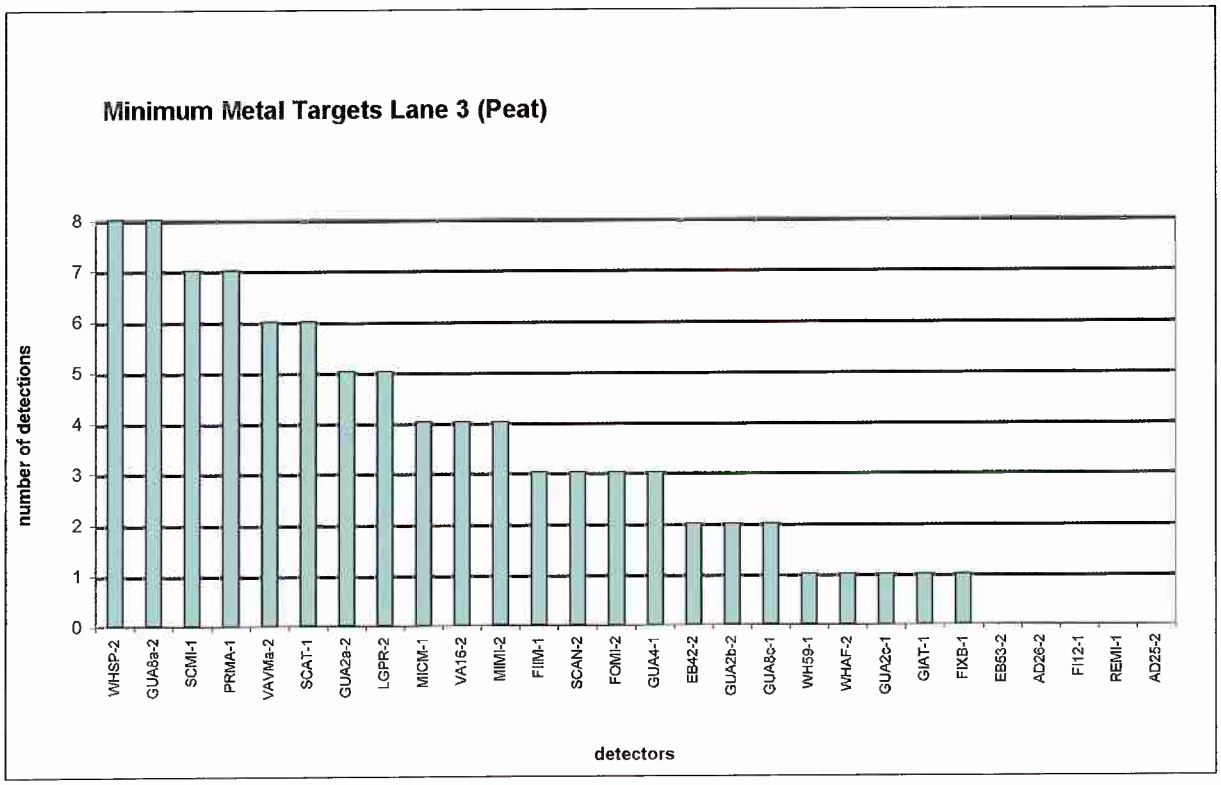


Figure 4.10. Number of detections of minimum metal targets in the peat lane

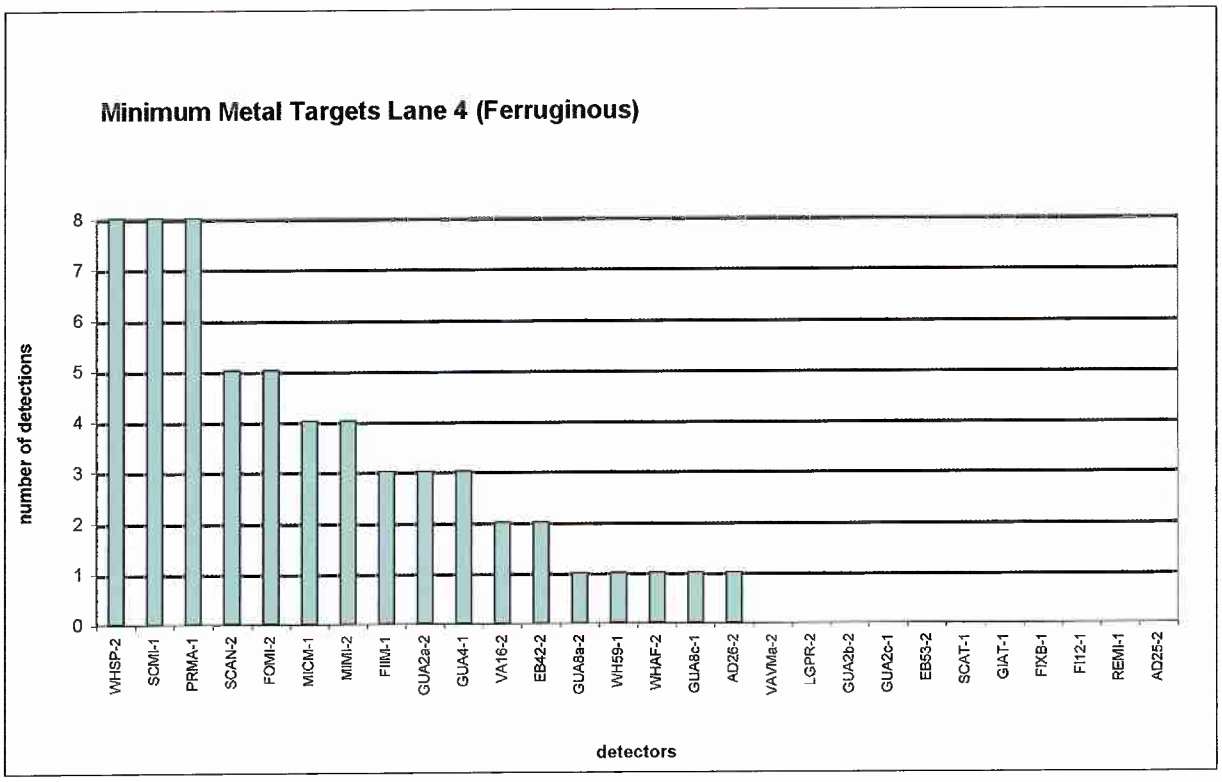


Figure 4.11. Number of detections of minimum metal targets in the lane with ferruginous soil

Detector	*Lane 1 Sand (20 targets)*	*Lane 2 Clay (20 targets)*	*Lane 3 Peat (20 targets)*	*Lane 4 Ferruginous (20 targets)*
AD25	9	5	5	2
AD26	6	7	5	4
EB42	15	12	12	12
EB53	7	10	8	7
FI12	7	5	4	3
FIIM	18	17	15	15
FIXB	7	8	10	7
FOMI	15	15	15	17
GIAT	8	9	10	6
GUA2a*	17	17	17	14
GUA2b	12	12	13	8
GUA2c	11	12	10	9
GUA4	12	12	13	14
GUA8a	20	18	20	12
GUA8c	13	12	12	11
LGPR	13	13	15	8
MICM	17	16	16	16
MIMI	16	16	16	16
PRMA*	17	18	19	20
REMI	6	3	5	2
SCAN	17	18	15	17
SCAT	9	13	15	9
SCMI*	16	15	19	20
VA16	17	15	16	13
VAVMa	18	20	18	7
WH59	17	11	10	10
WHAF	12	11	11	11
WHSP	20	20	20	20

* Large differences in results between two samples tested. Only the sample with the highest score is reported

Table 4.3 *– Number of detections per lane.*

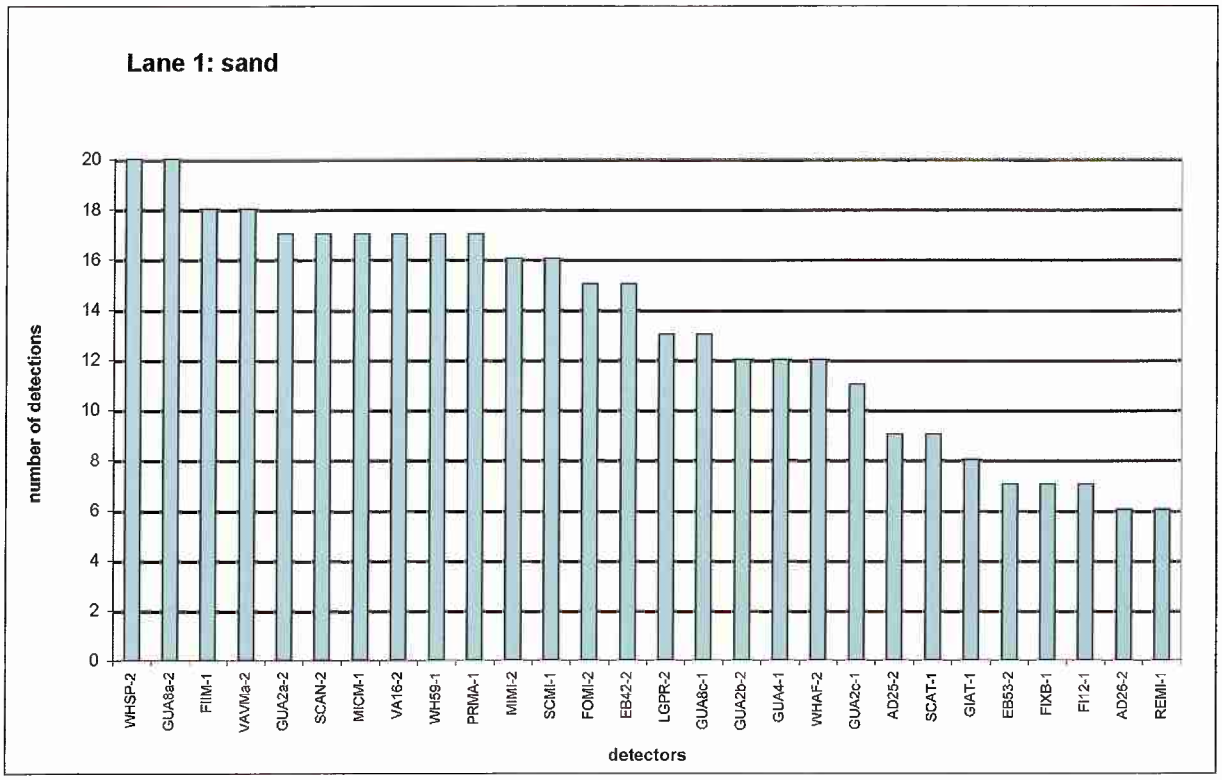


Figure 4.12. *Detections in the sand lane*

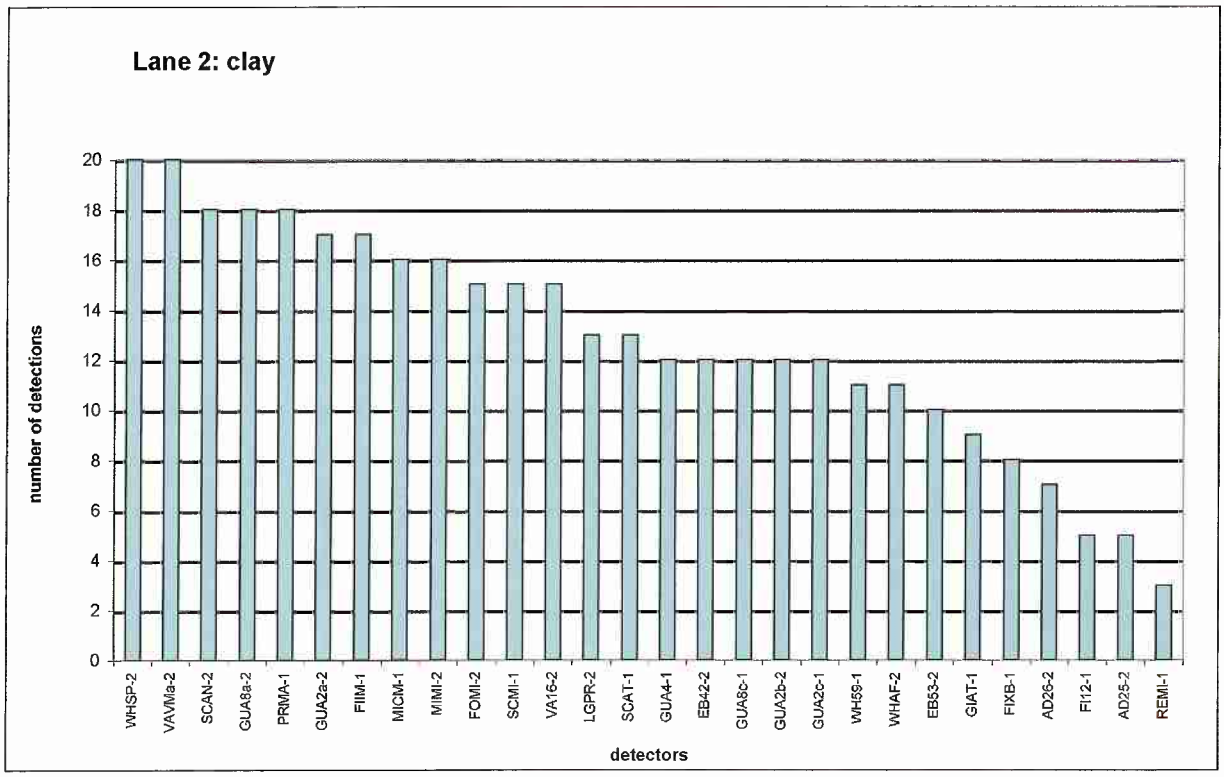


Figure 4.13. *Detections in the clay lane*

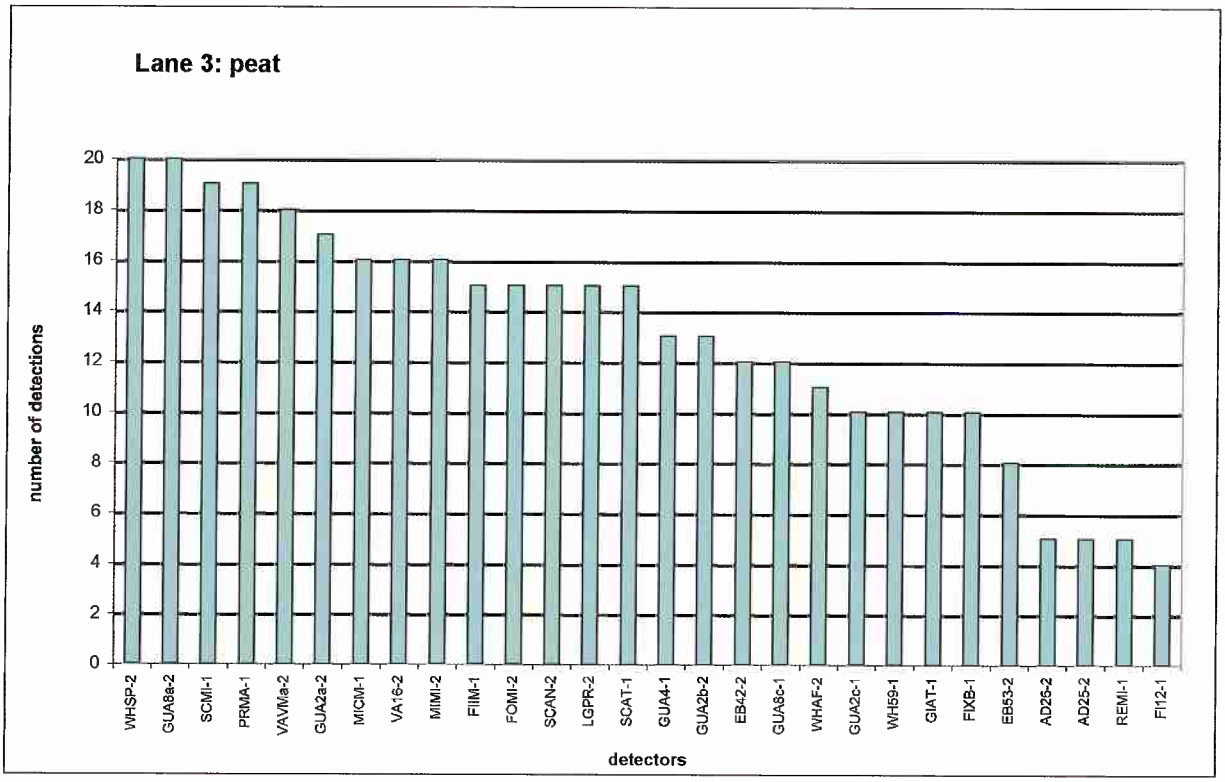


Figure 4.14. Detections in the peat lane

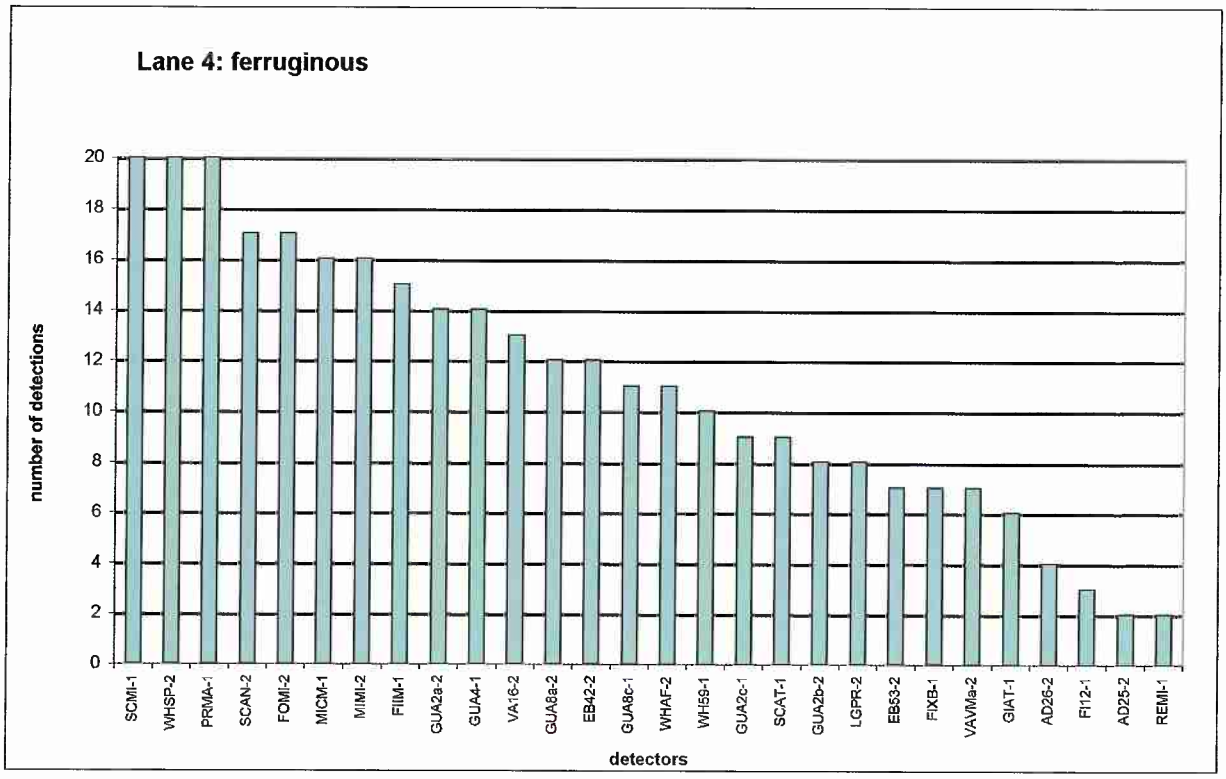


Figure 4.15. Detections in the lane with ferruginous soil

5. Field Tests

This section summarizes the results of the Cambodian and Croatian Field Tests conducted during the International Pilot Project for Technology Cooperation. It is derived from the full technical reports. [5, 6]

Objective

The objective of these field tests was to evaluate and determine the detection performance and human factors characteristics of the 29 different detectors, in test fields in Cambodia and Croatia. All detectors had been tested previously in laboratory settings (In-Soil, In-Air and preliminary Human Factors tests). The factors considered in this evaluation included: detection of targets buried at 5 cm and 10 cm depths; occurrence of false positives[1]; detection of targets buried in typical Cambodian configurations or additional depths of interest to Croatia; and human factors. For the human factors evaluation, a questionnaire was given to each deminer to establish the perceived ergonomics, ruggedness, and level of difficulty in using each detector. The analyses of the questionnaire inputs were combined with a previously conducted Human Factors Assessment and are presented elsewhere in this report.

Methodology

In order to train local instructors and deminers adequately on given detectors, without impacting the overall schedule, training and testing was conducted in a parallel and staggered fashion. After two IPPTC military instructors had trained local instructors and deminers, a pair of deminers was selected to conduct each test run. The deminers calibrated a given detector, in accordance with the manufacturer's instruction manual, against known targets and soil types to optimize the detector sensitivity. They practiced in calibration lanes until they felt proficient with the detectors' operation. Operators were instructed to operate their equipment according to standard demining practice. However, they were requested to disregard any visual clues and rely only on the detector signals to ensure that the detectors were given an objective evaluation. Once the training and practice was complete, the operators began the actual testing in the test lanes.

The training area for the Croatian field test used uncovered targets placed in open holes in the calibration area. The holes were left uncovered to help the deminers train on just the signals from the targets without the distraction of the signals that were prevalent all over the training area, presumably from a combination of metal objects and effects from the metallic minerals in the soil. This was different from the training regimen in the Cambodian field test.

Each operator started at the beginning of each lane and moved forward as he swept the lane, placing a marking chip at the center of each suspected target location. At the completion of each test lane, IPPTC team members measured and recorded the x-y coordinate of each marker chip. The location of each marker was compared to ground truth. A target was considered to have been detected when a marker was placed within 20 cm from the center of the target. This "halo size" was used to allow for operator inaccuracy in placing markers precisely in the center of a suspected target. When a marking chip fell outside of the halo, it was considered a "false positive." In the field tests, no attempt was made to determine the source of each false positive. During the testing procedure, a human factor questionnaire was completed.

Cambodian Field Test

The Cambodian field test was performed with the support of the Cambodian Mine Action Center (CMAC). The personnel who participated in the test consisted of six IPPTC members and 33 CMAC mem-

[1] A 'false positive' is defined for the purpose of this report as a response from a metal detector indicating presence of a metal object in a place that was believed, on the basis of previous searches to be free from metallic pollution and where no target for this test had been placed.

bers. The support from CMAC was in the areas of operating detectors, administration, logistics, facilitation of training/test, and construction of test lanes. The 16 operators who participated in the test were all experienced deminers from a single demining unit with at least one year of operational field experience.

Test Site

The training and testing were conducted at the CMAC Training Center in Kampong Chhnang, Cambodia.

Test Targets and Test Lane Description

The week before the test, CMAC personnel constructed two test lanes under the guidance of the IPPTC members. All metal objects were removed from these lanes prior to burying test targets. Each lane was 1.5 m wide x 60 m long x 0.5 m deep, and the lanes were 20 m apart. One lane contained clay, the predominant soil type in the region, and the other contained laterite soil, which was brought in from a nearby site. Both lanes were constructed such that they were clear of vegetation, and flush with the adjacent ground. The lanes were compacted after construction and each was marked every 10m with wooden stakes to define a 1 m width as shown in Figure 5.1.

A total of 28 targets were buried in each test lane. Two copies of PMN, PMN-2, PMD-6 and Type72 and four copies of G_0, I_0 and M_0 were buried using two different depths (5 cm and 10 cm) maintaining a minimum of 2 m between the targets in the first 50 m. This was termed the "IPPTC Configuration." Additionally, at the request of CMAC, targets were buried in the last 10 m of each lane in the configurations described below.

- Configuration 1 -- A PMD-6 and PMN-2 were each buried at a depth of 10 cm while maintaining a 1 m distance between the mines along the Y-axis.
- Configuration 2 -- Type 72 and PMN-2 were buried at 5 cm and 20 cm depths, respectively, 10 cm apart along the X-axis.
- Configuration 3 -- PMN and Type 72 were buried at 20 cm and 10 cm depths, respectively, 20 cm apart along the X-axis.
- Configuration 4 -- Both PMN and PMD-6 were buried at 20 cm depth while maintaining a 1 m distance between the mines along the Y-axis.

These were termed the "CMAC Configurations." Figure 5.2 shows the overview of the target layout in each test lane.

Test Site Conditions

Throughout the test period, the weather was hot and humid with no rain. The air temperature varied between 35 and 45 degrees Celsius. Due to very small changes in air temperature and humidity throughout the test, soil measurement data were taken for only one day. Soil conductivity and magnetic susceptibility data were collected to characterize local soil conditions of both the clay and laterite types. **(See Annex B - Soil Measurements)**

Cambodian Field Test Methodology

For each detector, an operator performed two separate test runs in each test lane. In order to avoid fatigue and memorization of target positions, each operator performed the test runs separated by at least one day. After the first runs of all detectors were completed, the same operators conducted the second test runs using the same detectors. A picture of an operator conducting a typical test run is shown in Figure 5.3.

Test Data Analysis and Results

The results of both test runs for each detector were compiled and tabulated by soil type (i.e., clay and laterite) for each test target type at each depth (i.e., 5 cm and 10 cm). The test data was analyzed separately for the targets buried in the IPPTC Configuration and the CMAC Configurations. The

Figure 5.1. *Clay and Laterite Test Lanes at the Time of Target Burial*

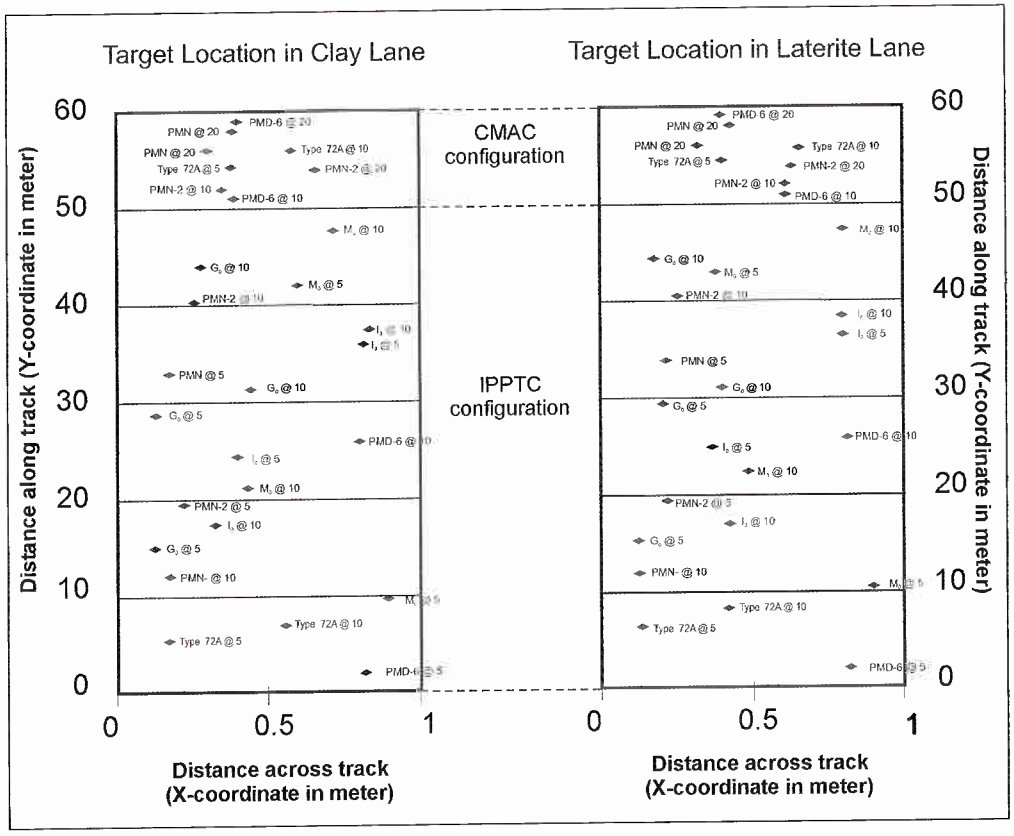


Figure 5.2. Target Layout in Clay and Laterite Test Lanes (Note: Target depths are in cm)

results pertaining to CMAC configuration should not be interpreted as indicating the ability of a detector to resolve adjacent targets. No inference can also be made regarding possible interaction between nearby targets. In this report the targets in CMAC configuration are treated simply as additional individual targets. The results were then analyzed further to show the overall performance of each detector by combining all detections made in both configurations.

Figure 5.3. Test Run in Clay Lane

Clay Lane

IPPTC Configuration in Clay Lane

The results of both test runs for targets buried in the first 50 m of the clay lane by each detector were combined and tabulated for target type and depth. (See Tables 5.1 and 5.2)

As shown in Table 5.1, 12 detectors detected all four mine target types buried 5 cm deep in the clay lane. Among these, four detected all mines and simulants.

Table 5.2. shows that a decreased number of detectors were able to detect the targets as the depth was increased from 5 cm to 10 cm. Among 12 detectors capable of detecting all four mine targets at 5 cm depth, only three of them were able to do the same at 10 cm depth; and, only one detected all mines and simulants buried at 10 cm.

CMAC Configurations in Clay Lane

The results of both test runs for targets buried in the last 10 m for each detector were combined and then tabulated for each target and configuration. (See Table 5.3)

Among all detectors tested, three detectors were able to detect both targets in all four configurations at least once and only one (Vallon VMH2) detected all mines. It should be noted that the Schiebel ATMID model detected a Type 72 target buried at 10 cm depth and 20 cm apart from PMN but it did not detect when the same type target was buried at shallower depth (i.e., 5 cm) and only 10 cm apart from PMN2.

Depector Types	*TARGETS (number buried)*						
	PMN (2)	*PMN-2 (2)*	*Type 72 (2)*	*PMD-6 (2)*	*G_0 (4)*	*I_0 (4)*	*M_0 (4)*
AD25	2	2	0	2	0	0	4
AD26	2	2	0	2	0	0	2
EB42	2	2	2	2	4	4	4
EB53	2	2	2	2	3	3	4
FI12	2	2	2	2	3	3	4
FIIM	2	2	2	2	4	3	4
FIXB	2	2	2	2	4	4	4
FOMI	2	2	2	2	4	4	4
GIAT	2	1	0	1	0	0	0
GUA2a	2	2	1	2	1	1	4
GUA2b	2	2	0	1	3	3	4
GUA2c	2	2	0	2	0	0	2
GUA4	2	2	2	2	2	2	4
GUA8a	2	2	0	2	0	1	3
GUA8b	2	2	0	2	0	0	4
GUA8c	2	2	1	2	3	2	4
LGPR	2	2	0	2	1	0	3
MICM	2	2	2	2	3	4	4
MIMI	1	2	1	1	2	2	2
PRMA	2	2	1	2	3	1	4
REMI	2	2	0	2	0	0	4
SCAN	2	2	2	2	4	3	4
SCAT	2	2	0	2	0	0	3
SCMI	2	2	2	2	2	2	4
VA16	2	2	2	2	4	3	4
VAVMa	2	2	2	2	4	4	4
WH59	2	2	1	2	0	0	4
WHAF	2	2	0	2	0	0	4
WHSP	2	2	0	2	2	2	4

Table 5.1 *– Detections for IPPTC Configuration (5 cm depth in Clay Lane).*

Depector Types	TARGETS (number buried)						
	PMN (2)	PMN-2 (2)	Type 72 (2)	PMD-6 (2)	G_0 (4)	I_0 (4)	M_0 (4)
AD25	2	0	0	0	0	0	0
AD26	2	0	0	0	0	0	0
EB42	2	2	1	1	4	0	4
EB53	2	2	0	2	0	0	4
FI12	2	2	0	2	0	0	4
FIIM	2	2	0	2	3	0	4
FIXB	2	2	2	2	1	0	4
FOMI	2	2	2	2	3	0	4
GIAT	2	0	0	0	0	0	0
GUA2a	2	2	0	2	0	0	3
GUA2b	2	1	0	2	0	0	3
GUA2c	2	2	0	0	0	0	0
GUA4	2	2	0	2	0	0	4
GUA8a	2	0	0	1	0	0	1
GUA8b	2	0	0	0	0	0	0
GUA8c	2	2	0	2	0	0	1
LGPR	2	1	0	1	0	0	0
MICM	2	2	2	2	4	4	4
MIMI	2	1	1	2	2	2	2
PRMA	2	2	0	2	3	0	4
REMI	2	2	0	2	0	0	4
SCAN	2	2	0	2	1	0	4
SCAT	1	2	0	2	0	0	1
SCMI	2	2	0	2	0	0	4
VA16	2	2	1	1	1	0	4
VAVMa	2	2	0	2	3	0	4
WH59	2	2	0	2	0	0	2
WHAF	2	2	0	2	0	0	0
WHSP	2	2	0	2	0	0	3

Table 5.2 *– Detections for PPTC Configuration (10 cm depth in Clay Lane).*

Summary of Clay Lane Tests

The total number of detections and false positives in both the IPPTC and CMAC configurations are shown in a chart, Figure 5.4.

The number of targets detected in the IPPTC Configuration ranged from 6 to 39 with the number of false positives ranging from 0 to 29. The number of targets detected in the CMAC Configurations ranged from 0 to 16 with the number of false positives ranging from 0 to 4. For the total of 40 targets (20 targets x two runs) in the IPPTC and 16 targets (8 x two runs) in the CMAC Configurations, the number of targets detected ranged from 6 to 51. On the far left of the chart is a reference bar depicting an ideal detector with a "perfect score" (56 targets, no false positives).

It should be noted that the Minelab F1A4 MIM model showed a substantial disparity between the two test runs. This disparity may have resulted from the fact that the detector electronic box overheated during the previous day.

Laterite Lane

IPPTC Configuration in Laterite Lane

The results of both test runs for targets buried in the first 50 m of laterite lane by each detector were combined and tabulated for each target and depth, except for the White's DI-PRO 5900 where data from one run in the laterite soil was unavailable for analysis and the number of detections shown in the tables represents twice the first test run results. (See Tables 5.4. and 5.5)

Depector Types	Configuration 1		Configuration 2		Configuration 3		Configuration 4	
	PMD6 (10 cm deep)	PMN2 (10 cm deep)	Type 72 (5 cm deep)	PMN2 (20 cm deep)	PMN (20 cm deep)	Type 72 (10 cm deep)	PMN (20 cm deep)	PMD6 (20 cm deep)
	1 m apart		10 cm apart		20 cm apart		1 m apart	
AD25	1	0	0	0	2	0	0	0
AD26	1	0	0	0	1	0	0	0
EB42	1	2	1**	1**	2	0	1	0
EB53	2	2	1	0	2	0	0	0
FI12	2	2	2	2	2	0	2	0
FIIM	2	2	2	2	2	0	2	2
FIXB	2	2	2	2	2	0	2	2
FOMI	2	2	2	1	2	2	2	2
GIAT	0	0	0	0	0	0	0	0
GUA2a	2	2	0	2	2	0	2	1
GUA2b	2	2	1	1	2	0	1	0
GUA2c	2	1	0	0	2	0	0	0
GUA4	2	2	0	2	2	0	2	0
GUA8a	2	0	0	0	2	0	0	0
GUA8b	2	0	0	0	2	0	0	0
GUA8c	2	2	2	0	2	0	0	0
LGPR	1	1	0	0	1	0	1	0
MICM	2	1	2	1	2	1	2	1
MIMI	2	0	2	1	2	0	2	1
PRMA	2	2	1	2	2	0	2	2
REMI	2	2	0	2	2	0	2	0
SCAN	2	2	2	2	2	0	1	2
SCAT	2	1	0	0	2	1	1	0
SCMI	2	2	1**	1**	2	0	2	0
VA16	2	1	2	1	2	0	1	1
VAVMa	2	2	2	2	2	2	2	2
WH59	2	2	2	2	2	0	0	0
WHAF	2	1	0	2	2	0	0	0
WHSP	2	2	0	1	2	0	1	0

** Detections occurred on different runs.

Table 5.3 *– CMAC Configurations in Clay Lane.*

As shown in Table 5.4, only two detectors found all mines and simulants buried 5 cm deep at least once. No other models detected Type 72 targets buried at a depth of 5 cm. For the targets buried 10 cm deep, only one detector was able to detect all mines and simulants at least once. Three detected a Type 72 target buried at 10 cm depth although one of these failed to detect the same type target buried at 5 cm depth.

A significant anomaly that should be noted is that many of the detectors found PMN mines buried at 10 cm depth, but very few of them detected the same target type buried at 5 cm depth.

CMAC Configurations in Laterite Lane

The results of both test runs for targets buried in the last 10 m for each detector were combined and then tabulated for each target and configuration. (See Table 5.6)

As shown in Table 5.6, three detectors performed unexpectedly by detecting a deeper target while missing the shallower target:

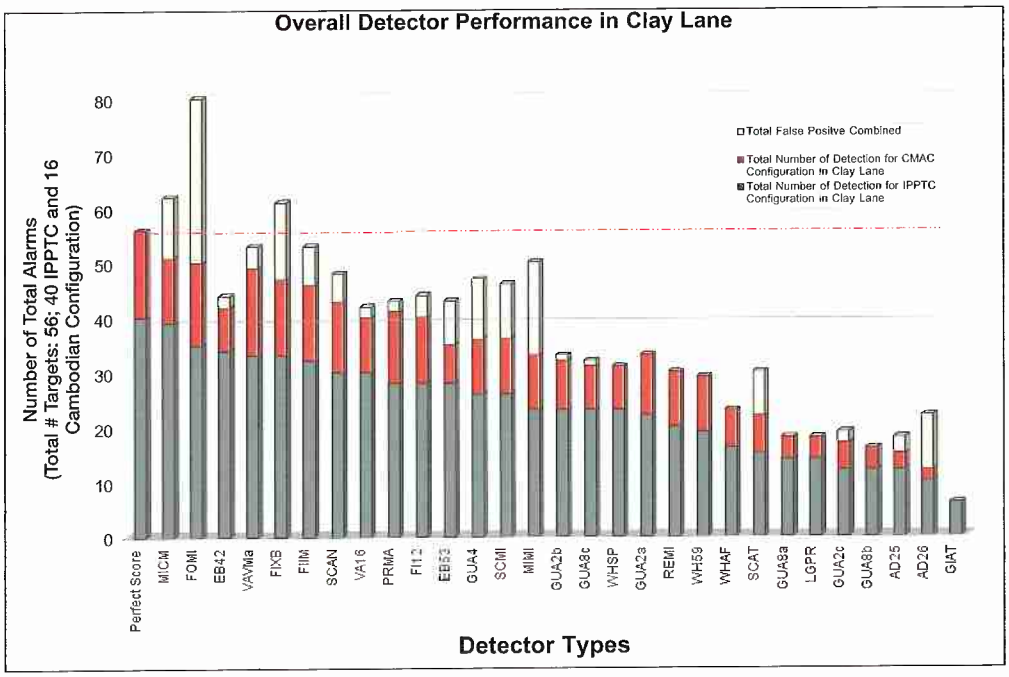


Figure 5.4. Overall Performance in Clay Lane (sorted by IPPTC results)

- one detected a PMN-2 mine buried at 20 cm while missing the same type target buried at 10 cm;
- the other two detected a PMD-6 mine buried at 20 cm while missing the same type target buried at 10 cm.

Summary of Laterite Lane Tests

The total number of detections and false positives in both the IPPTC and CMAC configurations were tabulated and are shown in a chart, Figure 5.5.

The number of detections in the IPPTC configuration ranged from 2 to 28 with the number of false positives ranging from 2 to 57. The number of detections in the CMAC configuration ranged from 0 to 12

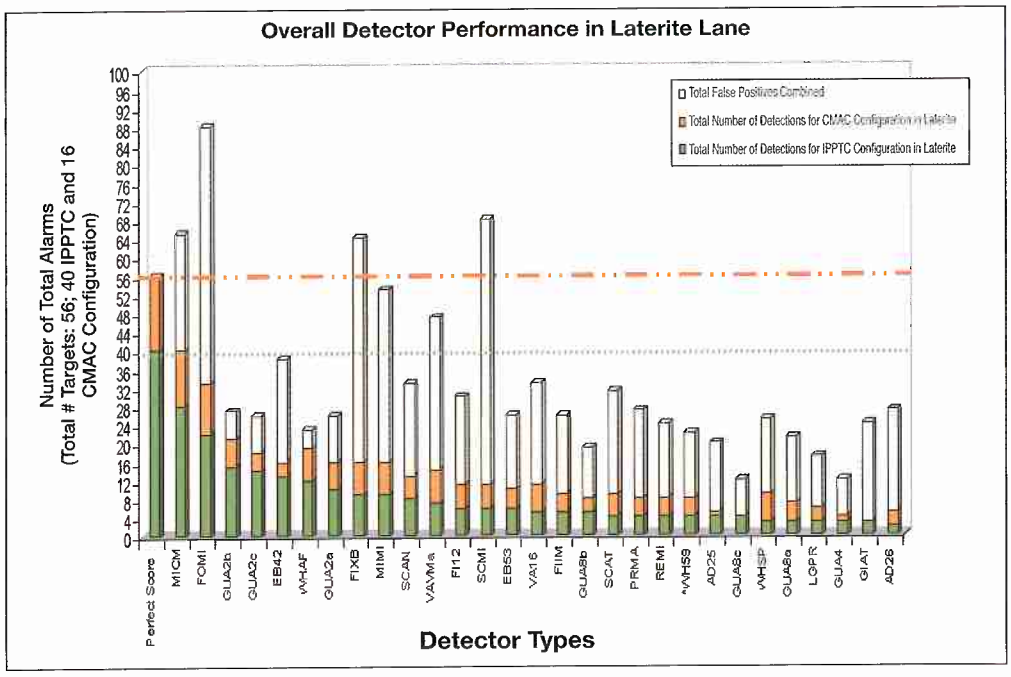


Figure 5.5. Overall Performance in Laterite Lane (sorted by IPPTC results)

Depector Types	TARGETS (number buried)						
	PMN (2)	PMN-2 (2)	Type 72 (2)	PMD-6 (2)	G_0 (4)	I_0 (4)	M_0 (4)
AD25	0	1	0	0	0	0	0
AD26	0	0	0	0	0	0	0
EB42	1	1	0	1	2	1	0
EB53	0	1	0	0	0	0	0
FI12	0	1	0	0	1	0	0
FIIM	0	2	0	0	0	0	0
FIXB	0	0	0	1	2	0	0
FOMI	1	2	1	1	3	2	2
GIAT	0	0	0	0	0	1	1
GUA2a	2	1	0	2	0	0	0
GUA2b	2	2	0	2	0	0	1
GUA2c	2	2	0	2	0	0	3
GUA4	0	1	0	0	0	0	0
GUA8a	0	1	0	0	0	0	0
GUA8b	0	2	0	0	0	0	0
GUA8c	0	2	0	0	0	0	0
LGPR	0	1	0	0	0	0	0
MICM	1	2	1	1	3	2	2
MIMI	0	2	0	0	0	0	0
PRMA	0	1	0	0	0	0	0
REMI	0	2	0	0	0	0	0
SCAN	0	1	0	2	1	0	0
SCAT	0	2	0	0	0	0	0
SCMI	0	1	0	1	1	0	0
VA16	0	1	0	0	1	0	0
VAVMa	0	1	0	0	1	0	0
*WH59	0	2	0	0	0	0	0
WHAF	2	2	0	2	0	0	2
WHSP	0	1	0	0	0	0	0

* WH59 detector has results for one run in the laterite soil (number of detections shown in the above table represents double of the first test run results).

***Table 5.4** – IPPTC Configuration (5 cm Depth in Laterite Lane).*

with the number of false positives occurring from 0 to 12. For the total of 40 targets in the IPPTC and 16 targets in the CMAC configurations, the number of targets detected ranged from 3 to 40. On the far left of the chart is a reference bar depicting an ideal detector with a "perfect score" (56 targets, no false positives).

Summary of the Cambodian Field Test

The main purpose of this field test was to evaluate the performance of the detectors in the less-controlled field environment of Cambodia. Detectors were tested against targets in two soils, clay and laterite, using both IPPTC and CMAC configurations. Overall detector performance in clay and laterite are summarized in Figures 5.4 and 5.5. The results highlight the difficulty of detecting targets in laterite with some detectors failing to find any of the targets.

A number of problems were experienced during the tests. The Minelab F1A4 MIM detector performed poorly during its first test run. However, the detector performed very effectively in the second test run. A possible reason for this disparity is the reported overheating of the electronic box when the battery was low. The operators of the Reutech Midas PIMD and Fisher Impulse model detectors reported difficulty wearing the headsets under sultry conditions. In both cases the headsets were too tight; the ear

Depector Types	TARGETS (number buried)						
	PMN (2)	PMN-2 (2)	Type 72 (2)	PMD-6 (2)	G_0 (4)	I_0 (4)	M_0 (4)
AD25	2	0	0	0	1	0	0
AD26	2	0	0	0	0	0	0
EB42	1	1	0	1	1	0	3
EB53	2	0	0	2	0	0	1
FI12	2	0	0	1	1	0	0
FIIM	2	0	0	1	0	0	0
FIXB	2	0	0	2	1	1	0
FOMI	2	1	1	2	2	0	2
GIAT	1	0	0	0	0	0	0
GUA2a	2	1	0	1	0	0	1
GUA2b	2	2	1	2	1	0	0
GUA2c	2	2	0	1	0	0	0
GUA4	2	0	0	0	0	0	0
GUA8a	2	0	0	0	0	0	0
GUA8b	2	0	0	1	0	0	0
GUA8c	2	0	0	0	0	0	0
LGPR	2	0	0	0	0	0	0
MICM	2	1	1	2	4	3	3
MIMI	2	0	0	1	2	2	0
PRMA	1	0	0	1	1	0	0
REMI	2	0	0	0	0	0	0
SCAN	2	0	0	2	0	0	0
SCAT	2	0	0	0	0	0	0
SCMI	2	0	0	1	0	0	0
VA16	2	0	0	1	0	0	0
VAVMa	2	0	0	1	1	1	0
*WH59	2	0	0	0	0	0	0
WHAF	2	1	0	1	0	0	0
WHSP	2	0	0	0	0	0	0

* WH59 detector has results for one run in the laterite soil (number of detections shown in the above table represents double of the first test run results).

Table 5.5 *– Detectors for IPPTC Configuration (10 cm Depth in Laterite Lane).*

cups collected sweat thereby hindering the operators' ability to hear target signals.

The performance of each detector against four mine targets -- PMD-6, PMN-2, Type 72 and PMN -- in the IPPTC and CMAC configurations is shown in **Annex A - Detectors Performance Summaries.**

Croatian Field Test

The Croatian field test was performed with the support of the Croatian Mine Action Center (CroMAC). Five IPPTC members and 15 CroMAC members (12 operators) participated in the test. CroMAC support was in the areas of operating detectors, administration, logistics, facilitation of training/test, and construction of test lanes. The 12 operators were all experienced deminers from a single detachment of a special police force, from the local city of Zadar, broken into six teams of two deminers each.

Test Site

The site is in an area that is being developed as a regional test center by CroMAC. This test site is at Krusevo, near Obrovac in southern Croatia. (See Figure 5.6)

Test Targets and Test Lane Description

Prior to testing, CroMAC marked out and cleared

Depector Types	Configuration 1		Configuration 2		Configuration 3		Configuration 4	
	PMD6 (10 cm deep)	PMN2 (10 cm deep)	Type 72 (5 cm deep)	PMN2 (20 cm deep)	PMN (20 cm deep)	Type 72 (10 cm deep)	PMN (20 cm deep)	PMD6 (20 cm deep)
	1 m apart		10 cm apart		20 cm apart		1 m apart	
AD25	1	0	0	0	0	0	0	0
AD26	0	0	1	0	0	0	1	1
EB42	0	0	1	0	1	0	1	0
EB53	0	0	0	0	2	0	2	0
FI12	0	0	1	0	2	0	2	0
FIIM	0	0	0	0	2	0	2	0
FIXB	1	0	1	0	2	1	2	0
FOMI	1	1	2	1	2	1	2	1
GIAT	0	0	0	0	0	0	0	0
GUA2a	1	1	1	0	1	0	2	0
GUA2b	0	2	0	0	2	0	2	0
GUA2c	1	0	0	0	1	0	2	0
GUA4	0	0	0	0	0	0	1	0
GUA8a	0	0	0	0	2	0	2	0
GUA8b	0	0	0	0	1	0	2	0
GUA8c	0	0	0	0	0	0	0	0
LGPR	0	0	0	0	1	0	2	0
MICM	1	2	2	1	2	1	2	1
MIMI	0	0	2	0	2	0	2	1
PRMA	0	0	0	0	2	0	2	0
REMI	0	0	0	0	2	0	2	0
SCAN	1	0	0	0	2	0	2	0
SCAT	0	0	1	0	2	0	2	0
SCMI	0	0	1	0	2	0	2	0
VA16	0	0	2	0	2	0	2	0
VAVMa	0	0	2	0	2	1	2	0
*WH59	0	0	0	0	2	0	2	0
WHAF	2	1	0	0	2	0	2	0
WHSP	0	0	1**	1**	2	0	2	0

* WH59 detector has results for one run in the laterite soil (number of detections shown in the above table represents double of the first test run results).

** Detections occurred on different runs.

Table 5.6 *– Detections for CMAC Configurations in Laterite Lane.*

two test lanes approximately 20 m apart from each other. Unlike the Cambodian layout, no soils were brought in to construct lanes. Rather, the lanes were simply laid out over the natural soils in the area.

Both test lanes were clear of vegetation other than grass and their surface was flush with the ground. Some pieces of metal were found in the lanes during testing despite previously clearing the lanes with two different metal detectors. This may have been due to the high number of metal fragments originally in the area and the strong interference from bauxite reported to be in the soil.

Each test lane was 1 m wide, and 60 m long (Figure 5.7). A total of 64 targets were buried in each test lane (8 each of inert mines and simulants: PMN, PMN-2, PMA-2, PMA-3, PMD-6, G_0, I_0, M_0). With some exceptions, in the first 50 m of each lane, two copies of each of the targets were buried at two depths, 5 cm or 10 cm. This was termed the IPPTC Configuration. In the last 10 m of each lane, some of

Figure 5.6. *Croatian Field Test lane at Obrovac*

the targets were buried at additional depths of 15 and 20 cm. This was termed the CroMAC Configuration.

Test Site Conditions

The weather at the site was dry for the entire time of the test with very little rain. The temperature remained between 27 and 30 degrees Celsius. Due to very small changes in air temperature and humidity throughout the trial, soil measurement data were taken for only one day. Soil conductivity and magnetic susceptibility data were collected to characterize local soil conditions. **(See Annex B - Soil Measurements)**

Croatian Field Test Methodology

One sample of each detector was tested in the test lanes with the other sample being on-site for backup. Each detector was tested over both lanes in a serial fashion, with a different operator for each lane. The layout within the first 50 m of each lane was designed to be as similar as possible to the equivalent lengths of the lanes used in the Cambodian tests. Five of the eight target types were the same for both countries.

Test Data Analysis and Results

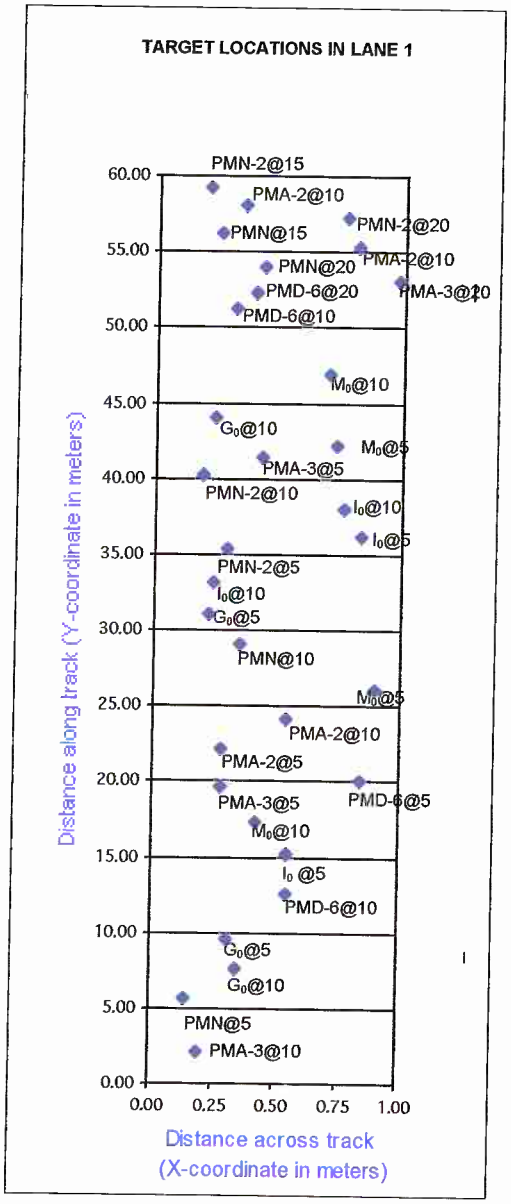
The major results from the analyses of all the detectors tabulated for all targets were sorted to show:

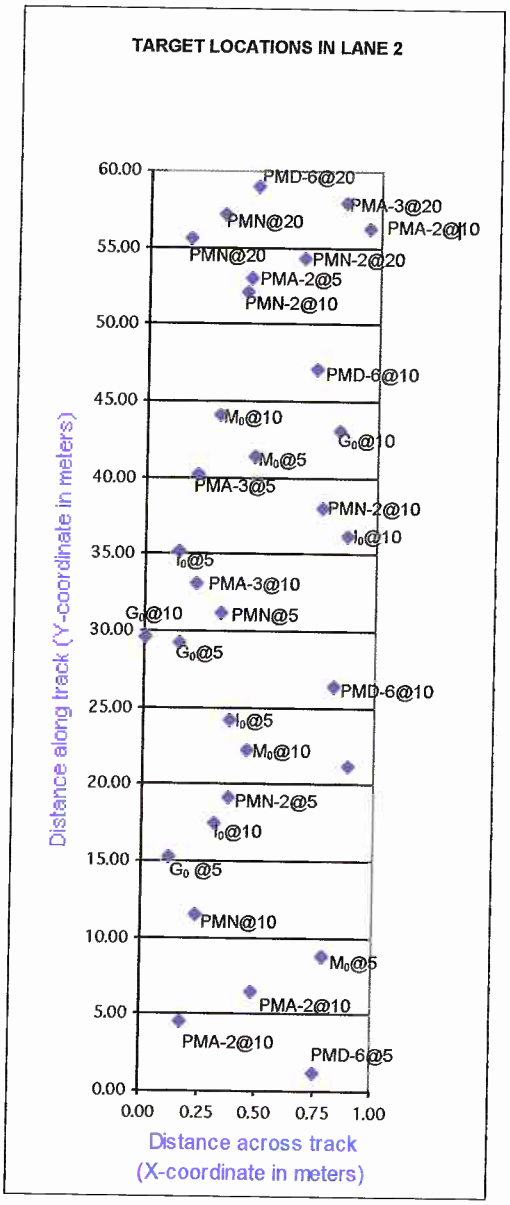
- The number of targets detected in the IPPTC Configuration, buried at 5 cm depths with a minimum of 1 m between targets. (See Table 5.7)
- The number of targets detected in the IPPTC Configuration, buried at 10 cm depths with a minimum of 1 m between targets. (See Table 5.8)
- The number of targets detected in the CroMAC Configuration, buried at 15 and 20 cm depths with a minimum of 1 m between targets. (See Table 5.9)

IPPTC Configuration

From data in Tables 5.7, 5.8 and 5.9, the number of detections for 5 cm depths, 10 cm depths, and 15-20 cm depths were determined. For the IPPTC Configuration, where all targets were placed at 5 cm and 10 cm depths, an initial look seems to indicate that there is greater success at the 10 cm depth as there are more detections. However, the total number of targets at this depth was higher and the proportion of successful detections to total targets is similar

Figure 5.7. Layout of Lanes 1 and 2 (not to scale) showing positions and distribution of ground truth (e.g., "PMD-6@10" = PMD-6 mine target at 10 cm depth). Note: A PMA-3 mine target was unintentionally buried without its metal spring clip, making it differ from all the other PMA-3 targets. This target, marked above with ( ) in Lane 2, was not used in the scoring.





in each case. A trend that can be clearly drawn is that detection levels do not seem to significantly change between the 5 cm and 10 cm depths.

There is a trend in the 5 cm and 10 cm depth figures that indicates that most of the missed detections were due to the lower metal-content simulants (G_0 and I_0) used in this test, While not mines, these simulants represent a range of the low-metal -content actually found in mines.

The Giat Model F1, as seen in Tables 5.7 and 5.8, had a boost to its score through detections of the simulants (G_0 and I_0) that had given difficulty to all other detectors. Without these simulants included, the Giat Model F1 would not have fared so well relative to the other detectors as it did less well on the mine targets. It is not known why this single detector did so well on the simulants.

One detector showed an inconsistency in performance. The White's Spectrum scored a total of 23 targets out of 32 total in Lane 1, while only scoring 6 targets out of 31 total in Lane 2. This discrepancy is the largest difference in detections between the two lanes of the entire test.

Depector Types	TARGETS (Number Buried)							
	PMA-2 (3)	PMA-3 (3)	PMD-6 (2)	PMN (2)	PMN-2 (2)	G_0 (4)	I_0 (4)	M_0 (4)
AD25	1	0	0	2	0	0	1	0
AD26	0	0	1	2	0	1	1	0
EB42	1	2	1	2	2	0	2	3
EB53	1	0	2	2	2	1	1	2
FI12	0	0	2	2	2	0	1	3
FIIM	0	0	2	2	2	0	0	2
FIXB	0	0	2	2	1	0	1	4
FOMI	1	1	2	2	2	0	1	3
GIAT	1	0	1	2	1	3	1	3
GUA2a	1	1	2	2	2	1	0	1
GUA2b	0	0	1	1	1	2	1	1
GUA2c	0	0	1	2	1	0	0	0
GUA4	1	1	0	2	1	0	2	0
GUA8a	0	1	2	2	2	0	1	0
GUA8b	0	0	1	2	1	0	1	2
GUA8c	0	1	1	2	1	0	2	2
LGPR	0	0	2	2	2	0	0	1
MICM	1	1	2	2	2	0	3	4
MIMI	1	2	2	2	2	1	3	4
PRMA	1	2	2	2	2	0	1	4
REMI	0	0	0	2	2	1	1	1
SCAN	0	0	1	2	2	0	0	1
SCAT	0	0	1	1	2	0	0	0
SCMI	0	0	1	2	2	1	1	1
VA16	1	2	2	2	2	0	3	4
VAVMa	1	1	0	2	2	0	1	3
WH59	0	1	2	2	2	0	1	3
WHAF	0	0	1	2	2	1	1	1
WHSP	1	2	2	2	2	1	1	2

Table 5.7 *– The results of all detectors tabulated against the number of targets that they detected in the IPPTC Configuration, buried at 5 cm depths with a minimum of 1 m between targets.*

CroMAC Configuration

For this field test, the CroMAC Configuration was a very simple modification of the IPPTC Configuration: objects were buried, to the extent the rocky terrain would allow, down to 20 cm in depth. It was expected that there would be fewer detections at this depth and this was borne out by the results (shown in Table 9). It was also expected that the detection results for the 5 cm and 10 cm depths would have shown many more successful detections, however the soil conditions making it difficult for detection seemed to have significantly affected the detection levels even at shallower depths.

Summary of the Croatian Field Test

The main purpose of this field test was to evaluate the performance of the detectors in the less-controlled field environment of Croatia. The relatively low number of targets detected highlights the difficulty of the soil. With a total of 63 targets in the IPPTC and CroMAC Configurations, the number of targets detected ranged from 8 to 41 targets. The total number of targets detected at all depths is summarized in a chart, Figure 5.8. On the far left of the chart is a reference bar depicting an ideal detector with a perfect score (63 targets, no false positives).

The results for the detection of minimum metal mines,

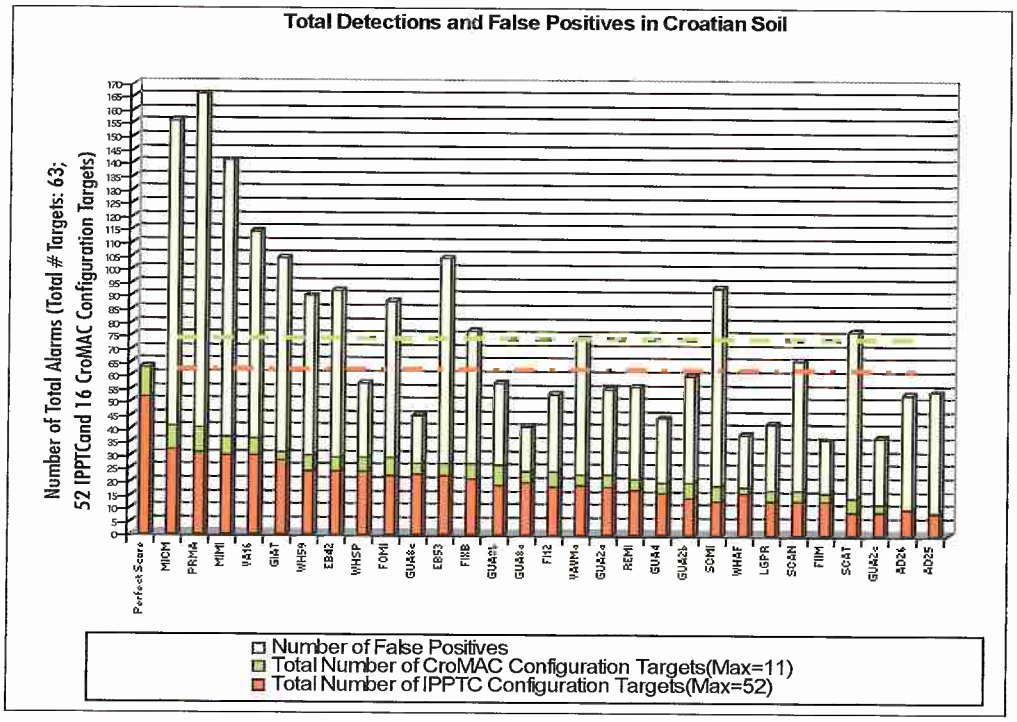
Depector Types	TARGETS (Number Buried)							
	PMA-2 (5)	PMA-3 (2)	PMD-6 (4)	PMN (2)	PMN-2 (3)	G_0 (4)	I_0 (4)	M_0 (4)
AD25	1	1	0	2	0	0	0	0
AD26	1	2	1	1	0	0	0	0
EB42	1	1	1	2	3	1	1	1
EB53	3	1	2	2	2	0	0	1
FI12	1	1	2	2	2	0	0	0
FIIM	1	0	0	2	2	0	0	0
FIXB	1	1	4	2	3	0	0	0
FOMI	1	2	1	2	3	0	1	0
GIAT	1	2	0	2	2	4	3	2
GUA2a	2	0	1	2	2	0	0	1
GUA2b	1	2	0	2	2	0	0	0
GUA2c	1	0	0	1	2	0	0	1
GUA4	2	2	2	2	0	0	0	1
GUA8a	1	1	2	2	3	1	1	1
GUA8b	2	2	2	2	1	1	1	1
GUA8c	3	2	1	2	1	2	1	2
LGPR	1	1	0	1	3	0	0	0
MICM	5	1	3	2	3	0	1	2
MIMI	2	1	3	2	2	0	1	2
PRMA	1	2	4	2	3	1	1	3
REMI	1	0	2	2	3	0	0	2
SCAN	0	0	1	2	2	1	1	0
SCAT	1	1	0	2	1	0	0	0
SCMI	2	0	0	0	2	1	0	0
VA16	1	2	2	2	2	0	2	3
VAVMa	1	1	2	2	2	0	0	1
WH59	3	2	2	2	2	1	0	1
WHAF	1	1	1	2	2	1	0	0
WHSP	2	1	1	2	2	0	2	1

Table 5.8 *– The results of all detectors tabulated against the number of targets that they detected in the IPPTC configuration, buried at 10 cm depths with a minimum of 1 m between targets.*

Depector Types	TARGETS (Number Buried)							
	PMA-2 (0)	PMA-3 (2)	PMD-6 (2)	PMN (4)	PMN-2 (3)	G_0 (0)	I_0 (0)	M_0 (0)
AD25		0	1	0	0			
AD26		0	0	0	0			
EB42		1	0	4	0			
EB53		1	0	3	1			
FI12		0	1	4	1			
FIIM		0	0	3	0			
FIXB		0	0	4	2			
FOMI		1	1	3	2			
GIAT		0	1	0	2			
GUA2a		0	1	2	2			
GUA2b		1	0	4	1			
GUA2c		0	0	2	1			
GUA4		1	0	2	1			
GUA8a		1	0	2	1			
GUA8b		1	1	3	2			
GUA8c		1	0	2	1			
LGPR		0	0	3	1			
MICM		0	2	4	3			
MIMI		0	0	4	3			
PRMA		1	1	4	3			
REMI		0	0	3	1			
SCAN		0	0	3	1			
SCAT		0	0	3	2			
SCMI		1	1	3	1			
VA16		0	0	4	2			
VAVMa		0	0	3	1			
WH59		0	2	4	0			
WHAF		0	0	2	0			
WHSP		0	1	2	2			

Table 5.9 *– The results of all detectors tabulated against the number of targets that they detected in the CroMAC Configuration, buried at 15 and 20 cm depths with a minimum of 1 m between targets.*

Figure 5.8. Total number of detections - both IPPTC (5 and 10 cm depths) and CroMAC (15 to 20 cm depths) with additional false positives graphed and sorted for all detectors. At far left, a representative bar shows height reached if all IPPTC and CroMAC targets were detected.



in Tables 5.7 and 5.8, show a consistent trend for all depths. In general, the PMA-2 and PMA-3 were more difficult to detect than the other mine targets and this was confirmed by the proportionally higher detections of other targets at 5 cm depth.

Further, the 3 simulants used in this test show a similar correlation. The G_0 and I_0, representing minimum metal mines, showed lower detection levels than the higher metal content of the M_0 at 5 cm and 10 cm depths. (These simulants were not used in the CroMAC Configuration at 20 cm depths.)

The results show that, while some detectors performed better than others, no single detector was capable of finding all the targets at any depth. This was interpreted as an indication of the difficulty of the soil conditions for detection. The deminers repeatedly reported that they received many signals over the test site. The IPPTC teams confirmed subsequently that these were uncorrelated to the buried targets.

The results of each detector performance against four mine targets for the IPPTC and CroMAC Configurations are shown in **Annex A - Detector Performance Summaries.**

6. Human Factors Assessment

This section summarizes the results of the Human Factors Assessment conducted during the International Pilot Project for Technology Cooperation. It is derived from the full technical report [7].

The Human Factors laboratory assessment was carried out at the Defence Research Establishment Suffield (DRES), Alberta, Canada. Field assessments were conducted within the tests in Cambodia and Croatia.

Objective

The objective of the Human Factors Assessment was to evaluate the ergonomic aspects of the detectors, and determine their level of suitability for humanitarian demining operations.

In contrast to many consumer products intended for everyday use by the general public, the consequences of poor ergonomics in the context of humanitarian demining are rather more severe. For example, an incomplete understanding on the part of the user of how the demining equipment functions, or the adjustment of the wrong control could easily lead to failure to detect an anti-personnel mine by the deminer – possibly resulting in severe or even fatal injury.

Laboratory Assessment

A human factors assessment of the metal detectors was conducted by DERA Centre for Human Sciences (CHS), and Subject Matter Experts (SMEs) on the topic of humanitarian demining. The Guartel MD8 and 2000 were both assessed as single detectors, even though they contained multiple detector heads.
The necessary steps to be followed, in order to use a detector were analyzed to provide a baseline description of the demining task (Figure 6.1). This task description formed the basis of a systematic assessment of each detector. The subtasks and associated questions were drawn together in the form of the Usability Assessment Questionnaire, which was followed by the SMEs over the course of each evaluation. The purpose of the Usability Assessment Questionnaire was to evaluate, systematically and comprehensively, each detector in a consistent manner. Whilst the primary task was to capture the full detail of the assessment for each detector, a secondary requirement was to support a top-level comparison between detectors.
The following topics were considered in the laboratory assessment:

- Suitability for prolonged use
- Simplicity of functions
- Robustness and weatherproofing of equipment
- Suitability of transit and field casings
- Type and amount of feedback to user (audio and visual)
- Adequacy of basic controls
- Batteries/power supply

Field Assessment

Subjective data was collected at both field trials (Cambodia and Croatia) using a questionnaire prepared by the CHS and SMEs.
The field trials consisted of a small number of users testing between two and four detectors each. The small sample size of responses to the questionnaire for each detector means that statistical analysis cannot be applied to the findings. Comparisons between responses must be treated cautiously due to the individual preferences, tendencies and biases that were inevitably present within the sample of users. This comparison did allow support for the laboratory findings to be identified from the field trials data where there was agreement between them. Also, this process allowed differences or contradictions between the laboratory and field trials to be highlighted (see Table 6.1 under "Notes- Lab. Assessments and Notes- Field Trials").

Results

Table 6.1 summarizes the laboratory and field assessments.
Table 6.2 summarizes the laboratory assessments for practicality, simplicity and usability. For each

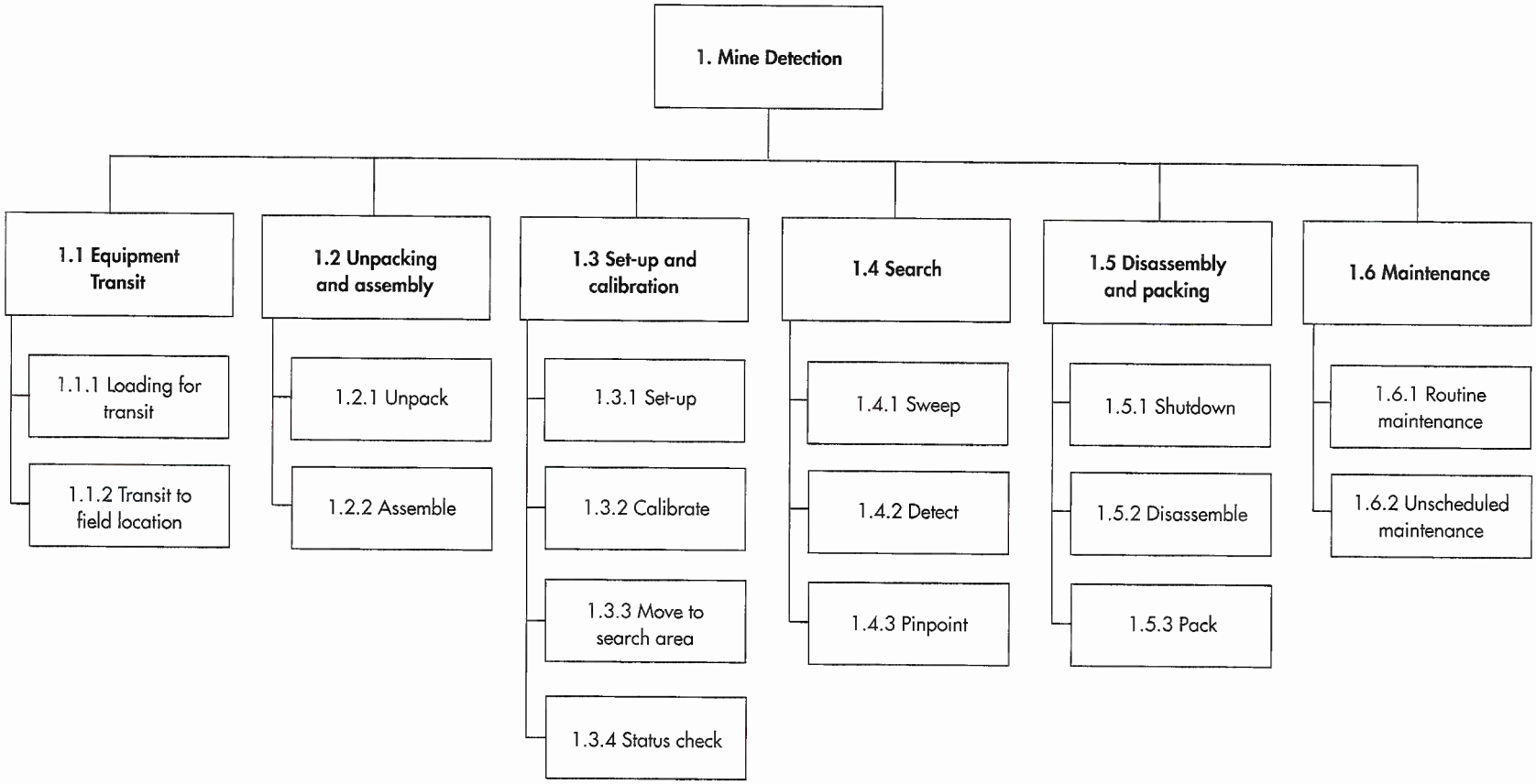


Figure 6.1. *Breakdown of mine detection tasks*

Detector	*Practicality*	*Simplicity*	*Usability*	*Total Score (within tested group)*
Ebinger EBEX 420 GC	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	15 / 15
Guartel MD8	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	15 / 15
Schiebel AN-19/2	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	15 / 15
Ebinger EBEX 535	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆	14 / 15
Schiebel ATMID	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆	14 / 15
Schiebel MIMID	◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	14 / 15
Fisher Impulse	◆◆◆◆	◆◆◆◆◆	◆◆◆◆	13 / 15
Foerster MINEX 2FD	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆	13 / 15
LG Precision PRS-17K	◆◆◆◆	◆◆◆◆◆	◆◆◆◆	13 / 15
Minelab F1A1 CMAC	◆◆◆◆	◆◆◆◆◆	◆◆◆◆	13 / 15
Vallon VMH2	◆◆◆◆	◆◆◆◆	◆◆◆◆◆	13 / 15
Fisher 1266-XB	◆◆◆	◆◆◆◆◆	◆◆◆◆	12 / 15
Guartel MD2000	◆◆◆◆◆	◆◆◆	◆◆◆◆	12 / 15
Guartel MD4	◆◆◆	◆◆◆◆◆	◆◆◆◆	12 / 15
Minelab F1A1 MIM	◆◆◆◆	◆◆◆◆	◆◆◆◆	12 / 15
Reutech Midas PIMD	◆◆◆◆	◆◆◆◆◆	◆◆◆	12 / 15
Vallon ML 1620 C	◆◆◆◆◆	◆◆◆	◆◆◆◆	12 / 15
Fisher 1235-X	◆◆	◆◆◆◆◆	◆◆◆◆	11 / 15
Giat Model F-1	◆◆◆	◆◆◆◆	◆◆◆	10 / 15
Pro-Scan Mark 2 VLF	◆◆	◆◆◆◆	◆◆◆◆	10 / 15
Whites NATO MD AF-108	◆◆◆	◆◆◆◆	◆◆◆	10 / 15
Adams AD2500	◆	◆◆◆◆◆	◆	7 / 15
Adams AD2600S	◆	◆◆◆◆◆	◆	7 / 15
Whites DI-PRO 5900 CB	◆◆	◆◆	◆◆◆	7 / 15
Whites Spectrum-XLT	◆◆	◆◆	◆◆◆	7 / 15

Table 6.2 *– Scores from the laboratory assessment for practicality, simplicity and usability.*

criterion the merits of all detectors in that respect were compared and then assigned a relative score out of 5 for each of the criteria. Maximum scores do not indicate perfection, only the better detectors within the tested batch.

For each criteria listed in Table 6.2 the following aspects were considered:

1. Practicality: Adequacy of transit and field casing, ruggedness and maintainability.
2. Simplicity: The number of set-up options, number of parts to assemble/disassemble, number of steps for calibration.
3. Usability: Avoidance of ambiguity, design features to prevent user error, user comfort for prolonged operation, clarity of guidance documentation – i.e. given the level of complexity how effectively is this presented to the user.

Summary of the Human Factors Assessment

Decisions regarding the selection of a detector suitable for humanitarian demining require a detailed consideration of their features in relation to the characteristics of the users and their environment. Candidate detectors can be identified using the features revealed. Filtering these into a short list should take into account the issues identified by the field trials. Final selection should be based on prolonged evaluation of the short-listed detectors by the demining organization in the intended operational scenario.

7. Conclusions

General

- Across the field tests, utilizing simulated real-world scenarios, none of the detectors evaluated detected all of the mine targets down to 10 cm. If the identification of the presence of individual mines were determined only through the use of metal detectors, then the potential implication of this would be that demining organizations today are missing mines.
- While some detectors performed better than others in some of the laboratory testing, no single detector demonstrated its clear superiority in all categories evaluated.

In-Air Tests

- Although a detector's ability to detect targets in air does not always correspond to its ability to detect targets buried in the soil, the results of the In-Air Sensitivity tests serve many useful purposes. For each detector they:
  - Provide useful information on the repeatability and stability of performance.
  - Provide information on the relative distance of detection of the various targets;
  - Identify detectors which do not have the minimum required detection distance for targets of interest since a detector is not likely to detect a target at a greater depth in soil than in air;
  - Allow comparison of the sensitivity of detectors against the same targets in soil;
  - Test against a number of real targets to reveal weaknesses in detectors that are optimized against a single target.
  - Indicate the unit-to-unit variation where more than one sample of a detector is tested.
- The results from the Scan Profile test show that the footprint for a small target (such as an AP mine) generally becomes smaller as the target distance increases. This finding is contrary to claims by some manufacturers. The footprint data may help the user improve his training and Standard Operating Procedures (SOPs). However, to make quantitative use of the footprint data, further measurements should be made for a range of targets.
- For future in-air tests, techniques should be devised for eliminating the effect of an operator on test results. This may be through the development of computerized algorithms to make "detection" decisions or through the use of a random sample of operators on the same data. This should allow more rigorous analysis of data collected.

In-Soil Tests

- Only one detector, the White's Spectrum XLT, found all targets at both 5 cm and 10 cm depth in all four soils.
- Apart from the White's Spectrum XLT mentioned above, the top performing detectors for the detection of minimum metal targets in sand were the Guartel MD8 with the round search head; in clay the Vallon VMH2; in peat the Guartel MD8 with the round search head, Pro Scan Mark 2 VLF and Schiebel MIMID; and in ferruginous soil Pro Scan Mark 2 VLF and Schiebel MIMID.
- The MineLab F1A4 CMAC and MineLab F1A4 MIM, that found all targets at 5 cm depth, performed rather less well for the targets at 10 cm depth.
- Ferruginous soils imposed the greatest difficulty for the detectors and sand caused the least problem. The Guartel MD8 with the round search head and the Vallon VMH2 experienced difficulties in the ferruginous soil, but performed well for targets in sand, clay and peat. In this respect the Foerster Minex 2FD 4.400.01, the Pro Scan Mark 2 VLF and the Schiebel MIMID were exceptions: they performed better in the ferruginous soil than in the three other soils.
- These tests (together with the field tests) confirmed correlation of soil electrical properties (magnetic susceptibility, in particular) with detector performance. In future minefield surveys simple conductivity and susceptibility measurements should be considered as a possible aid in the selection and prediction of performance of detectors.
- Broadly speaking, the results of the In-Soil Tests are confirmed by the results of the Field Tests, but for some detectors deviant results were obtained.

It should be kept in mind that in the In-Soil Tests the detectors were used at one sweep speed of 18 cm/s.

This sweep speed may not be optimal for some detectors.

Since the number of targets in In-Soil Tests was limited, small differences between the numbers of detected targets of detectors can not be regarded as significant.

Field Test (Cambodia)

- No detector found all the targets in both the clay and laterite soils.
- The number of targets detected in the clay lane was three times higher than in the laterite lane while having four times fewer false positives. This is not unexpected as laterite is considered a very difficult soil type for metal detectors.
- The leading detectors finding targets buried in clay in the IPPTC configuration were: Ebinger EBEX 420GC, Fisher Impulse, Fisher 1266 XB, Foerster MINEX 2FD, Minelab F1A4 CMAC, and Vallon VMH2.
- The leading detectors finding targets buried in clay for the CMAC configuration were: Fisher Impulse, Fisher 1266 XB, Foerster MINEX 2FD, Vallon VMH2, ProScan Mark 2 VLF and Schiebel AN-19/2.
- No detector found more than 75% of targets buried in laterite for either the IPPTC or the CMAC configurations. Only two detectors, Foerster MINEX 2FD and Minelab F1A4 CMAC, found more than 50% of the targets for both configurations.
- The relative proportion of targets detected in the CMAC configurations is generally the same for the targets buried in the IPPTC configuration in the same soil condition.
- For detection of a Type 72 (minimum metal AP mine), up to 10 cm deep in clay in the IPPTC configuration, the following performed best: Fisher 1266 XB, Foerster Minex 2FD 4.400.01 and Minelab F1A4 CMAC. In laterite soil for the same target, only the Foerster MINEX 2FD and Minelab F1A4 CMAC achieved some detections.
- For detection of Type 72 up to 10 cm in clay in the CMAC configuration, two detectors (Foerster MINEX 2FD and Vallon VMH2) performed best. In laterite soil for the same target, three detectors (Foerster MINEX 2FD, Minelab F1A4 CMAC and Vallon VMH2) scored better than others.

Field Test (Croatia)

- No detector found all the mines or simulants at 5 cm, 10 cm, or 15-20 cm depths.
- Among the 29 detectors, there is a simple distribution of performance. Given the somewhat uncontrolled nature of any field test, fine distinctions between detectors on the order of a single detection are unwarranted. However, sorting the detectors, based on a difference of +/-3 detections, identified a leading group of five detectors, followed by the next 20 detectors in a slowly descending but continuous distribution, with a final drop off of four trailing detectors at the end.
- The five leading detectors in the Croatian Field Test were the Minelab F1A4 CMAC, the Pro-Scan Mark 2 VLF, the Minelab F1A4 MIM, the Vallon ML 1620C, and the Giat Model F1 (DHPM-1A).
- The results show that, while some detectors performed better than others, no single detector was capable of finding all the targets at any depth. This was interpreted as an indication of the difficulty of the soil conditions for detection. A large number of detections were reported by the deminers during the tests. Later it was clear that very many of these did not correlate to the positions of the buried targets.

Human Factors Assessment

- The laboratory assessments resulted in two distinct groups: a group of four lower scoring and the rest forming a higher scoring group. The lower scoring group is considered less suitable for humanitarian demining from a human factors perspective. However, this does not take into account the detection capability.
- Within the higher scoring group several detectors scored only slightly higher than the rest. Therefore, singling out detectors from this group as better suited for humanitarian demining is unjustified. The spread of scores shows that the difference between any adjacent detectors is small. For this reason it is considered that any differences highlighted by the laboratory assessments are small compared to the different conditions, environment, task and personnel, connected to the different demining organizations.
- Human factors need to be considered in conjunction with other factors such as technical performance and cost in an overall cost benefit analysis in which human factors issues may conflict with other issues. It is for the demining organizations to determine their own priorities in this situation.

In closing, the IPPTC successfully addressed a number of problems during the tests and in particular tried to ensure that a standard test procedure was followed to ensure consistency and repeatability of the tests. The test methodology created for this project is offered to the demining and development, communities for consideration, further development and use in future assessments of metal detectors to meet demining requirements.

The results as presented will allow the reader to identify groups of detectors with above average performance capabilities for a variety of demining environments. Therefore, it is possible for the reader to eventually answer the question, "Which detector is the best for my needs?"

ANNEX A - Detector Performance Summaries

This annex presents, in a concise form, the results for each detector type that was measured in the International Pilot Project for Technology Co-operation.
At the top of the first page of each detector summary, information is given about the main characteristics of the detector. This is based on manufacturer provided data[1]. Following this, the test results are summarised, starting with extracts from the Human Factors assessment intended to highlight the major findings from this part of the project.
Performance tests are then presented starting with the field tests for Cambodia and Croatia. For each field test two charts are presented showing:

- the number of detection declarations classified by soil type made for each detector compared with the spread of results from all the detectors tested; and
- the number of detections declared, classified by mine type, again overlaid on a bar indicating the full range of detections declared from all the detectors.

On the second page the results of the In-soil test (conducted at the TNO test site in the Netherlands on four example soils) are presented as:

- Number of detections classified by soil type, and
- Number of detections by mine type viewed over all the test soils.

As on page 1 the results of the detector under discussion are shown against a background that depicts the range of detections achieved by the whole range of detector types tested.

The In-air test results are presented finally as:

- Maximum detection distance, classified by mine target,
- Detection distance in air determined under the conditions specified for the Calibration, and the effects of:
  - drift,
  - moisture,
  - sweep speed.

Where, during the tests it had been possible to record results from two samples of the detector type, both values are shown.

A fuller description of each measurement process is given in the appropriate section of this report. Also in those sections the reference to the full report of that aspect of the project is identified.

[1] Telepnone numbers are given in the form +NN__. The + signifies the number to be dialed to make an international call, which varies according to the country where the call originates. In EU, Canada and USA + signifies 00 - however there are exceptions.

ADAMS AD2500

Manufacturer Information:
Adams Electronics
Unit 10, Forest Row Business Park
Forest Row
East Sussex RH18 5DW
United Kingdom
Telephone: +44 1342 823856
Fax: +44 1342 826100
http://www.adamsinc.com

IPPTC Cost: US $465

Weight/Dimensions:
Length: 360 mm
Width: 105 mm (probe); 55 mm (body)
Height: 35 mm
Weight: 295 g

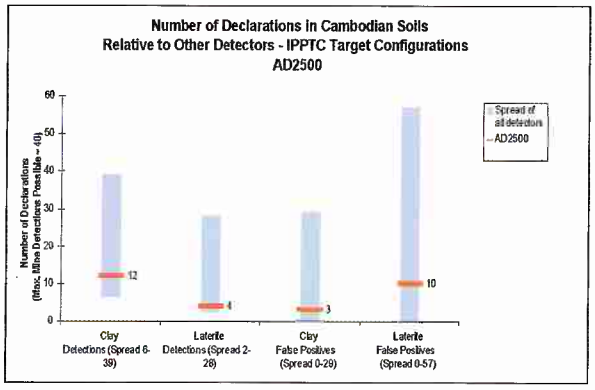
Power Supply: 1 x 9V battery

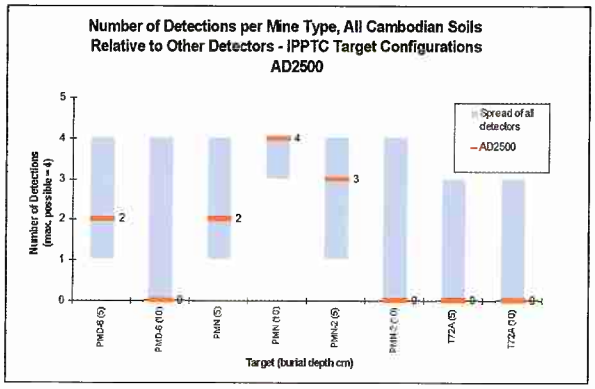
The AD2500 is a small, hand-held metal detector designed to support security such as in airports and prisons. Its size limits its use to kneeling and prone positions and in very localized detection areas. It provides both audio and visual indications and can be used with either standard or rechargeable batteries.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

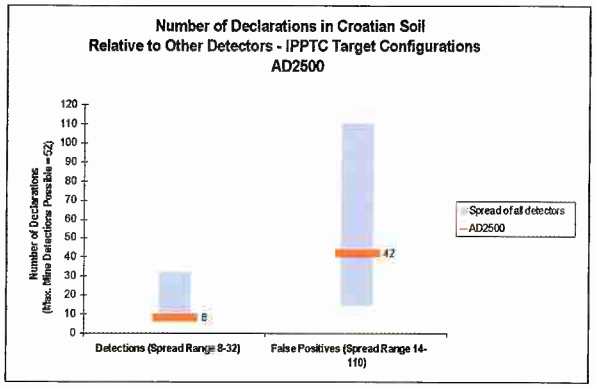
- Lightweight
- Simple operation
- Strong casing
- Must hold down button during operation
- Too small for standing operation
- Screwdriver required to install battery

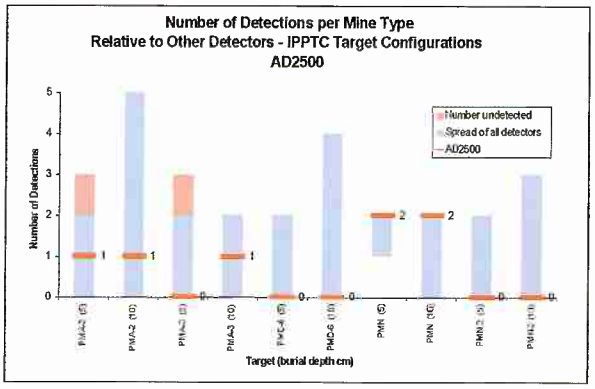
Field Tests – Cambodia





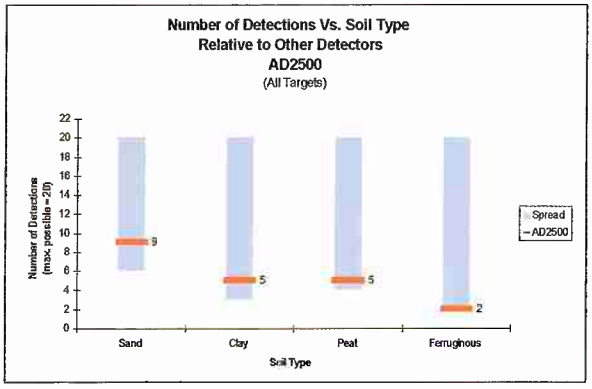
Field Tests – Croatia

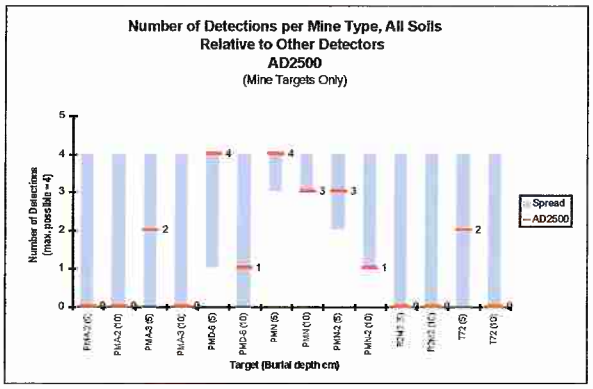




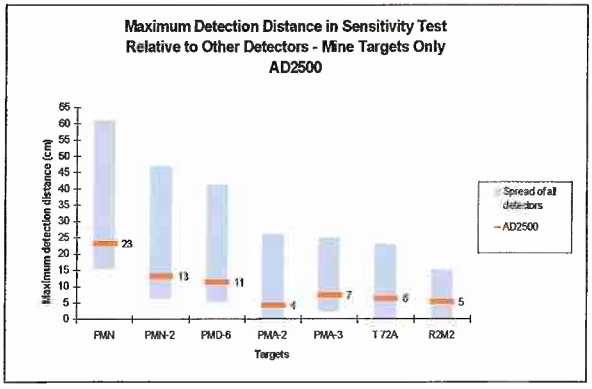
ADAMS AD2500

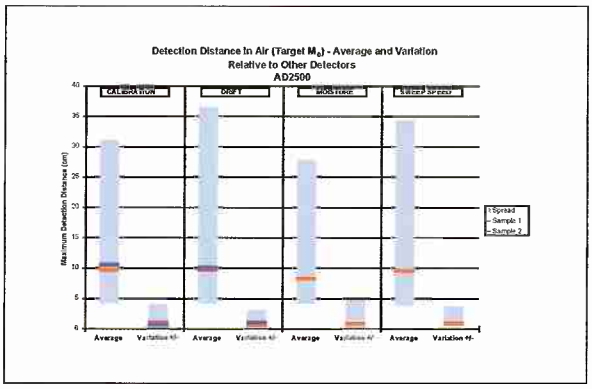
In-Soils Tests

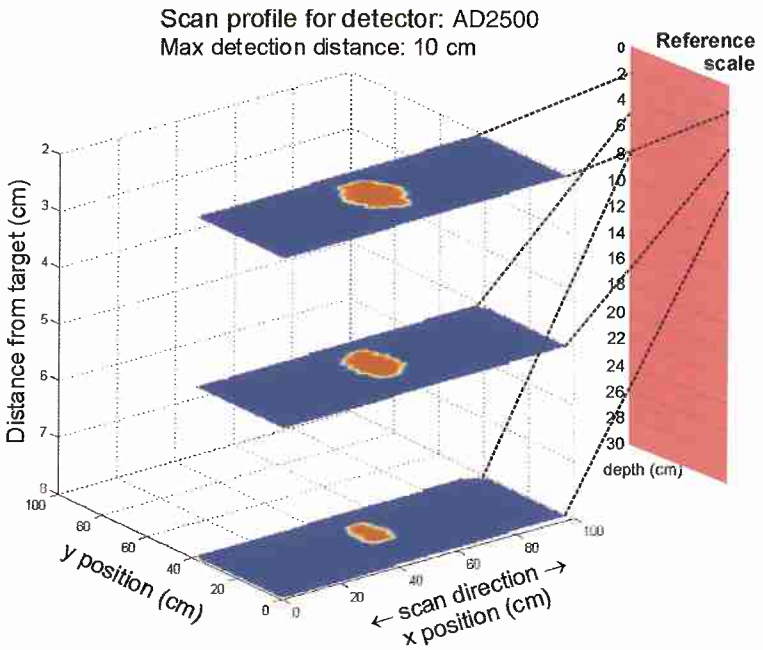




In-Air Tests



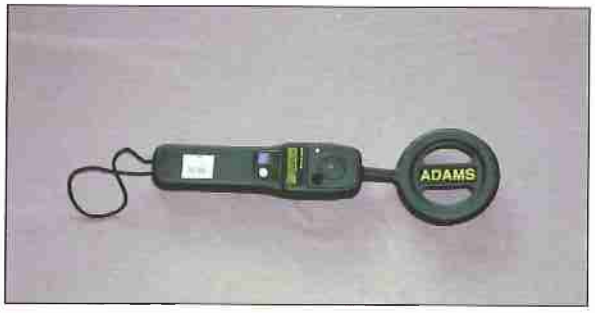




ADAMS AD2600S

Manufacturer Information:
Adams Electronics
Unit 10, Forest Row Business Park
Forest Row
East Sussex RH18 5DW
United Kingdom
Telephone: +44 1342 823856
Fax: +44 1342 826100
http://www.adamsinc.com

IPPTC Cost: US $487



Weight/Dimensions:
Length: 360 mm
Width: 105 mm (probe); 55 mm (body)
Height: 35 mm
Weight: 300 g

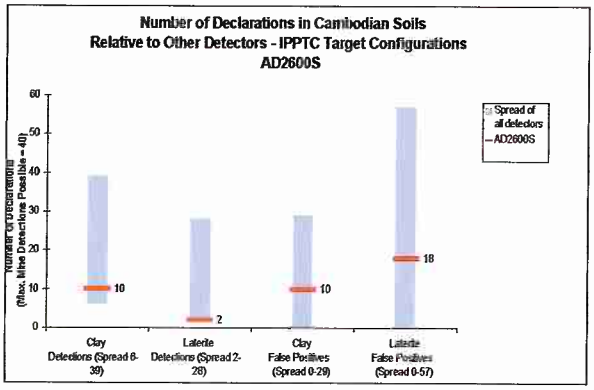
Power Supply: 1 x 9V battery

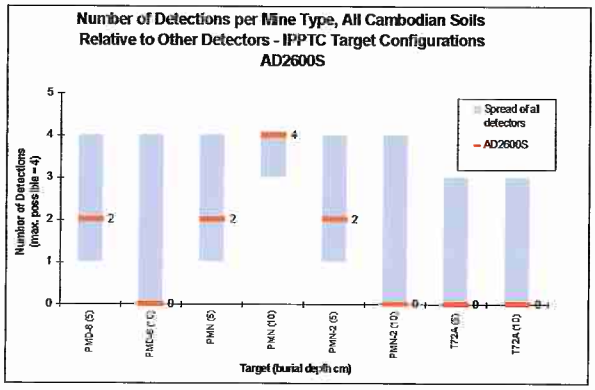
The AD2600S is a small, hand-held metal detector designed to support security such as in airports and prisons. Its size limits its use to kneeling and prone positions and in very localized detection areas. It can be used with either standard or rechargeable batteries. The AD2600S is identical to the AD2500 model, with the addition of a speaker on/off switch and a carrying case.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

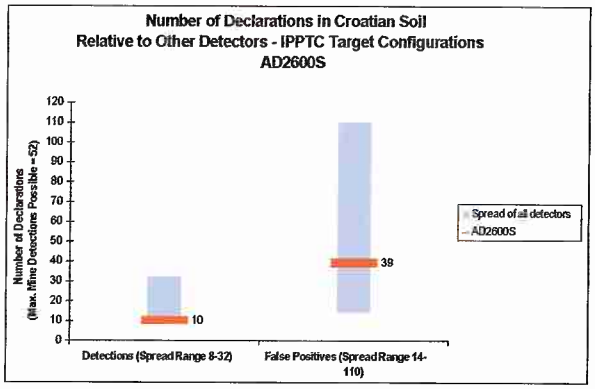
- Lightweight
- Simple operation
- Strong casing
- Must hold down button during operation
- Too small for standing operation
- Screw driver required to install battery

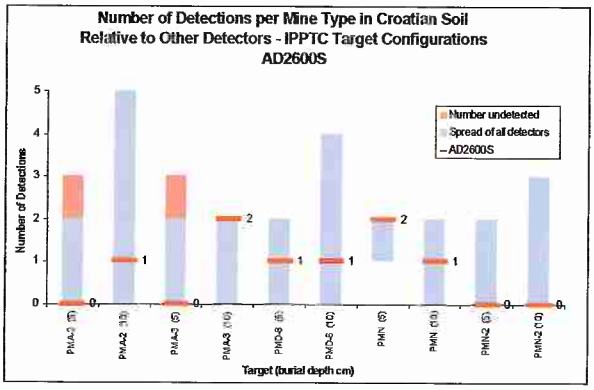
Field Tests – Cambodia





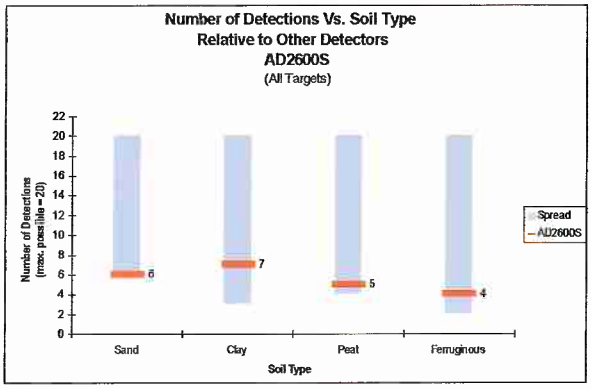
Field Tests – Croatia

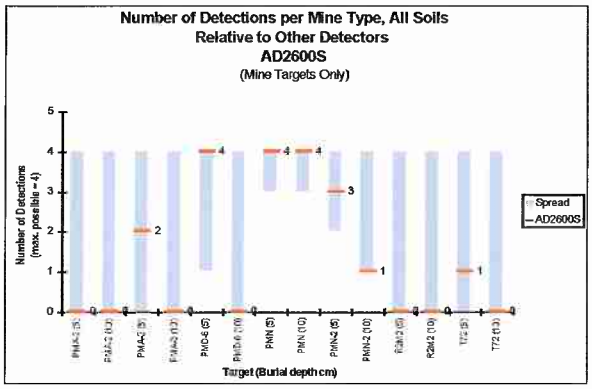




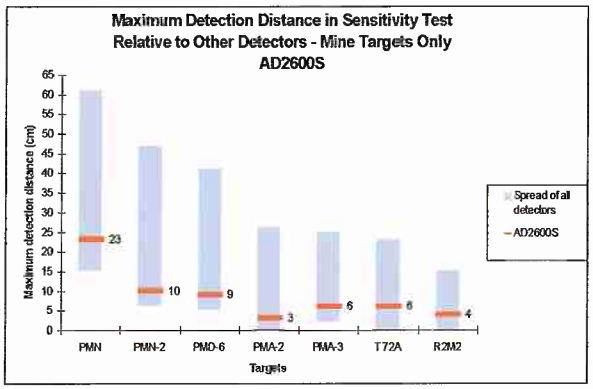
ADAMS AD2600S

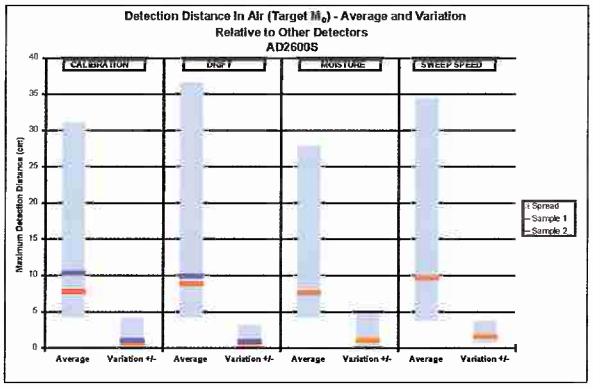
In-Soils Tests

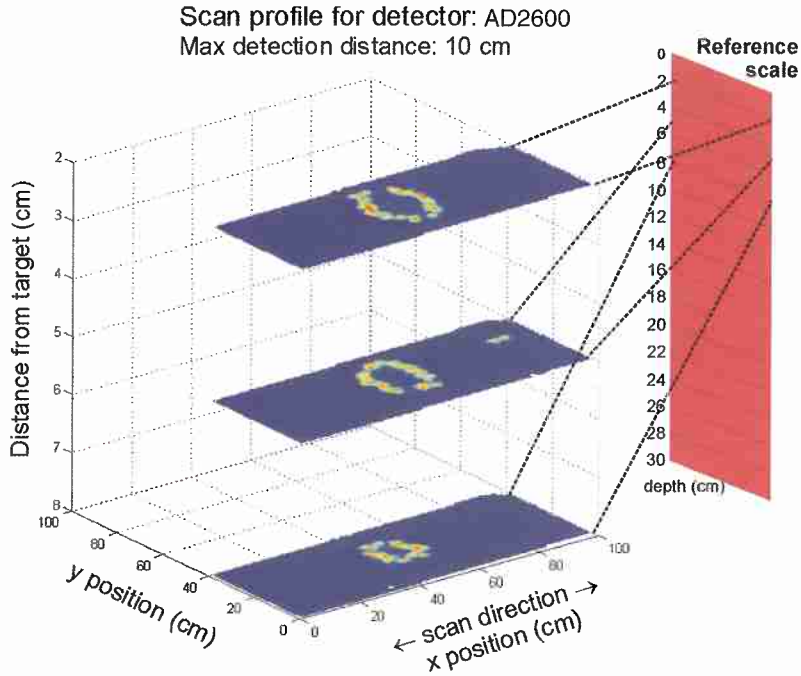




In-Air Tests







EBINGER EBEX 535

Manufacturer Information:
Ebinger GmbH
Hansestrasse 13
D-51149 Cologne
Germany
Telephone: +49 2203 36063/64
Fax: +49 2203 36062
http://www.ebingergmbh.com

IPPTC Cost: US $3,968

Weight/Dimensions:
Total Weight: 3.3kg
Electronics box: 1.6kg; 280 x 110 x 50mm
Search head: 1.0 kg; 300 x 170mm
Boom/Shaft: 0.8kg; 495 – 1550mm max.

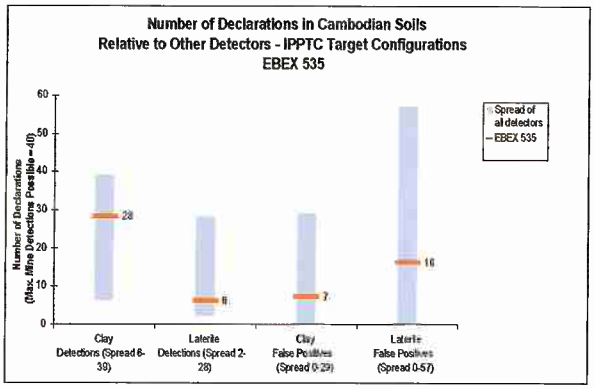
Power Supply: 8 x 1.5V "C"-size batteries

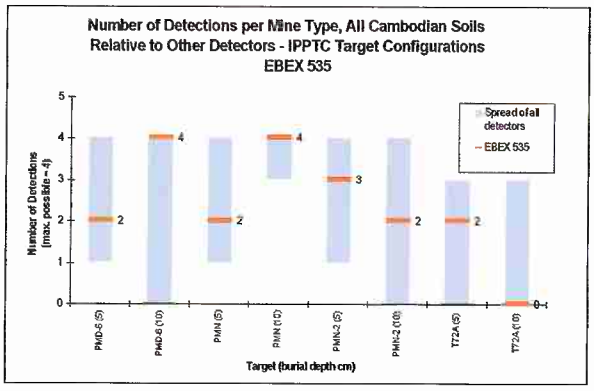
The EBEX 535 operates on pulse induction technology. It is robust and simple to use. It incorporates a separate tone for each coil of its dual-coil design, intending to aid in pinpointing and discriminating objects in close proximity. The search head is waterproof for detection in shallow water.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

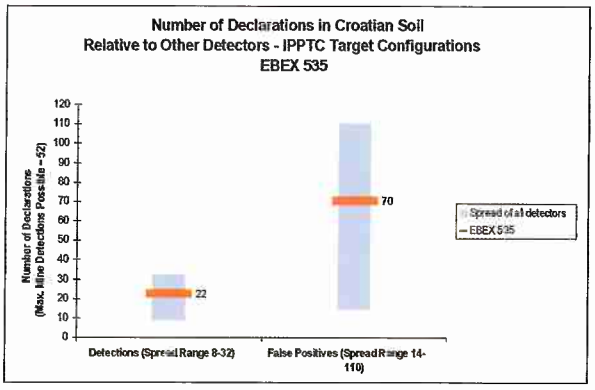
- Dual detection tone
- Rugged and water-resistant head
- Length adjustment
- No volume control on earphone
- Confidence tone in earpiece only/no fault indicator
- Unable to mount control box on shaft

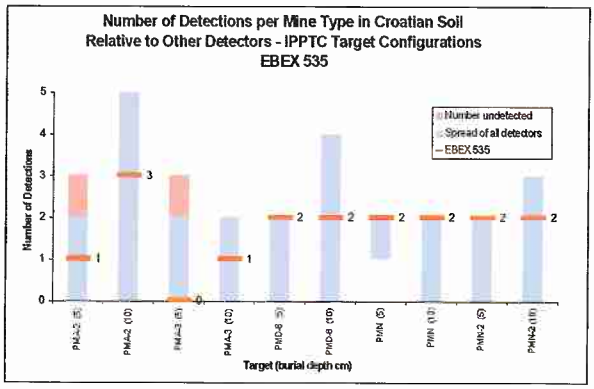
Field Tests – Cambodia





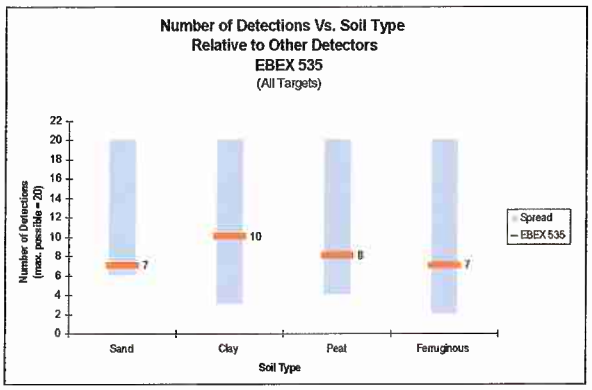
Field Tests – Croatia

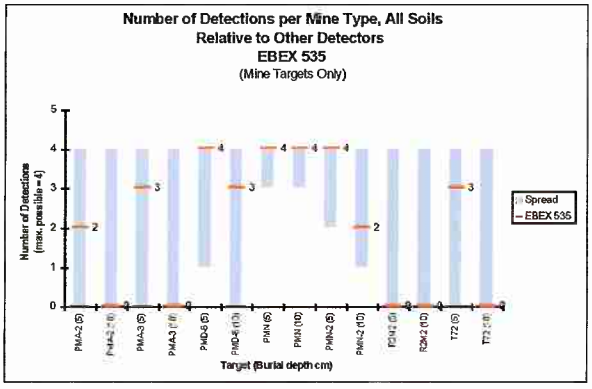




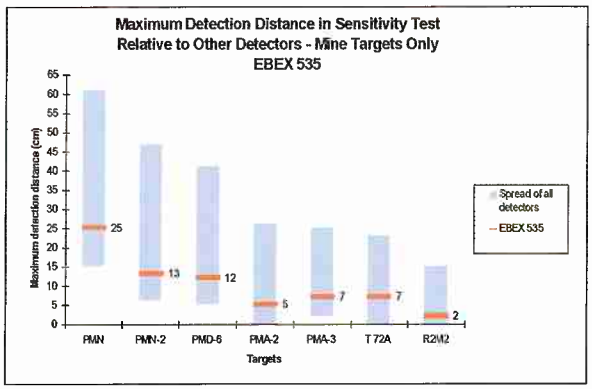
EBINGER EBEX 535

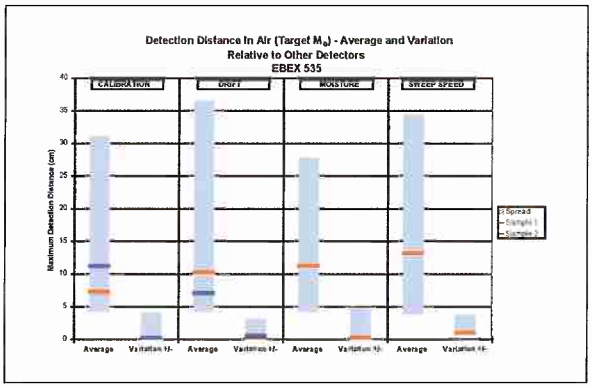
In-Soils Tests

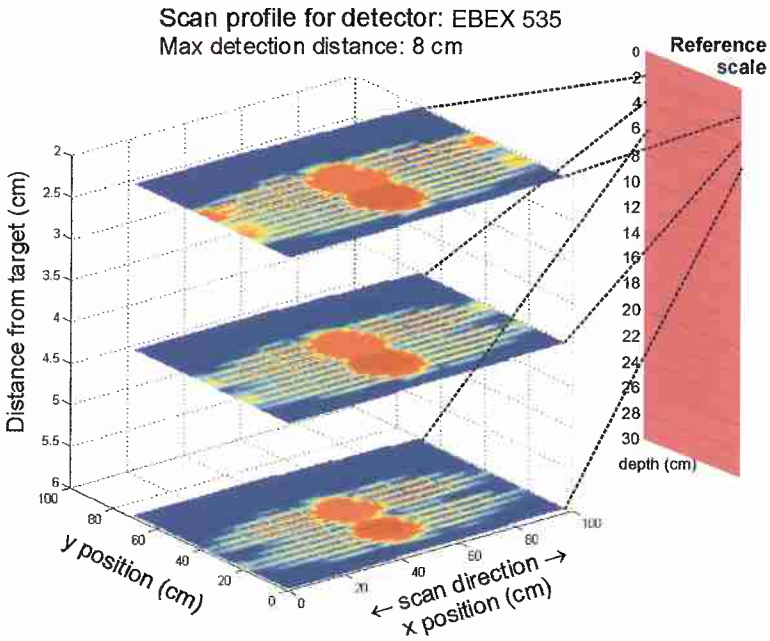




In-Air Tests







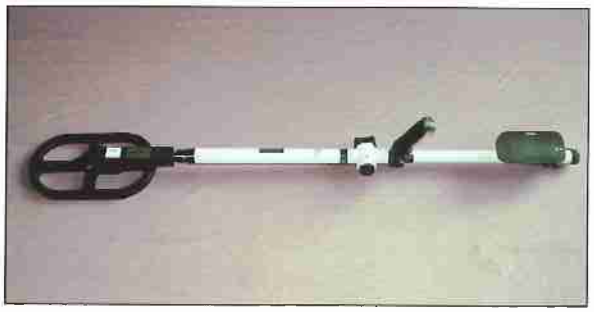
EBINGER EBEX 420 GC

Manufacturer Information:
Ebinger GmbH
Hansestrasse 13
D-51149 Cologne
Germany
Telephone: +49 2203 36063/64
Fax: +49 2203 36062
http://www.ebingergmbh.com

IPPTC Cost: US $3,003

Weight/Dimensions:
Weight: 2.2kg (short) or 2.4kg (long)
Search head: 260 x 156mm
Boom/Shaft: 1170mm (short) or 1730mm (long)

Power Supply: 8 x 1.5V "C"-size batteries

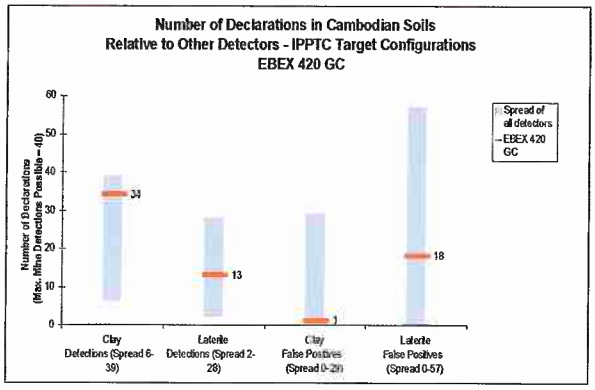


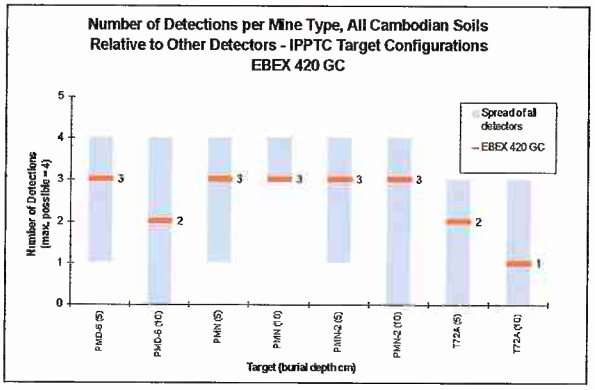
The EBEX 420 GC uses bipolar pulse induction and is designed to operate in high metallic soils by including a soil compensation feature. It has a modular design that allows for each component to be interchangeable with other detectors of the same kind and each component can be ordered individually.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

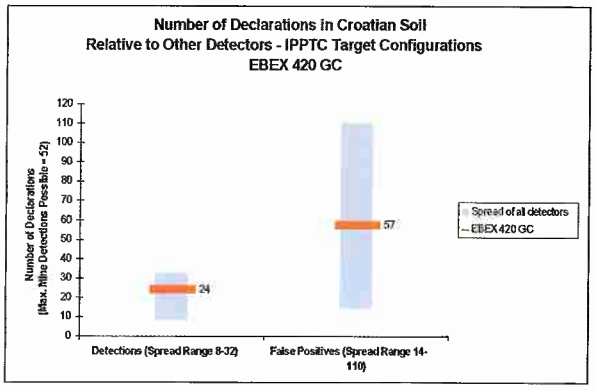
- Good auditory output devices – volume control on headset and external speaker (optional)
- Easy set up and operation
- Rugged and waterproof
- Poor range of length adjustment
- Front-heavy in long configuration
- Soil compensation adjustment screw is unlabelled and difficult to use

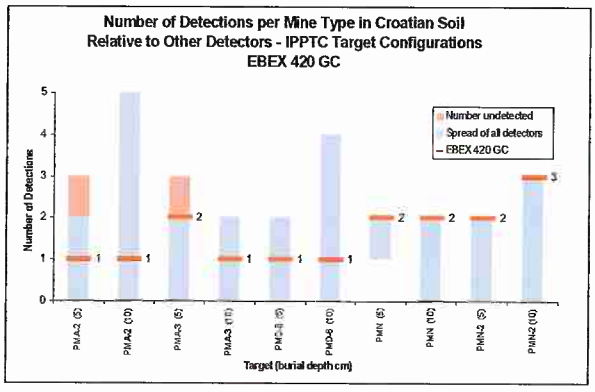
Field Tests – Cambodia





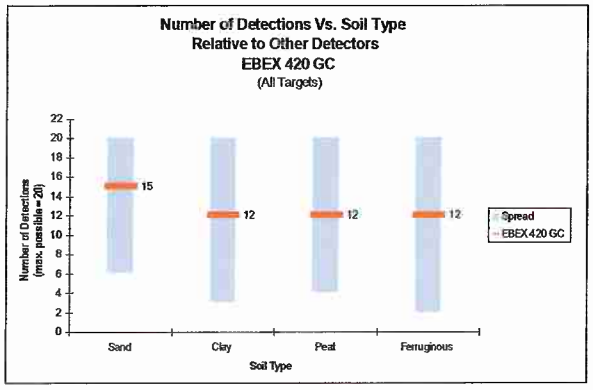
Field Tests – Croatia

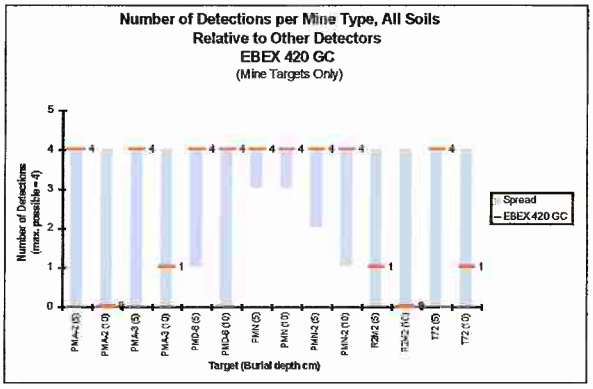




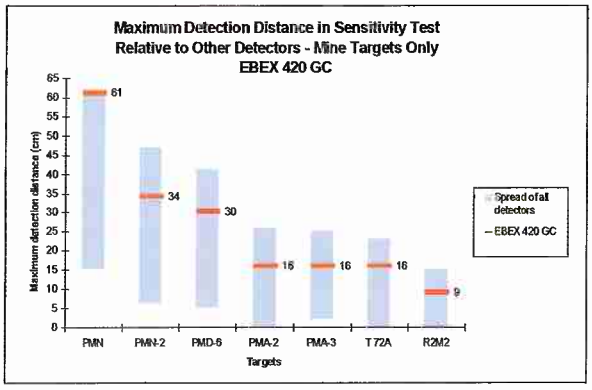
EBINGER EBEX 420 GC

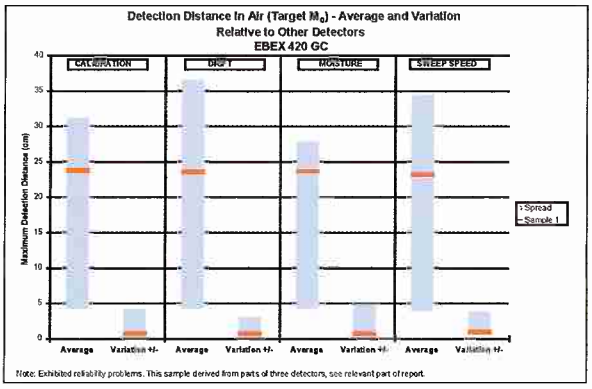
In-Soils Tests

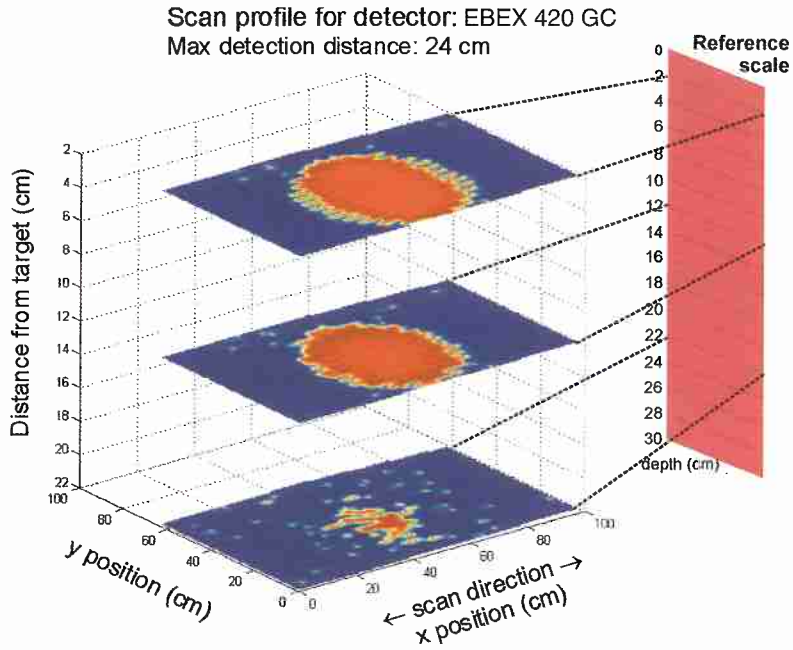




In-Air Tests







FISHER 1235 X

Manufacturer Information:
Fisher Research Laboratory
200 West Willmott Road
Los Banos, CA 93635
USA
Telephone: +1 209 826 3292
Fax: +1 209 826 0416
http://www.fisherlab.com/

IPPTC Cost: US $460

Weight/Dimensions:
Total Weight: 1.41 kg
Search head: 203 mm diameter
Boom/Shaft: 1168 – 1397 mm max

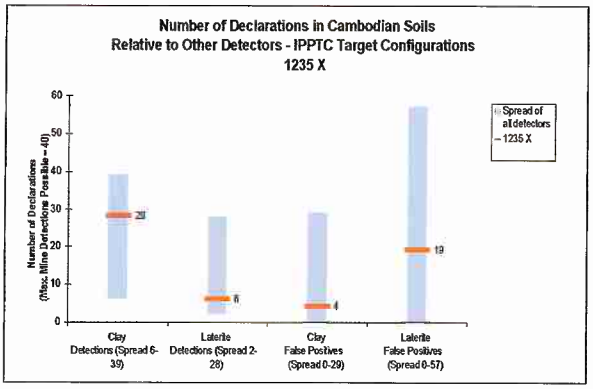
Power Supply: 2 x 9V batteries

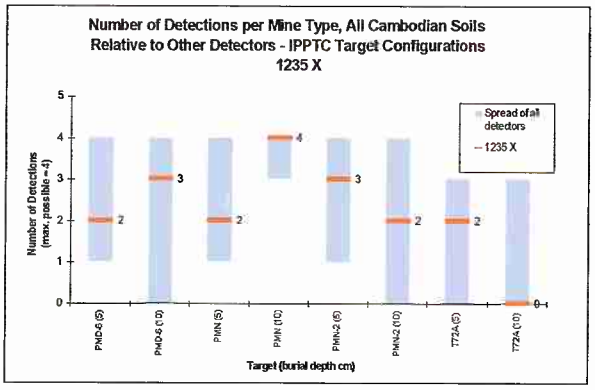
The 1235 X is designed for the hobbyist. It utilizes a "no-motion" pulse induction method of metal detection, meaning that it is intended to respond to metal without moving the search head. The audio signal increases in pitch and volume as the center of the search head passes over a target.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

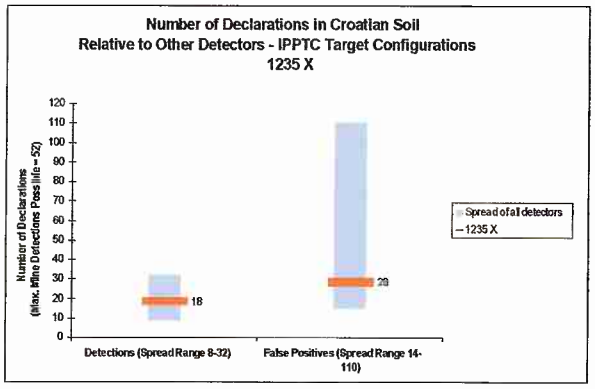
- Light and well balanced (good control box position)
- Easy to use
- Good pinpointing features
- Lack of robustness
- Not weather resistant
- No confidence or fault tones

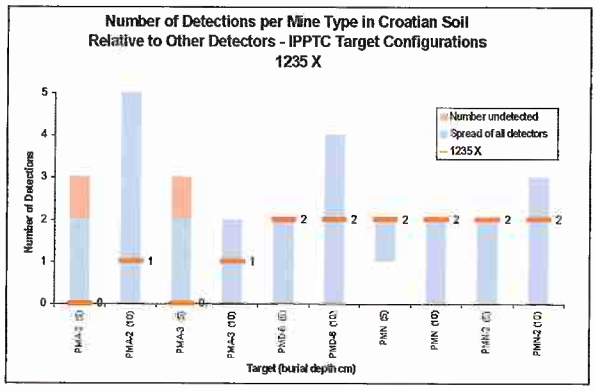
Field Tests – Cambodia





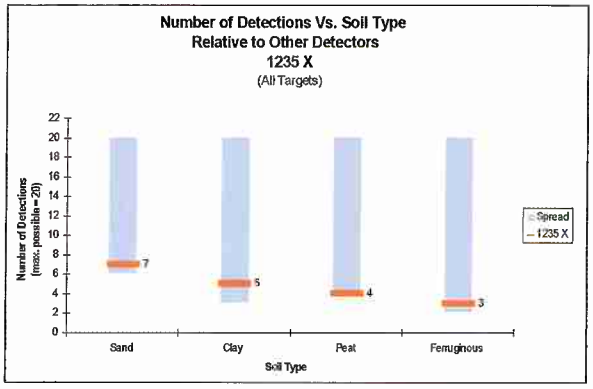
Field Tests – Croatia

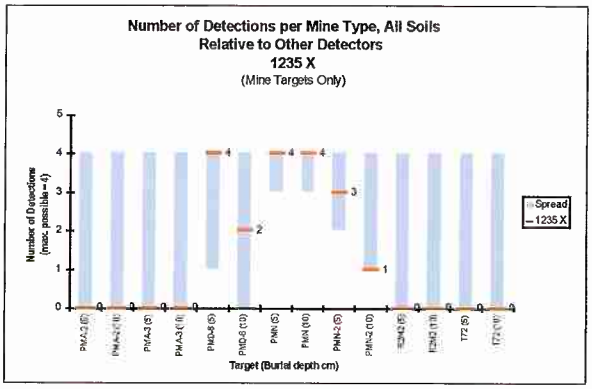




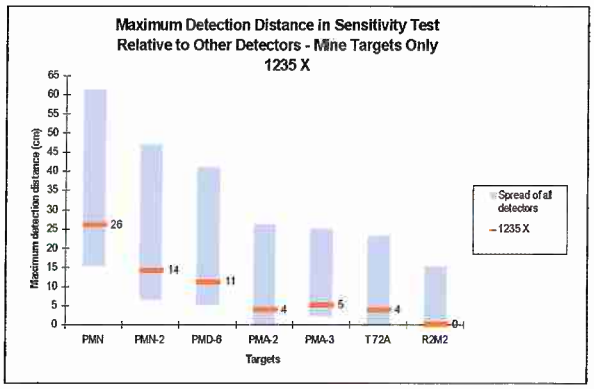
FISHER 1235 X

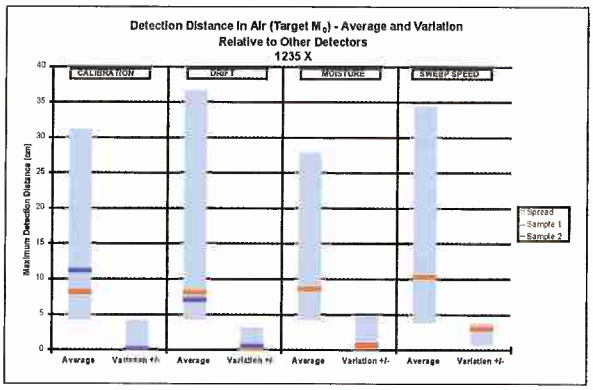
In-Soils Tests

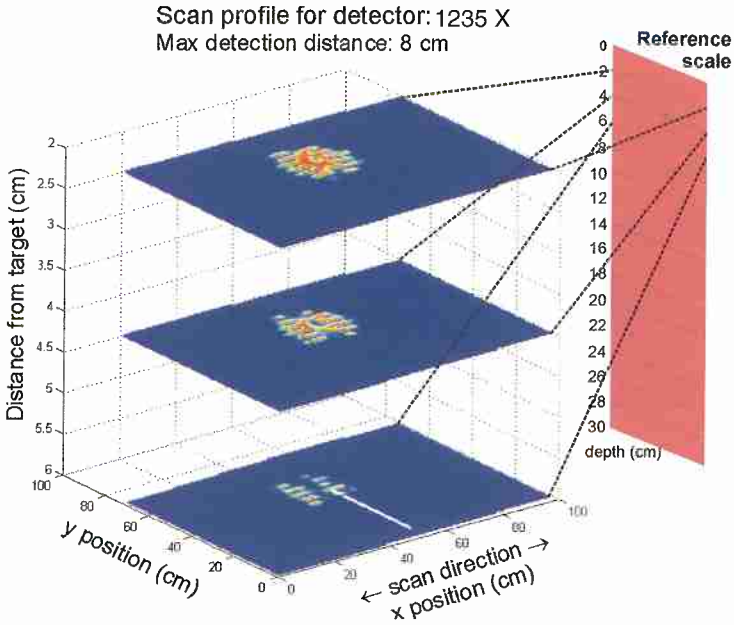




In-Air Tests







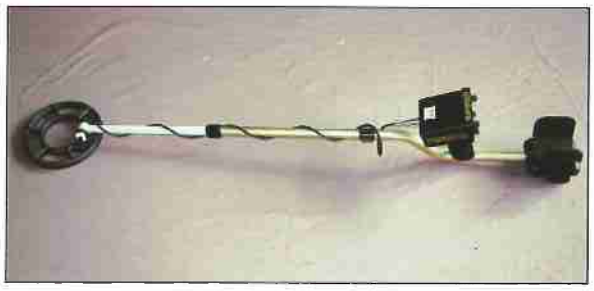
FISHER 1266 XB

Manufacturer Information:
Fisher Research Laboratory
200 West Willmott Road
Los Banos, CA 93635
USA
Telephone: +1 209 826 3292
Fax: +1 209 826 0416
http://www.fisherlab.com

IPPTC Cost: US $830

Weight/Dimensions:
Total Weight: 1.77 kg
Search head: 203 mm diameter
Boom/Shaft: 1092 - 1371 mm max.

Power Supply: 8 x 1.5V "AA" batteries

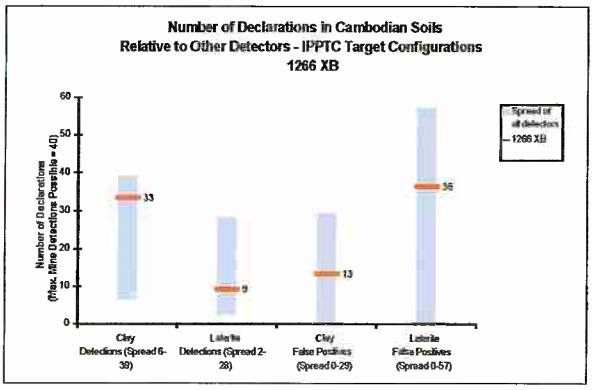


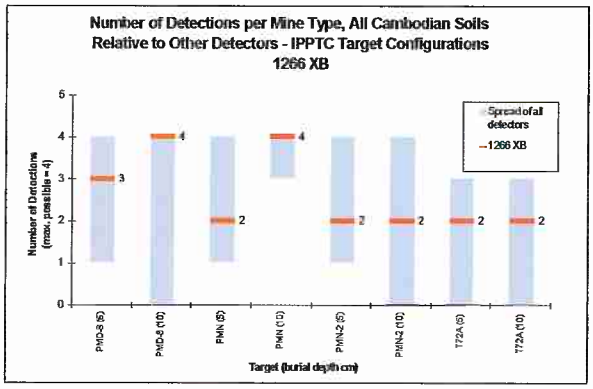
The 1266 XB is designed for the hobbyist. It features two independent discrimination modes for search and target identification, automatic ground adjust and tuning. It is similar to the other Fisher models evaluated (1235X and Impulse) in its operation

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

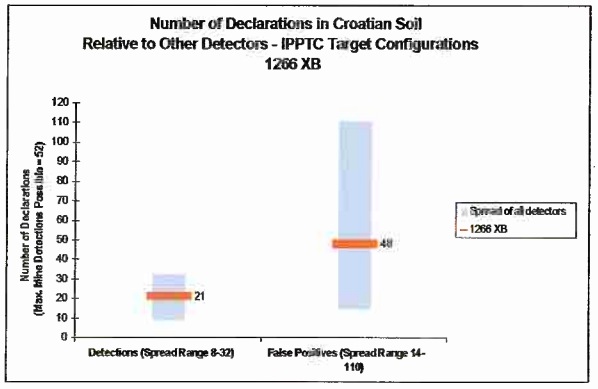
- Light and well balanced (good control box position)
- Easy to use
- Good pinpointing features
- Lack of robustness
- Not weather resistant
- No confidence or fault tones

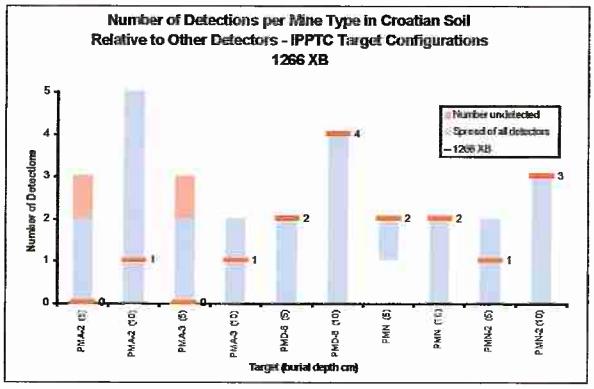
Field Tests – Cambodia





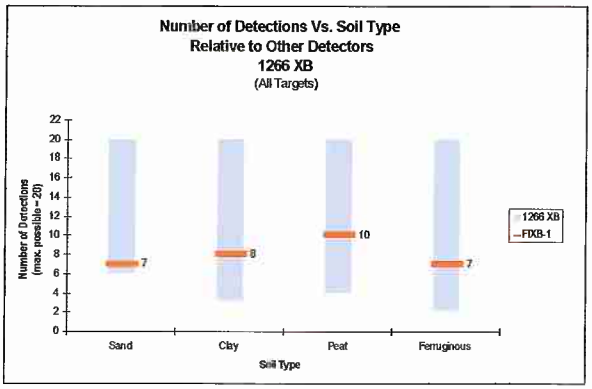
Field Tests – Croatia

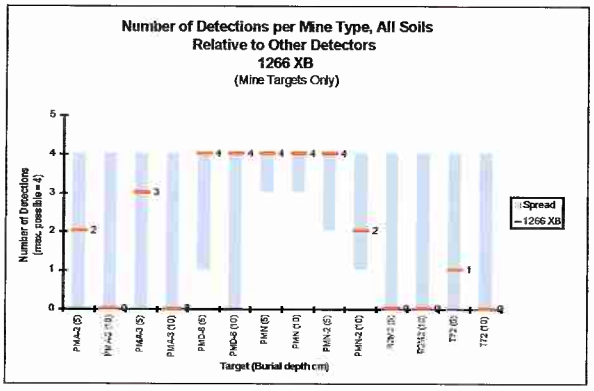




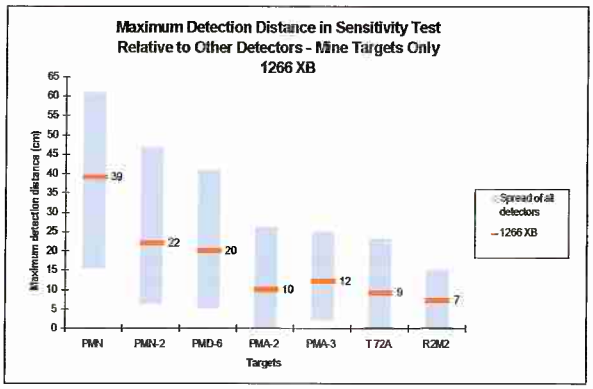
FISHER 1266 XB

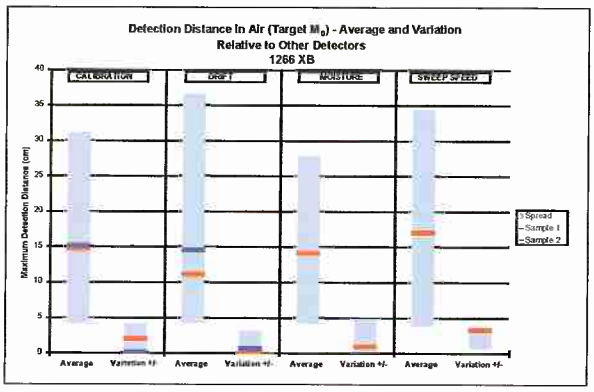
In-Soils Tests

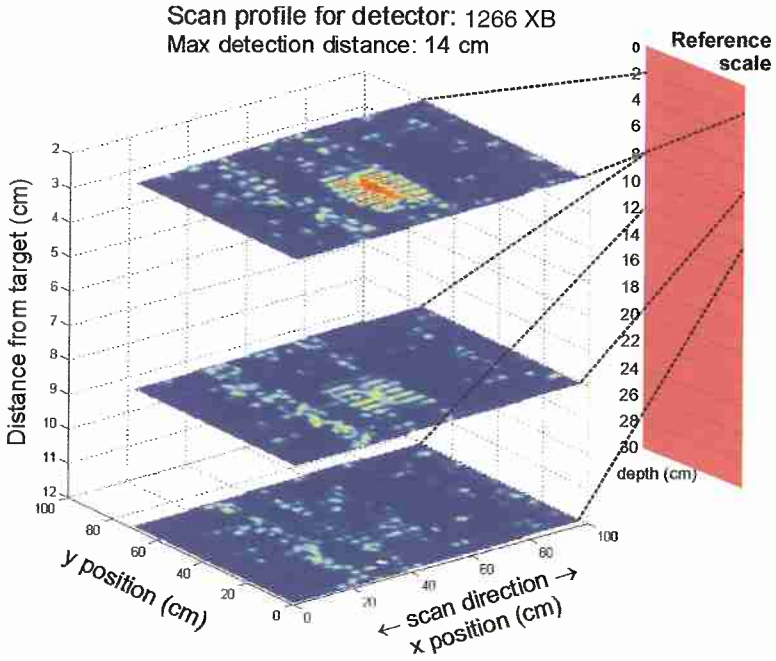




In-Air Tests







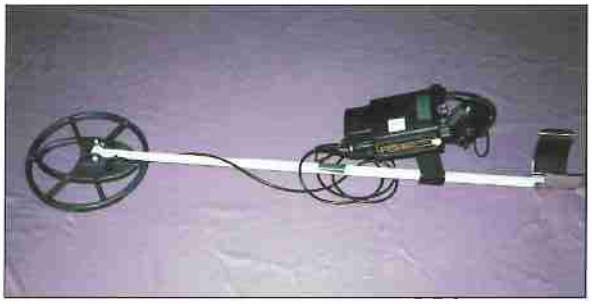
FISHER IMPULSE

Manufacturer Information:
Fisher Research Laboratory
200 West Willmott Road
Los Banos, CA 93635
USA
Telephone: +1 209 826 3292
Fax: +1 209 826 0416
http:// www.fisherlab.com

IPPTC Cost: US $820

Weight/Dimensions:
Total Weight: 2.49 kg
Search head: 266 mm diameter
Boom/Shaft: 787 - 1270 mm max.

Power Supply: 8 x 1.5V "AA" batteries

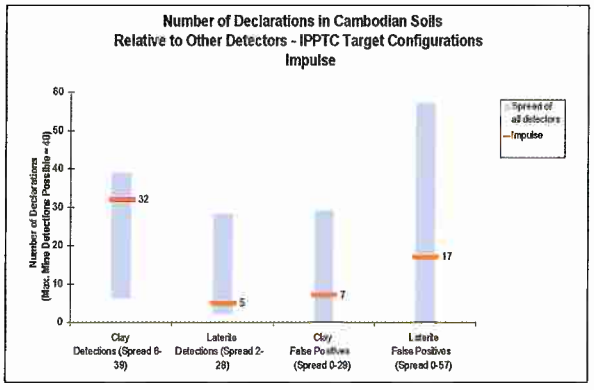


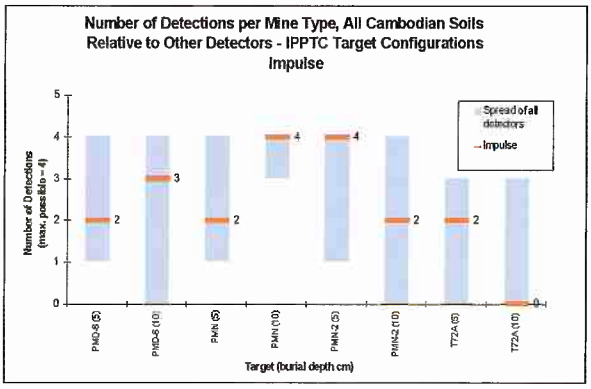
The Impulse is designed for the hobbyist. It utilizes a "no-motion" pulse induction method of metal detection, meaning that it is intended to respond to metal without moving the search head. The audio signal increases in pitch and volume as the center of the search head passes over a target.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

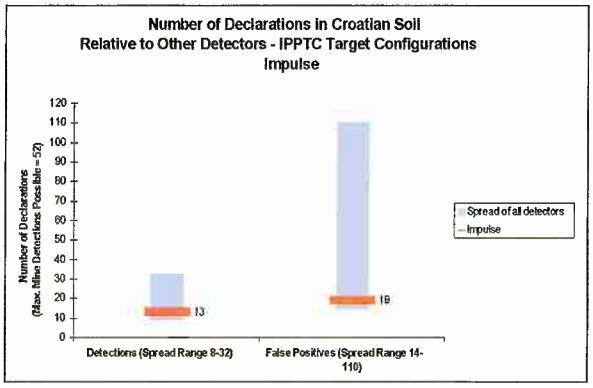
- Waterproof
- Versatility of control box position
- Light and east to easy
- No external speaker
- No field case
- No ground balance control

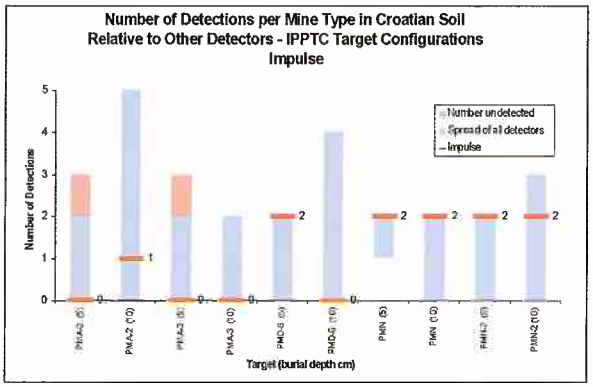
Field Tests – Cambodia





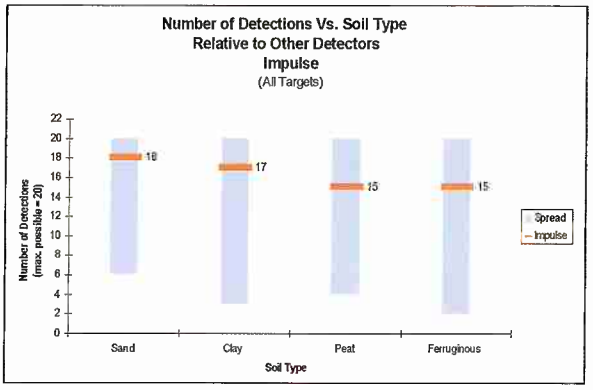
Field Tests – Croatia

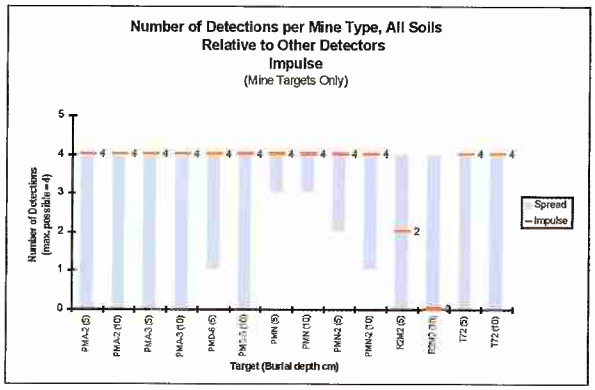




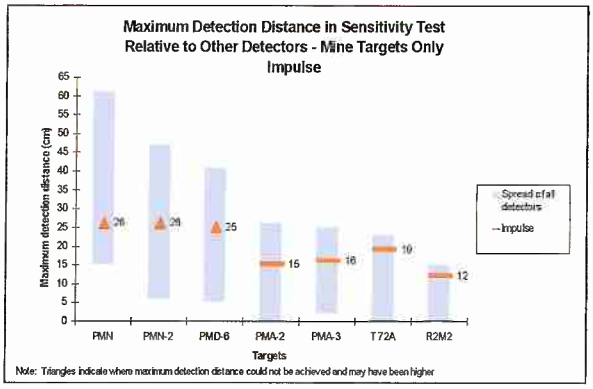
FISHER IMPULSE

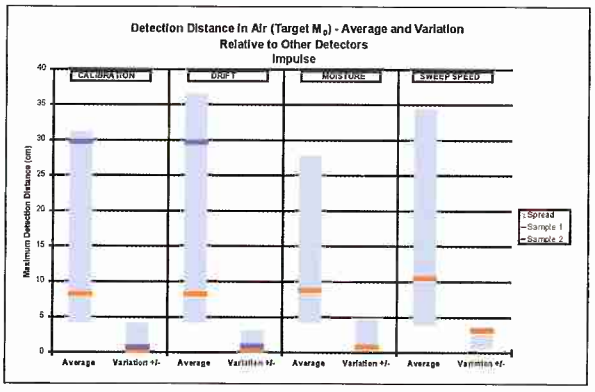
In-Soils Tests

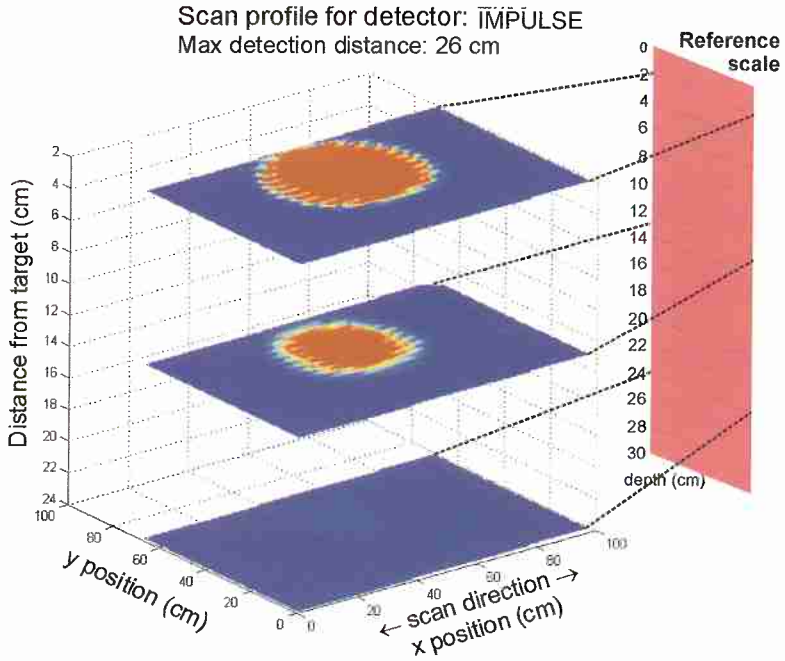




In-Air Tests







FOERSTER MINEX 2FD 4.400.01

Manufacturer Information:
Institut Dr. Foerster
In Laisen 70
Postfach 1564
D-72766 Reutlingen
Germany
Telephone: + 49 7121 140 354
Fax: +49 7121 140 335
http://www.foerstergroup.com/

IPPTC Cost: US $5,821

Weight/Dimensions:
Search head + telescopic wand: 1.85 kg
Electronics Box: 0.71 kg; 220 x 106 x 75 mm
Carrying harness + battery pack: 0.75 kg
Search head: 257 mm diameter
Telescopic wand: 800 - 1850 mm max.

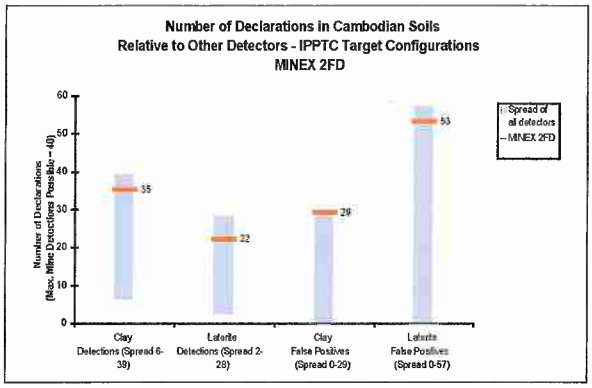
Power Supply: 3 x 1.5V "D"-cell batteries

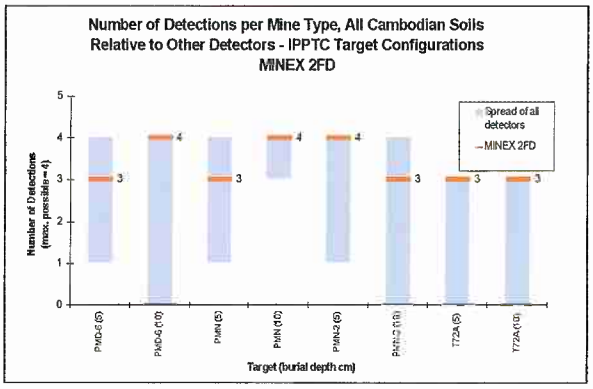
The MINEX 2FD was designed specifically for military use and deployment within harsh field environments. The search head emits electromagnetic energy at two simultaneous frequencies and operates in both the static detection mode and the dynamic detection mode. It utilizes a microprocessor for ground adaptation, sensitivity setting and fault detection. It incorporates a separate search tone for the two sides of the detector search head that is intended to support the pinpointing of targets.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

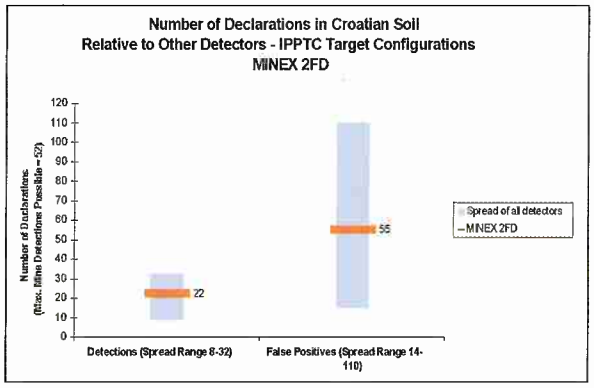
- Dual tone assists target pinpointing
- Good harness
- Good transit and field case
- Tuning sequence must be memorized
- Poorly labeled, membrane on/off switch
- No external speaker

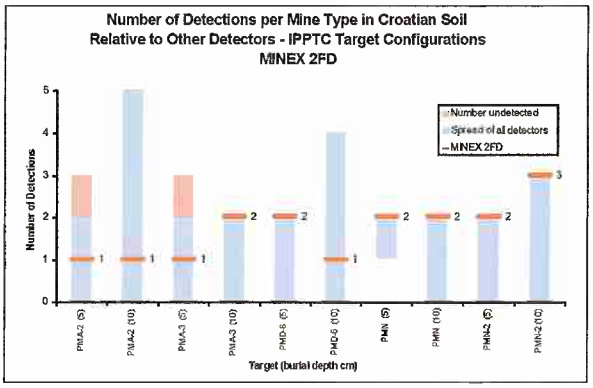
Field Tests – Cambodia





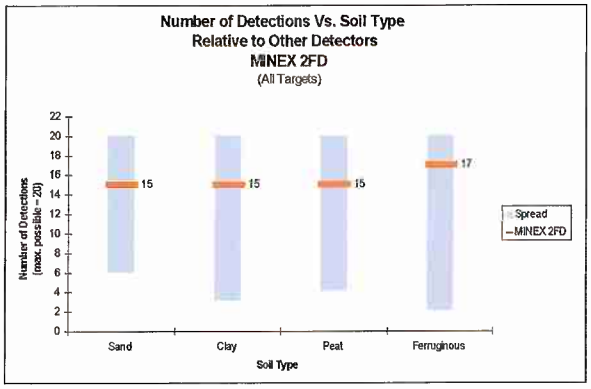
Field Tests – Croatia

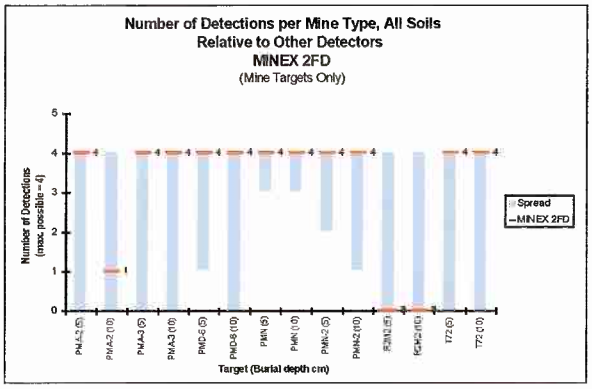




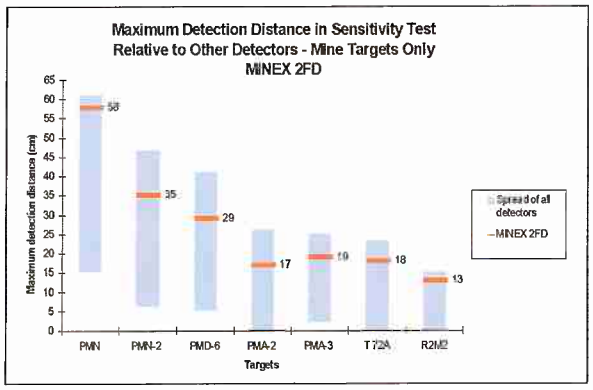
FOERSTER MINEX 2FD 4.400.01

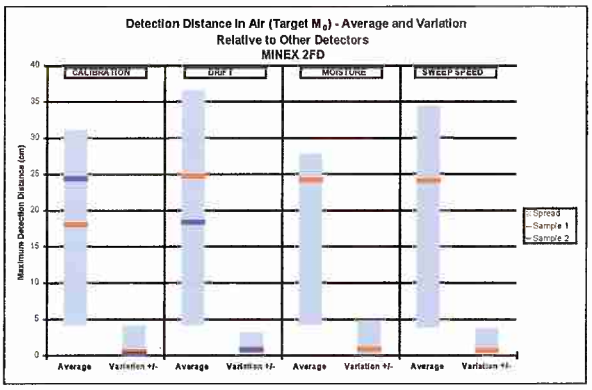
In-Soils Tests

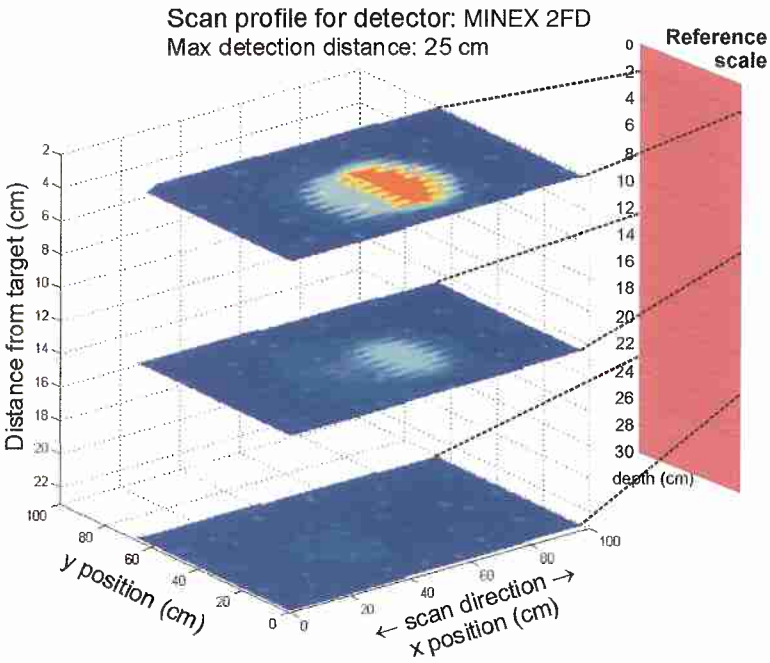




In-Air Tests







GIAT MODEL F1 (DHPM-1A)

Manufacturer Information:
Giat Industries
13, route de la Minière
F-78034 Versailles Cedex
France
Telephone: +33 1 30 97 37 37
Fax : +33 1 30 97 39 00
http://www.giat-industries.fr

IPPTC Cost: US $3,250

Weight/Dimensions:
Total weight: 3.6 kg
Telescopic wand: 850 - 1520 mm max.

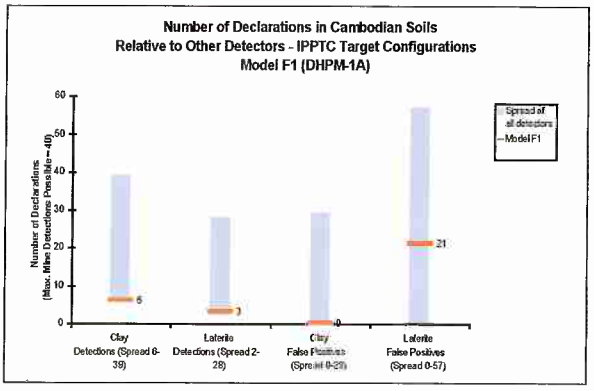
The DHPM-1A is an older generation military mine detector. It provides visual and audio indications of suspected metal objects. It includes a cover for the detection head for use in fluctuating terrain temperatures, such as shady and sunlit areas.

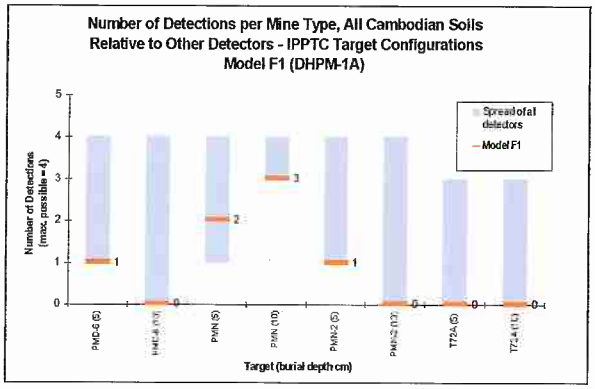
Power Supply: 6 x 1.5V "AA" batteries

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

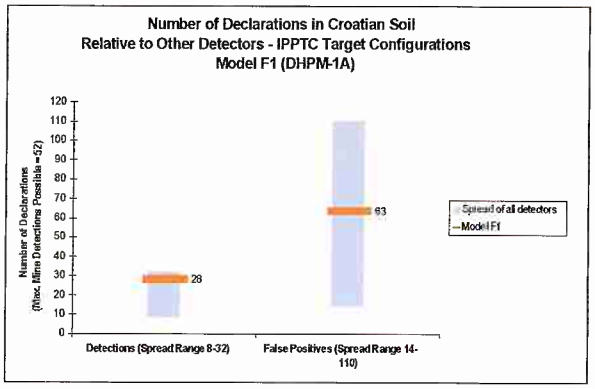
- Rugged, waterproof transit case
- Shoulder strap
- Capable of use in shallow water
- Lack of ruggedness in head/shaft and cable/head connections
- Poor documentation/manual

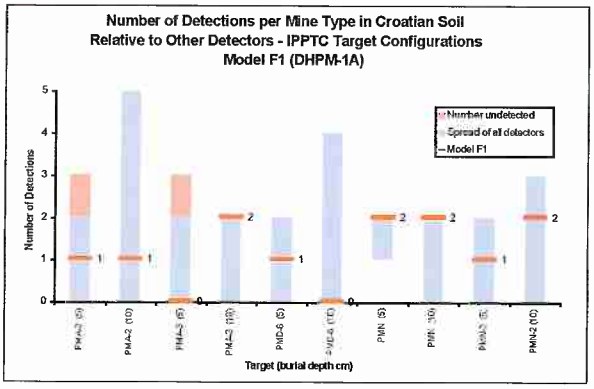
Field Tests – Cambodia





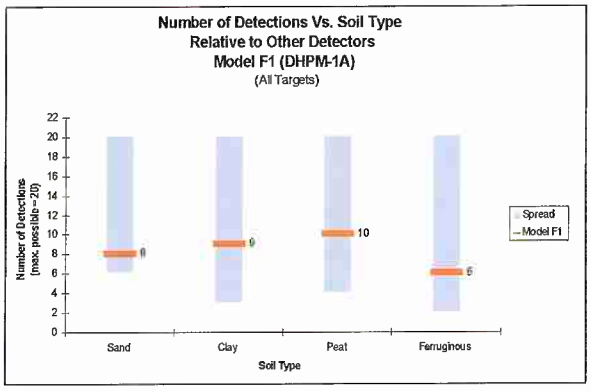
Field Tests – Croatia

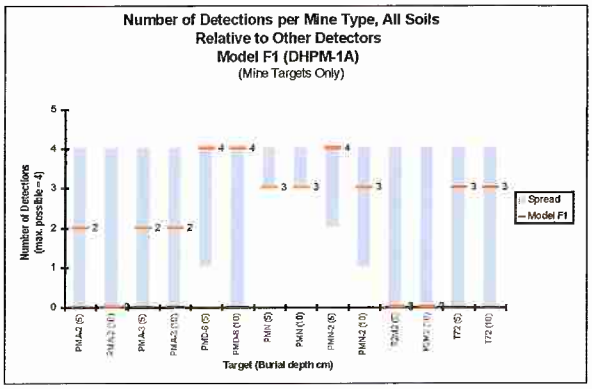




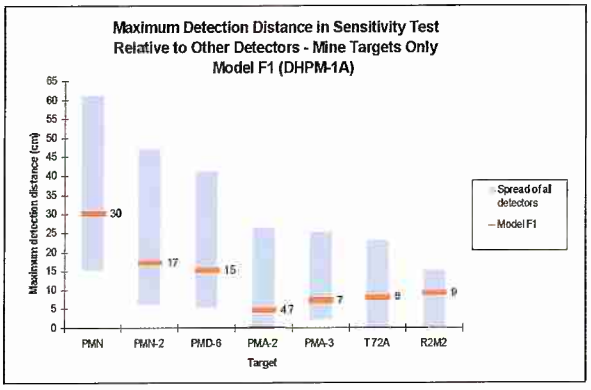
GIAT MODEL F1 (DHPM-1A)

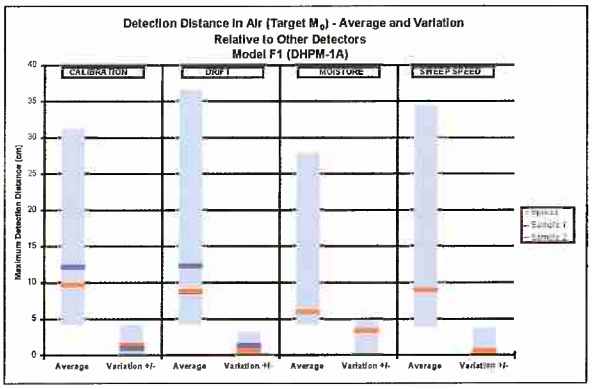
In-Soils Tests



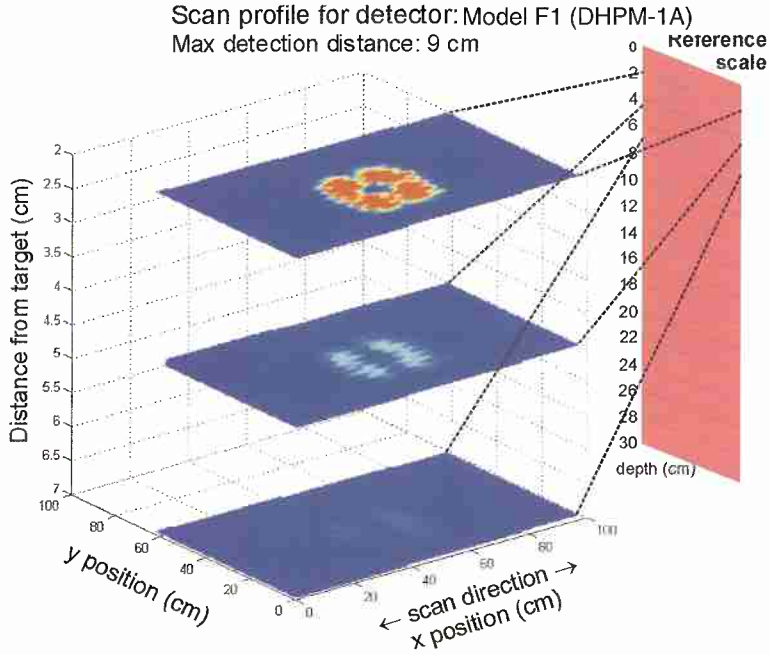


In-Air Tests





Scan profile for detector: Model F1 (DHPM-1A)
Max detection distance: 9 cm



GUARTEL MD2000 (Long Probe)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,457 (All three MD2000 sensors)

Weight/Dimensions:
Electronics Box: 1.9 kg; 250 x 172 x 42 mm
Probe Length: 1000 mm
Probe weight: 880 g

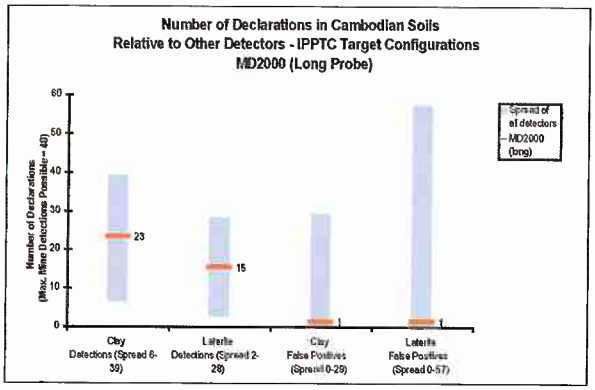
Power Supply: 20 x 1.5 V "AA" batteries

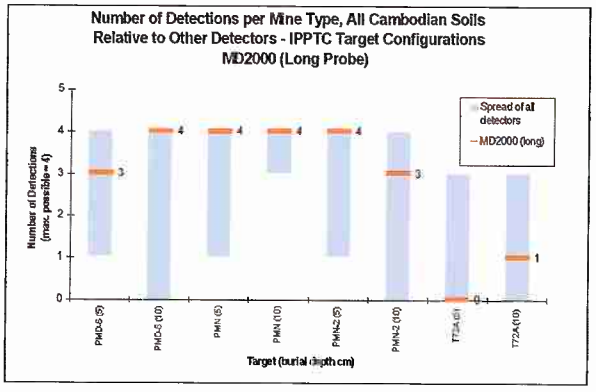
The MD 2000 operates on the pulse induction principle. It is available in full pack with the round search head and two search probes included or it can be purchased without the probes. It is completely automatic in operation and requires no tuning for changing ground conditions. All three sensor heads provided were evaluated in this test and results for each are presented separately.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

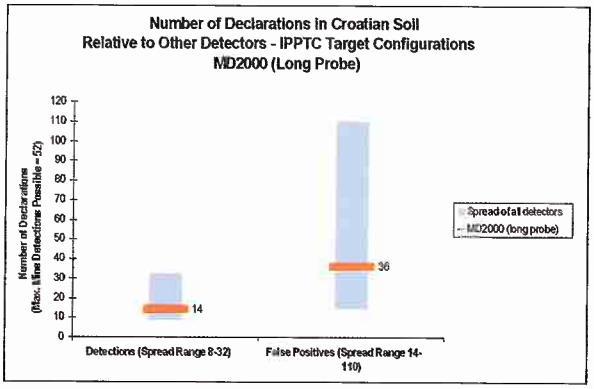
- 3 Different heads included
- Detailed trouble-shooting guide
- Robust militarised equipment
- Bottom-heavy and awkward wrist angle during standing operation
- Insecure mounting of the control box on the shoulder strap
- Absence of a volume control for the speaker and/or earpiece

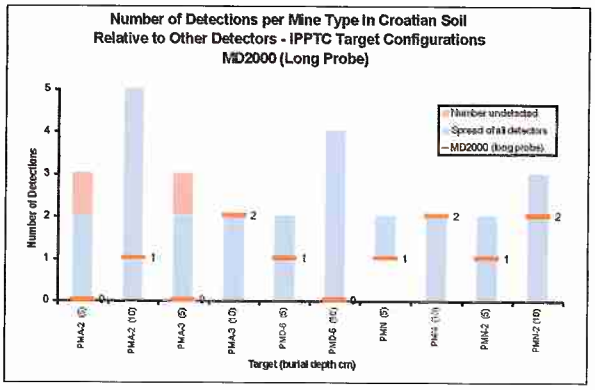
Field Tests – Cambodia





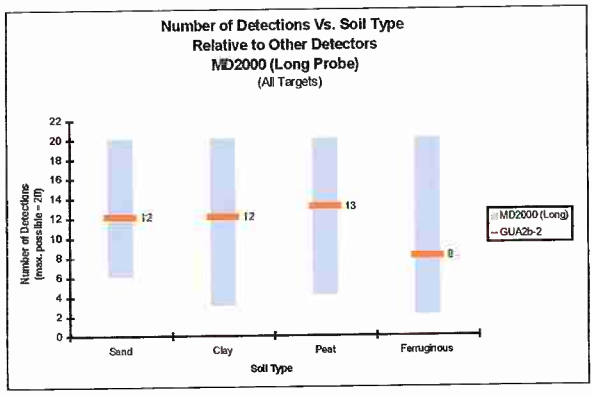
Field Tests – Croatia

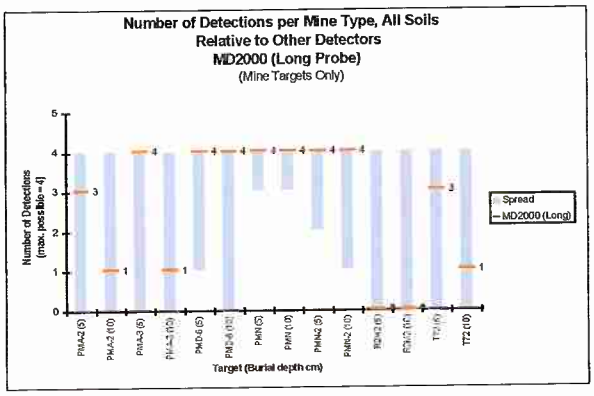




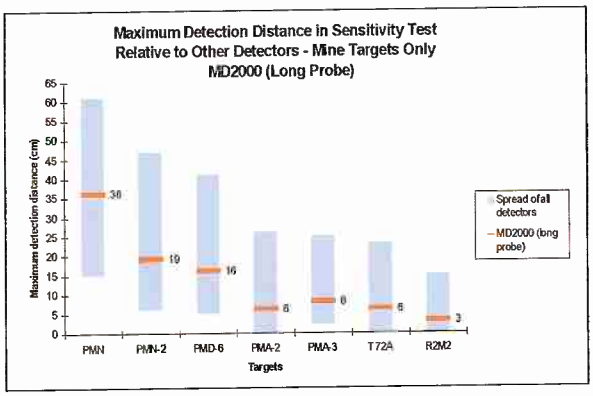
GUARTEL MD2000 (Long Probe)

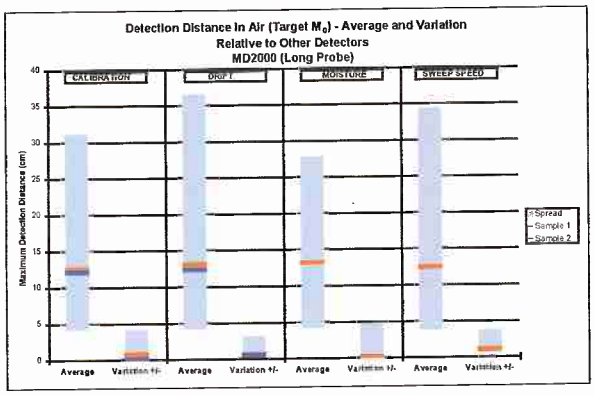
In-Soils Tests

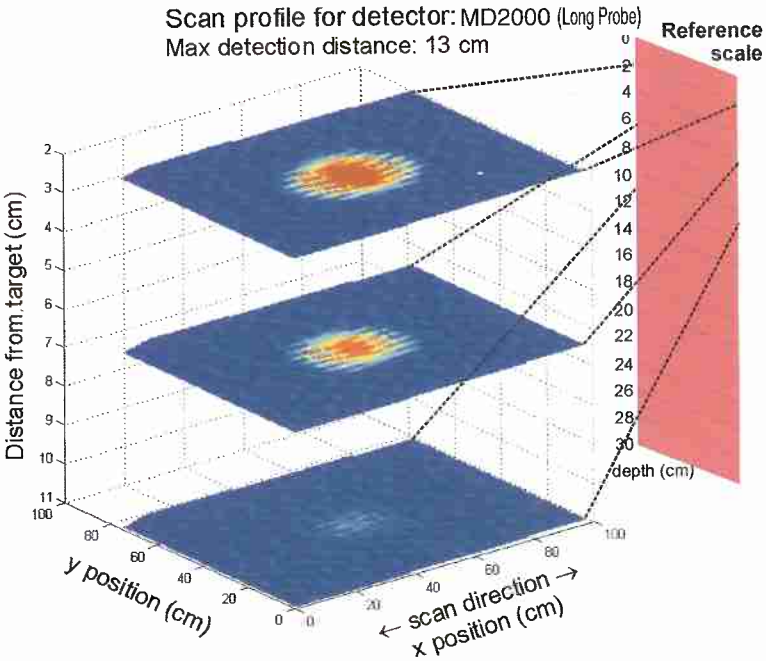




In-Air Tests







GUARTEL MD2000 (Round Head)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,457 (All three MD2000 sensors)

Weight/Dimensions:
Electronics Box: 1.9 kg; 250 x 172 x4 2 mm
Search Head: 980 g; 300 mm diameter
Boom length: 860mm – 1,600 mm max.

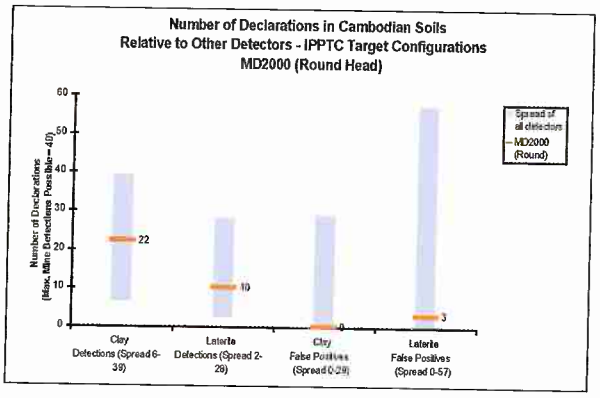
Power Supply: 20 x 1.5 V "AA" batteries

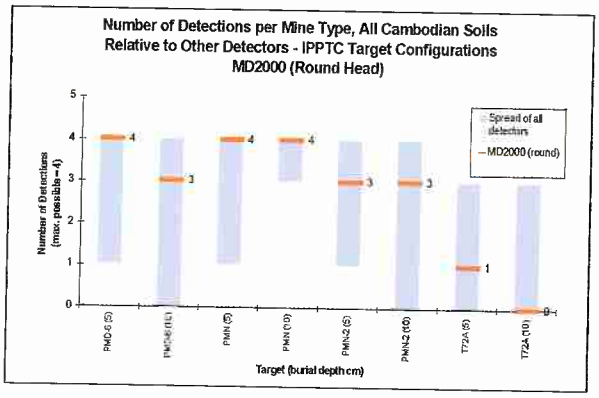
The MD 2000 operates on the pulse induction principle. It is available in full pack with two search probes included with the round search head or it can be purchased without the probes. It is completely automatic in operation and requires no tuning for changing ground conditions. All three sensor heads provided were evaluated in this test and results for each are presented separately.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

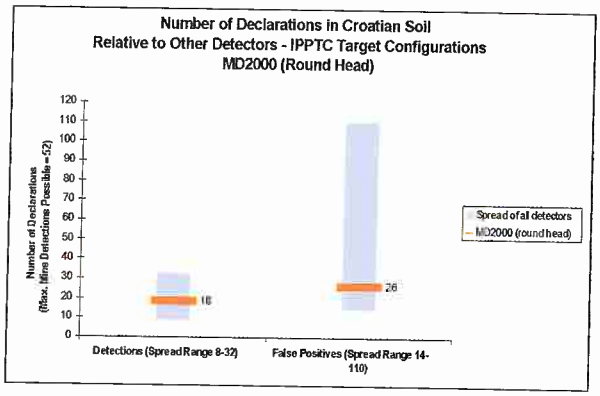
- 3 Different heads included
- Detailed trouble-shooting guide
- Robust militarized equipment
- Bottom-heavy and awkward wrist angle during standing operation
- Insecure mounting of the control box on the shoulder strap
- Absence of a volume control for the speaker and/or earpiece

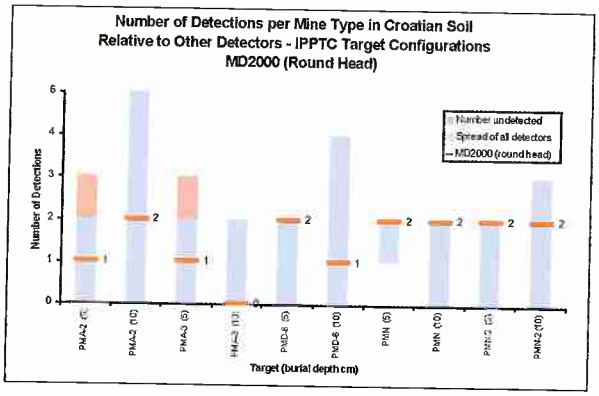
Field Tests – Cambodia





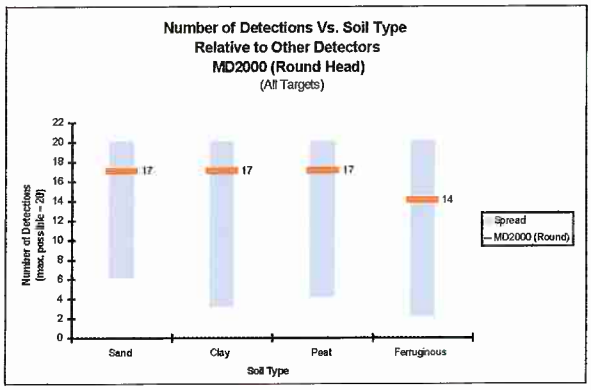
Field Tests – Croatia

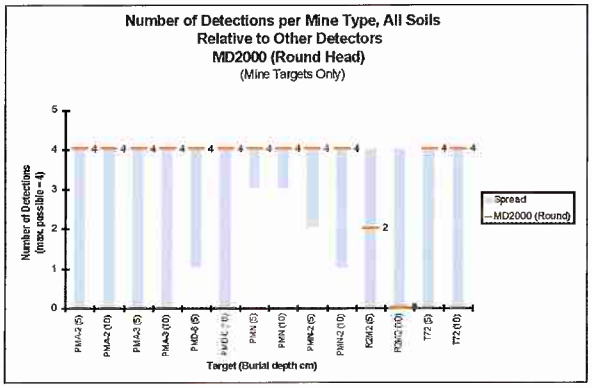




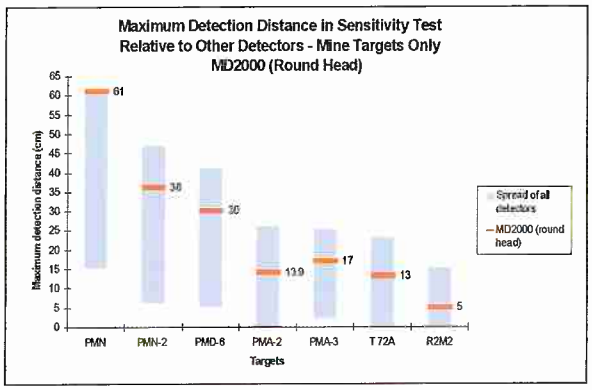
GUARTEL MD2000 (Round Head)

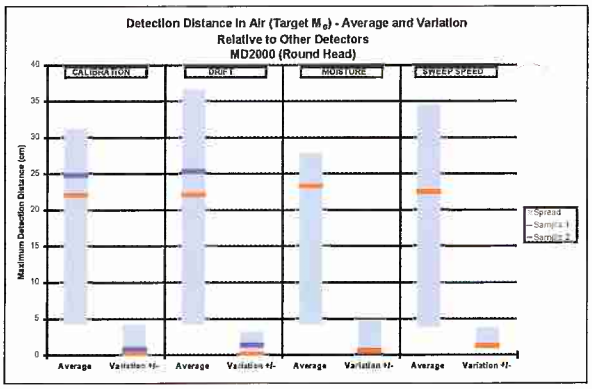
In-Soils Tests

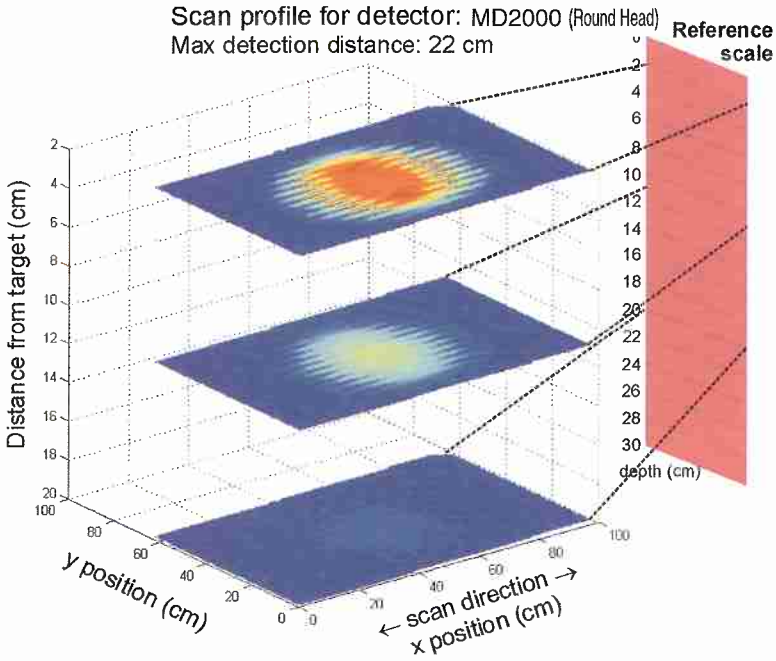




In-Air Tests







GUARTEL MD2000 (Short Probe)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,457 (All three MD2000 sensors)

Weight/Dimensions:
Electronics Box: 1.9 kg; 250 x 172 x 42 mm
Probe Length: 500 mm
Probe weight: 600 g

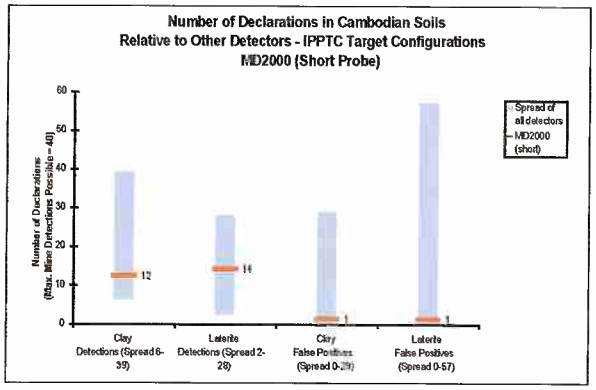
Power Supply: 20 x 1.5 V "AA" batteries

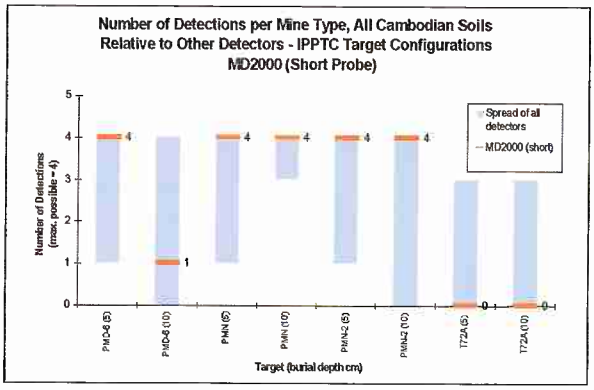
The MD 2000 operates on the pulse induction principle. It is available in full pack with two search probes included with the round search head or it can be purchased without the probes. It is completely automatic in operation and requires no tuning for changing ground conditions. All three sensor heads provided were evaluated in this test and results for each are presented separately.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

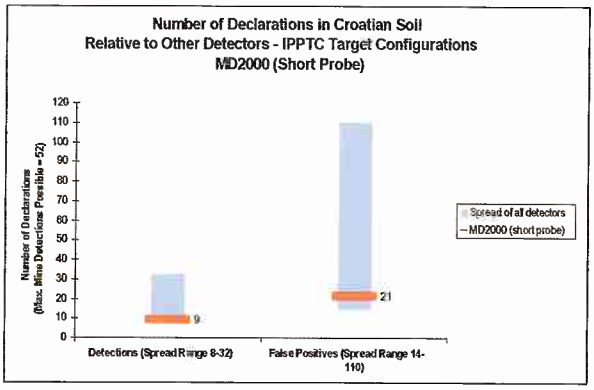
- 3 Different heads included
- Detailed trouble-shooting guide
- Robust militarized equipment
- Bottom-heavy and awkward wrist angle during standing operation
- Insecure mounting of the control box on the shoulder strap
- Absence of a volume control for the speaker and/or earpiece

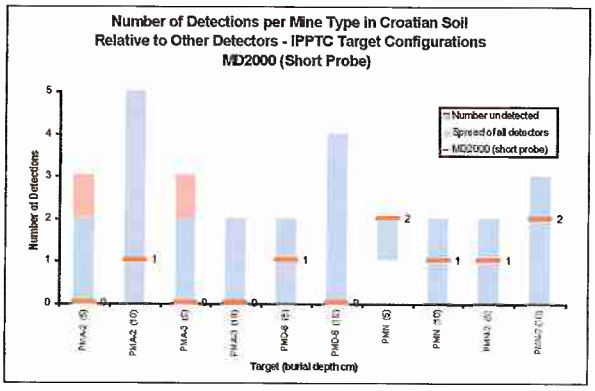
Field Tests – Cambodia





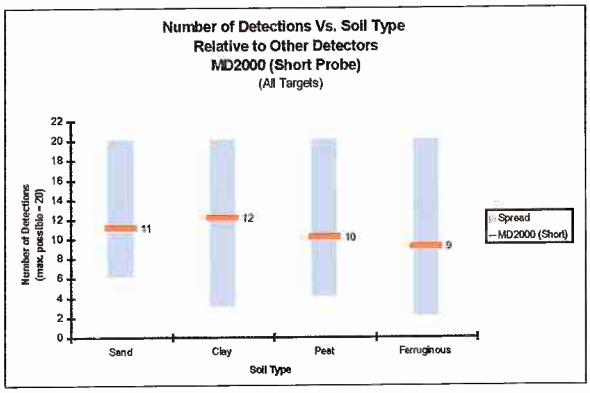
Field Tests – Croatia

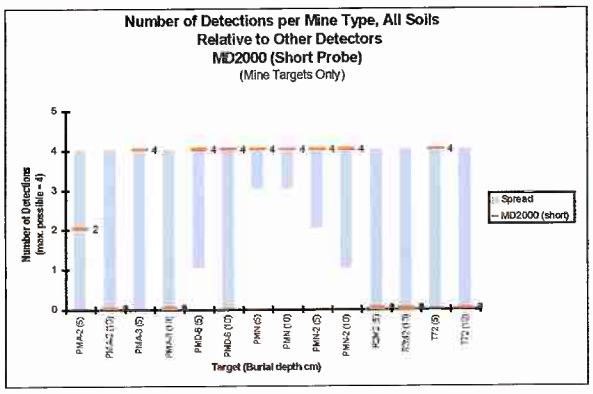




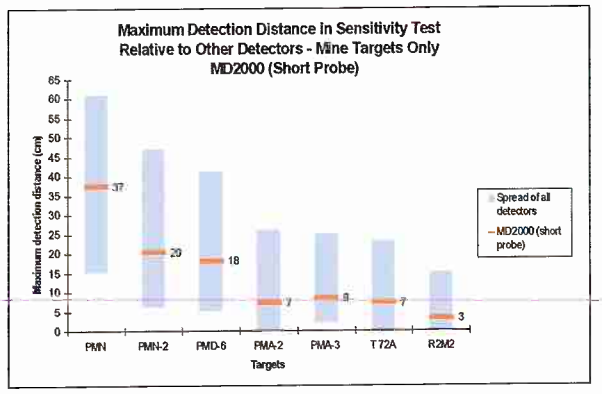
GUARTEL MD2000 (Short Probe)

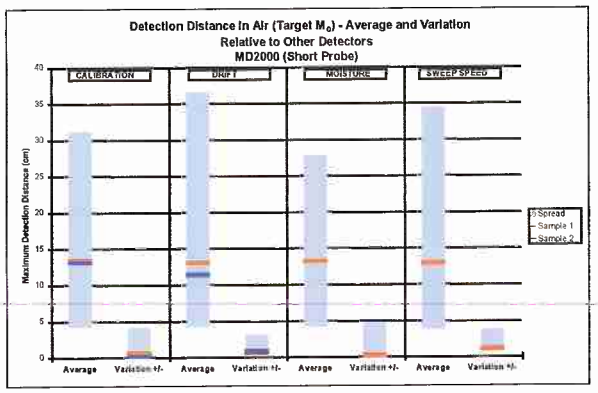
In-Soils Tests

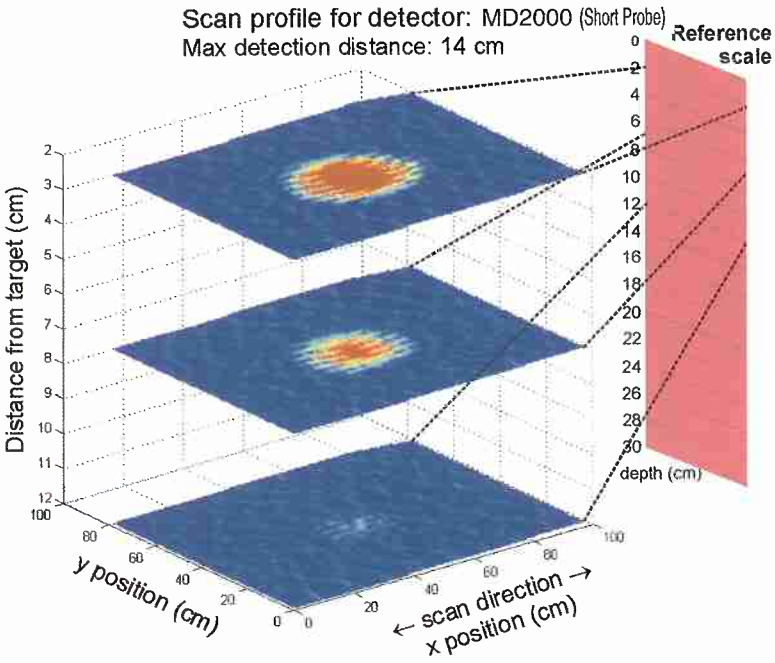




In-Air Tests







GUARTEL MD4

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $3,861

Weight/Dimensions:
Total weight: 2170 g
Total length: 1221 mm
Diameter: 34 mm

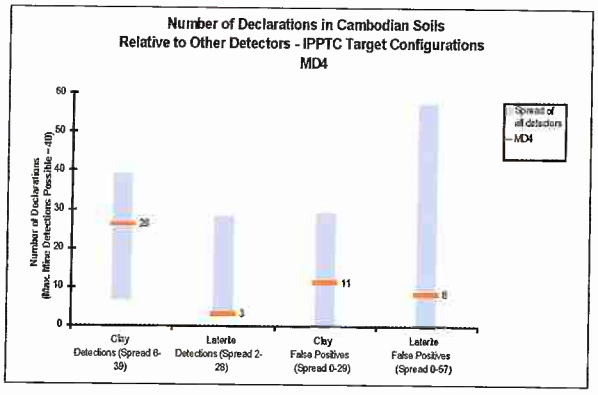
Power Supply: 4 x 1.5 V "C" size batteries

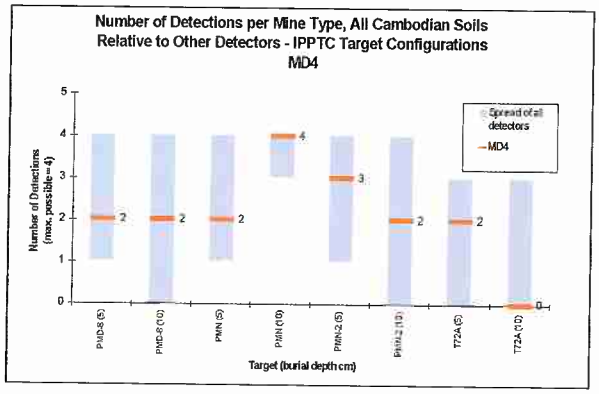
The MD4 is a probe-shaped detector. The operating principle is multi-sampling pulse induction. Detection indication is by built in speaker or earphone. The electronics, controls, detection head and batteries are all contained within the hand-held probe. It is designed specifically for EOD operations but the design allows it to be used in a wide range of conditions and postures.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

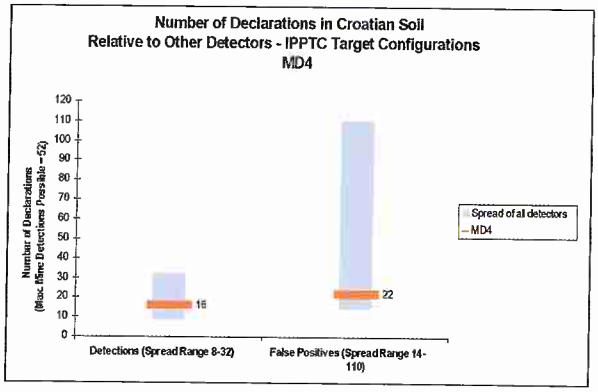
- Easy to operate
- Lightweight
- Rugged and waterproof
- No volume control or ground balance
- Small scan width requiring shallow sweep pattern
- Plastic battery pack

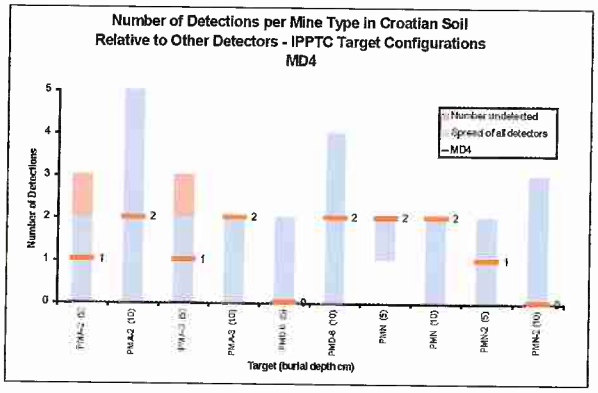
Field Tests – Cambodia





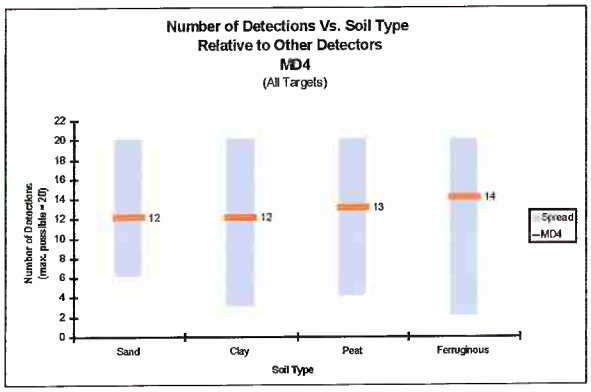
Field Tests – Croatia

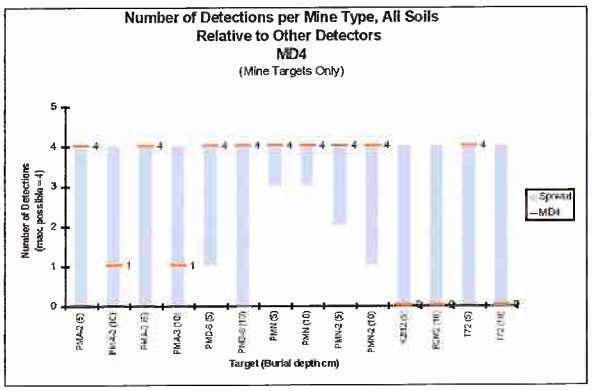




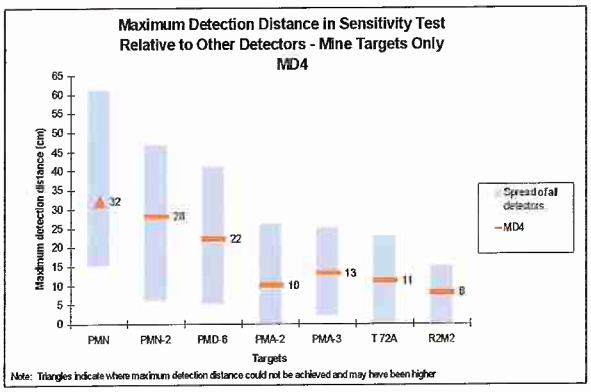
GUARTEL MD4

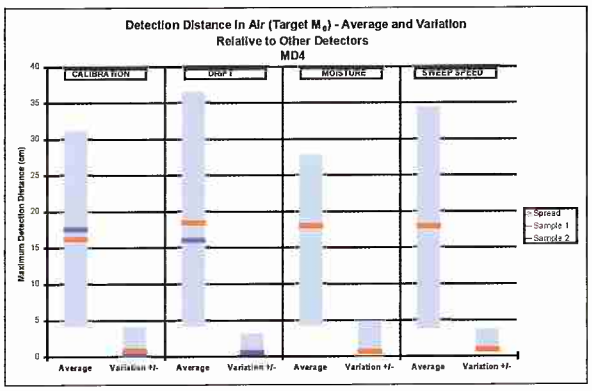
In-Soils Tests

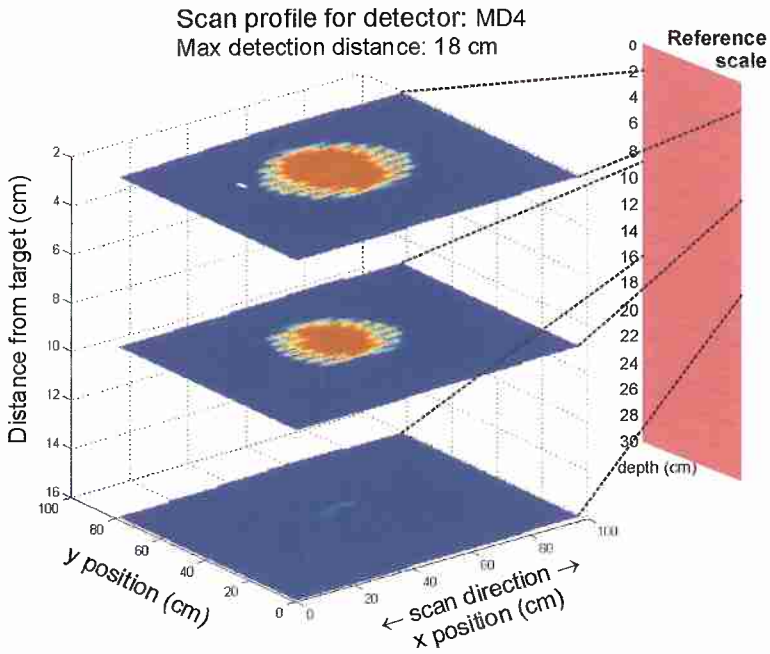




In-Air Tests







GUARTEL MD8 (Oval Head)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,386 (All three MD8 sensors)

Weight/Dimensions:
Total weight: 1790 g
Control Unit: 1100 g; 470 mm
Search Head: 194 x 267 mm
Length: 635 mm

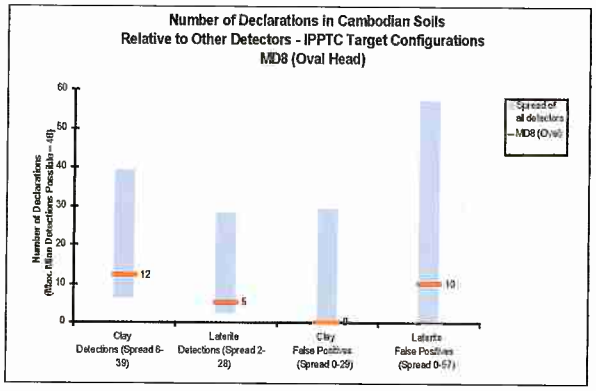
Power Supply: 2 x 1.5 V "D" size batteries

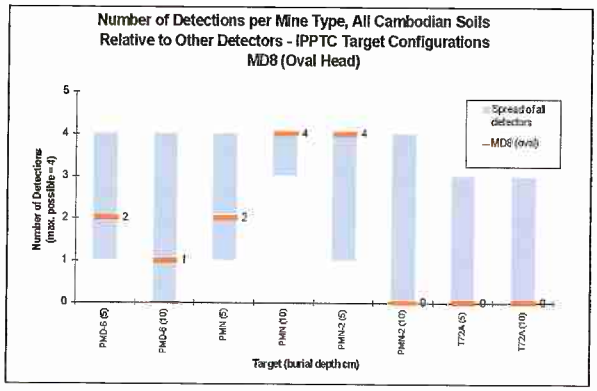
The MD8 is based on high-speed pulse induction technology. The search head is divided by a 'sighting bar' that produces a null in the audio signal, thus intending to aid in the pinpointing of a target. The electronics, controls, search head, and batteries are contained within one single unit. All three sensor heads provided were evaluated in this test and results for each sensor are presented separately. This sensor head is preliminary production with reliability concerns.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

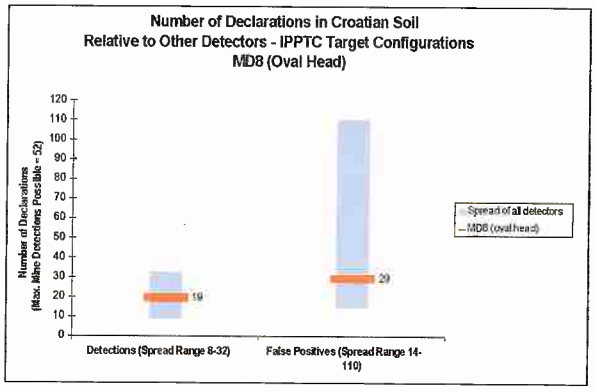
- Simple design
- Rugged and waterproof
- Three alternative sensor heads offers versatility
- Volume could not be reduced sufficiently for headphone use
- Switches are not labeled
- No low battery warning when using rechargeable batteries

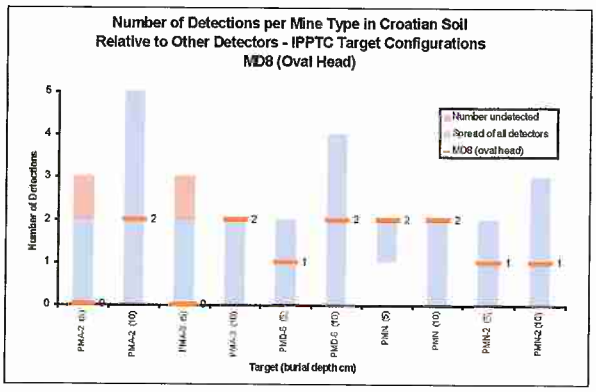
Field Tests – Cambodia





Field Tests – Croatia



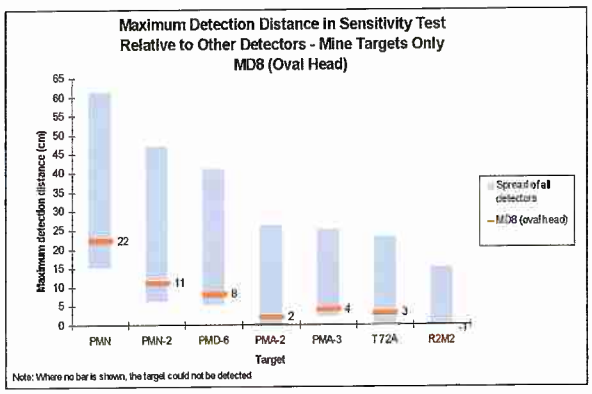


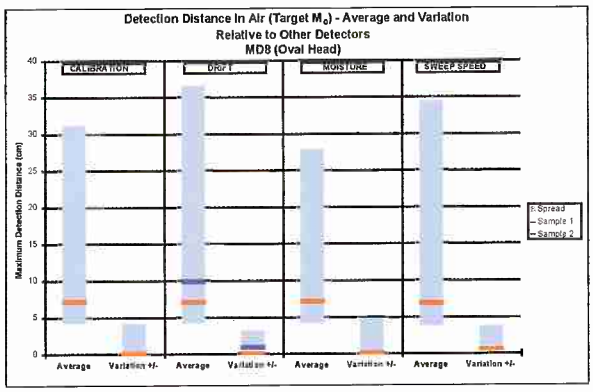
GUARTEL MD8 (Oval Head)

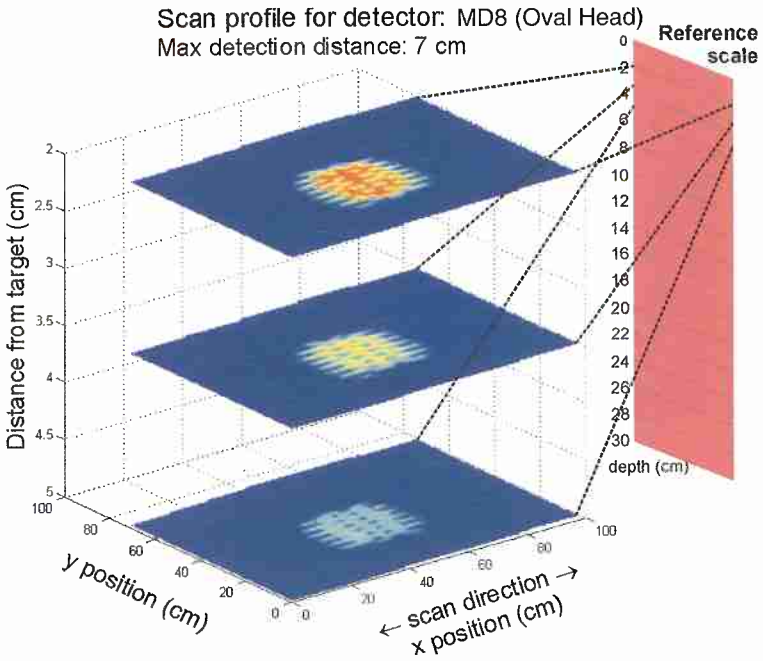
In-Soils Tests

(**Note:** No in-soil test results are presented for this detector. This is due to concerns over the reliability of the MD-8 detectors fitted with the oval search coil which prevented a full set of results being taken for this model).

In-Air Tests







GUARTEL MD8 (Probe)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,386 (All three MD8 sensors)

Weight/Dimensions:
Total weight: 1790 g
Control Unit: 1100 g; 470 mm
Probe: 690 g; 660 mm

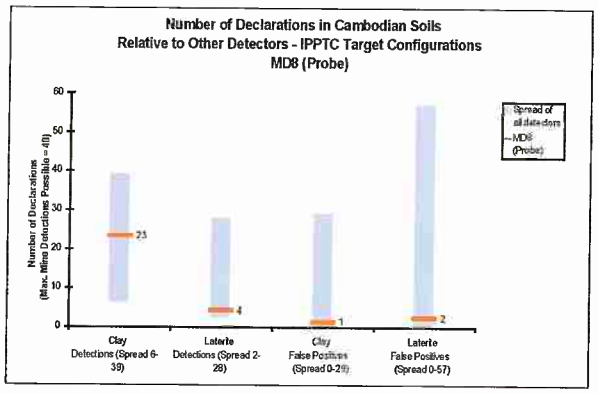
Power Supply: 2 x 1.5 V "D" size batteries

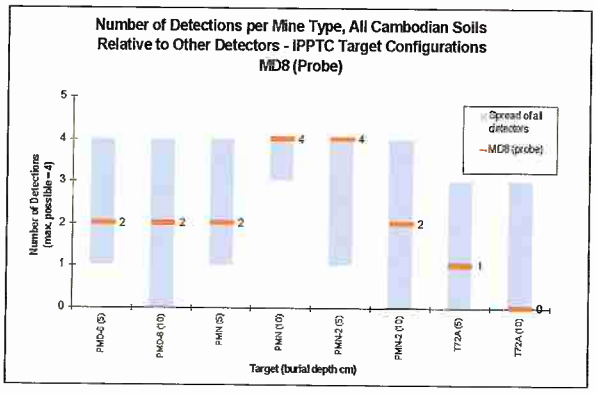
The MD8 is based on high-speed pulse induction technology. The electronics, controls, search head, and batteries are contained within one single unit. All three sensor heads provided were evaluated in this test and results for each sensor are presented separately.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

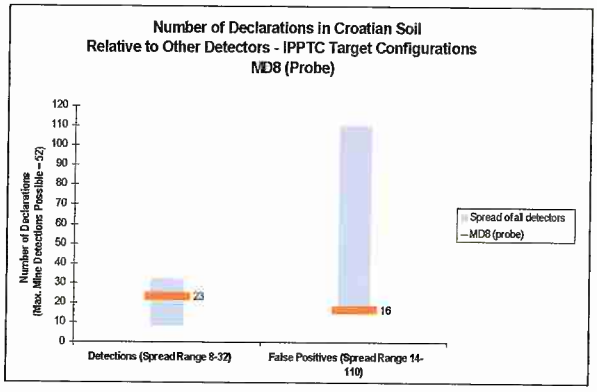
- Simple design
- Rugged and waterproof
- Three alternative sensor heads offers versatility
- Volume could not be reduced sufficiently for headphone use
- Switches are not labeled
- No low battery warning when using rechargeable batteries

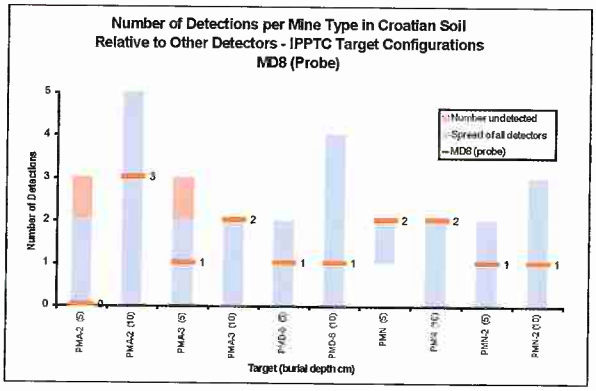
Field Tests – Cambodia





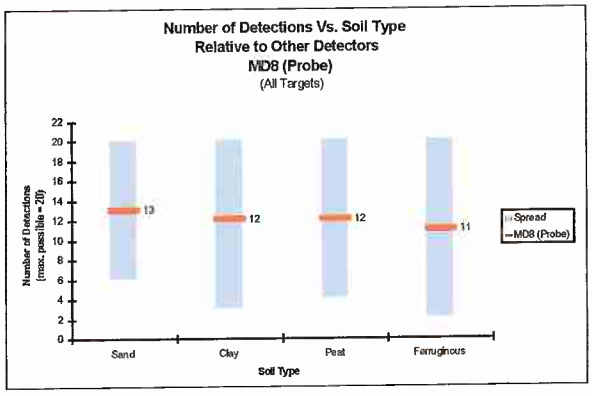
Field Tests – Croatia

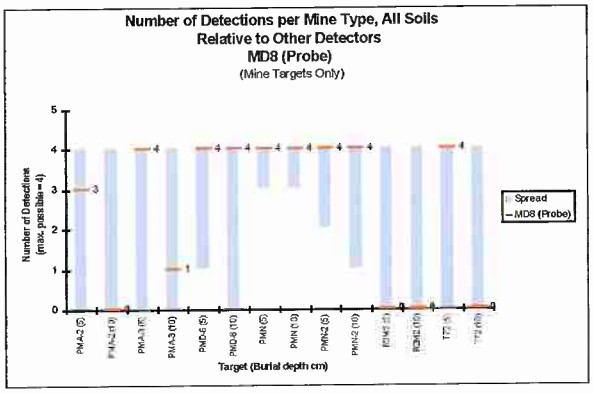




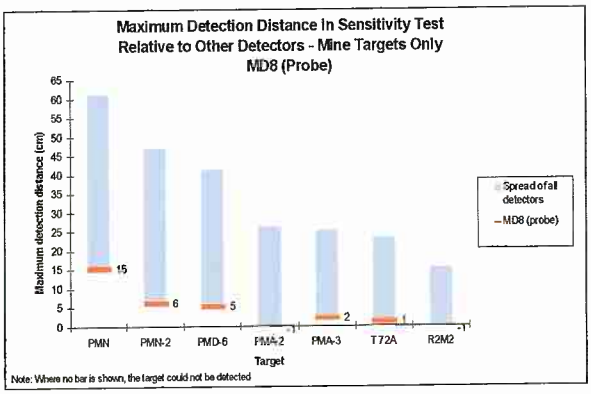
GUARTEL MD8 (Probe)

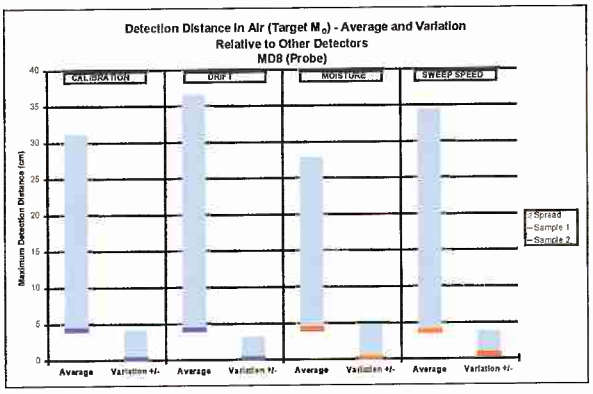
In-Soils Tests

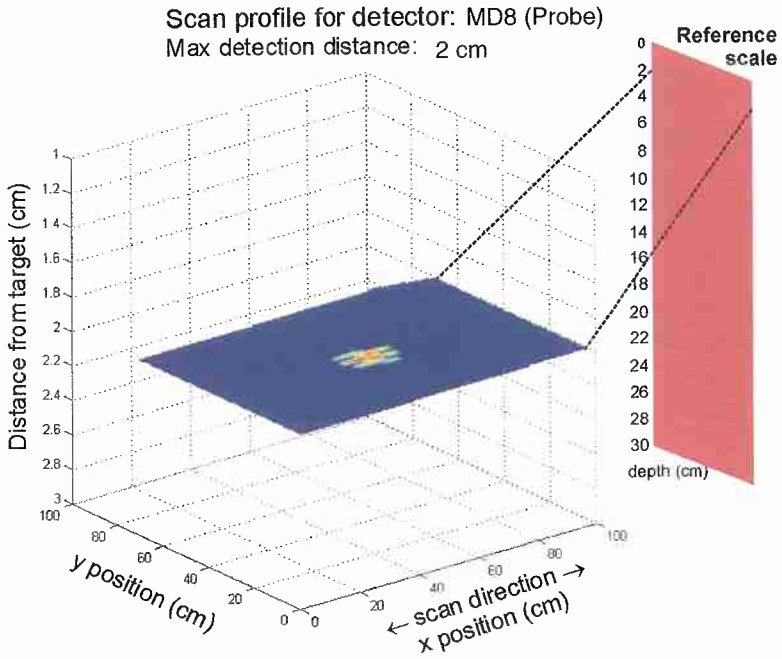




In-Air Tests







GUARTEL MD8 (Round Head)

Manufacturer Information:
Guartel Ltd
16 Alliance Court
Alliance Road
London W3 0RB
England
Telephone: +44 208 896 0222
Fax: +44 208 896 0333
http://www.guartel.com

IPPTC Cost: US $2,386 (All three MD8 sensors)

Weight/Dimensions:
Total weight: 2.4 kg
Control Unit: 1100 g; 470 mm
Search Head: 1100 g; 300 mm diameter
Length: 1120-1560 mm max.

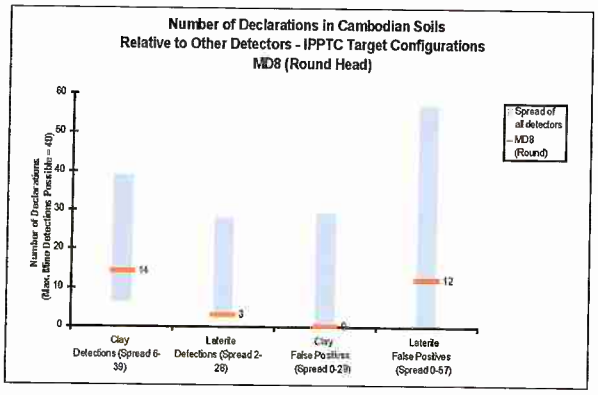
Power Supply: 2 x 1.5 V "D" size batteries

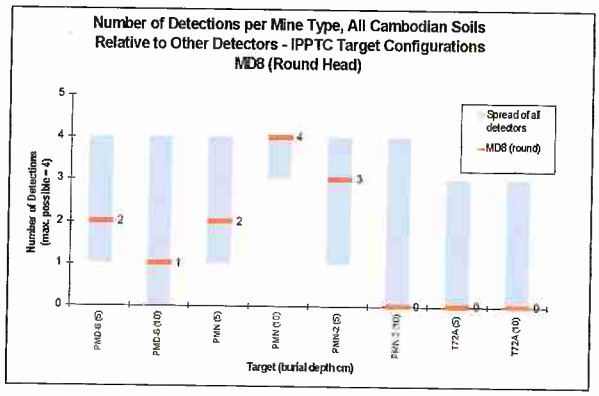
The MD8 is based on high-speed pulse induction technology. The search head is divided by a 'sighting bar' that produces a null in the audio signal, thus aiding in the pinpointing of a target. The electronics, controls, search head, and batteries are contained within one single unit. All three sensor heads provided were evaluated in this test and results for each sensor are presented separately.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

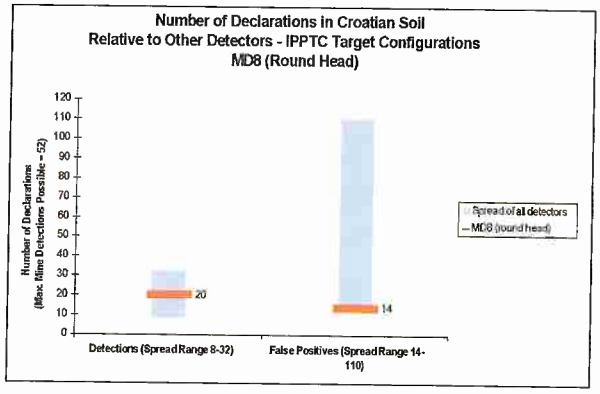
- Simple design
- Rugged and waterproof
- Three alternative sensor heads offers versatility
- Volume could not be reduced sufficiently for headphone use
- Switches are not labeled
- No low battery warning when using rechargeable batteries

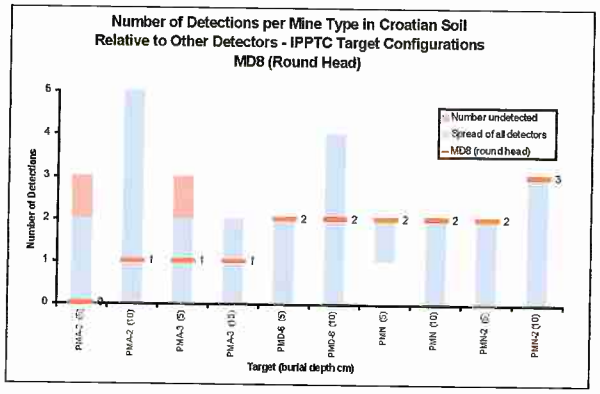
Field Tests – Cambodia





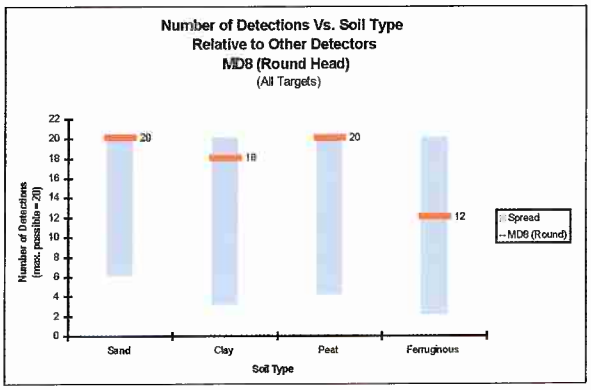
Field Tests – Croatia

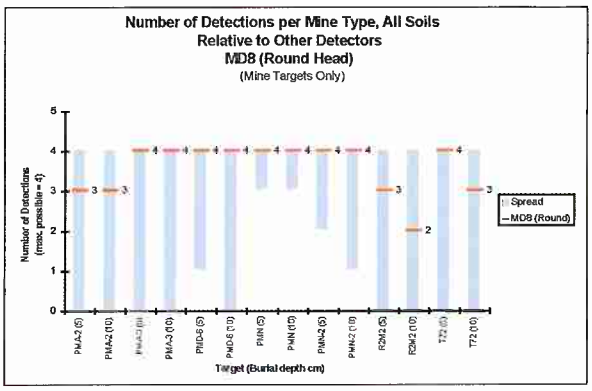




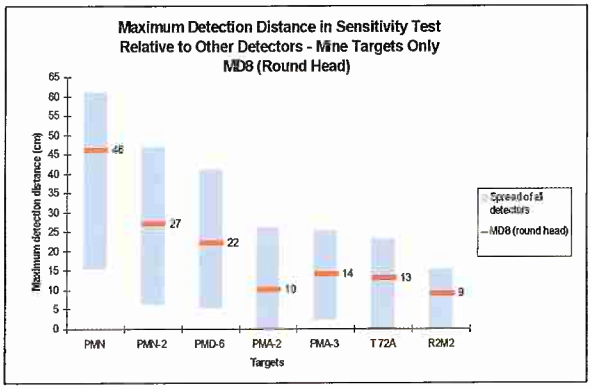
GUARTEL MD8 (Round Head)

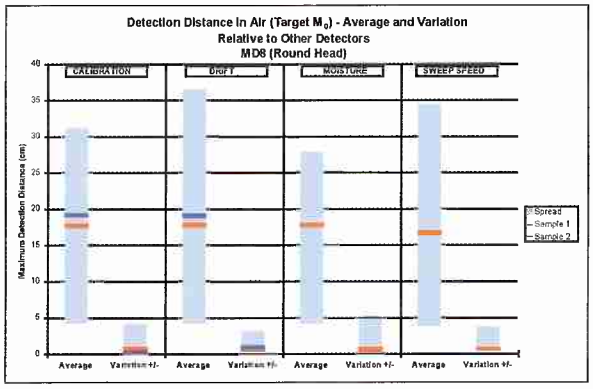
In-Soils Tests

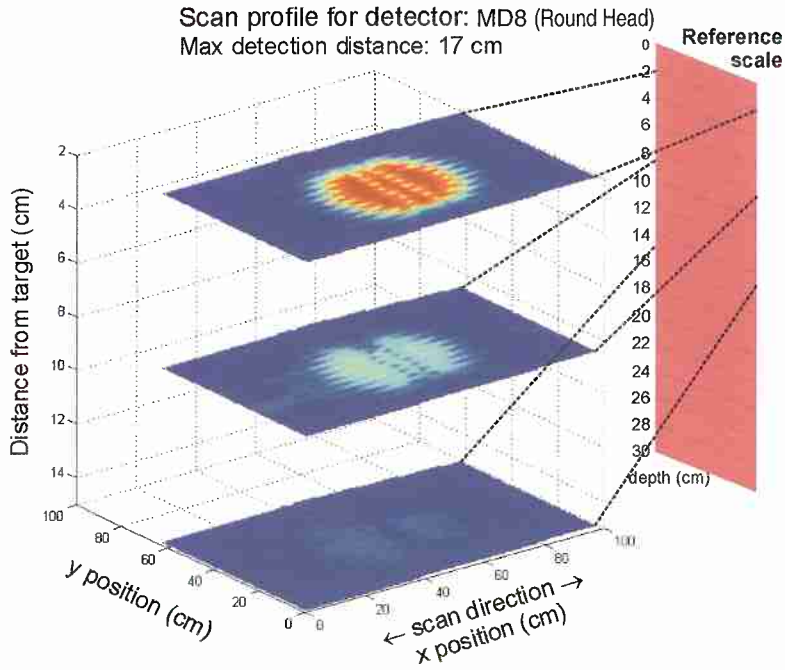




In-Air Tests







LG PRECISION PRS-17K

Manufacturer Information:
LG Precision Co Ltd
LG Youngdong Building
891 Dachi-dong Kangnam-gu
Seoul 135-738
South Korea
Telephone: +82 2 3459 5254
Fax: +82 2 3459 5265
http://www.lgp.co.kr/e_main/defense/f_pro_defen_12.htm

IPPTC Cost: US $2,700

Weight/Dimensions:
Weight: 4.0 kg
Search Head: 220 mm diameter
Length: 860-1850 mm

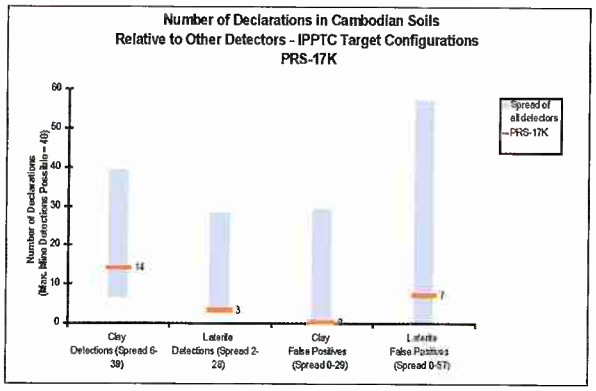
Power Supply: 8 x 1.5 V "AA" size batteries

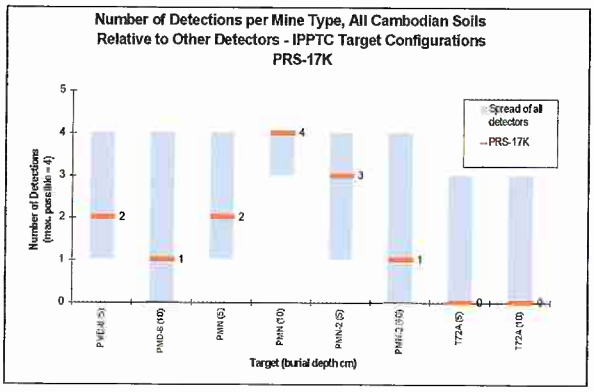
The PRS-17K operates on the pulse induction principle. It is designed for military use and provides both visual and audio indications. It can be used in either the prone or standing position.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

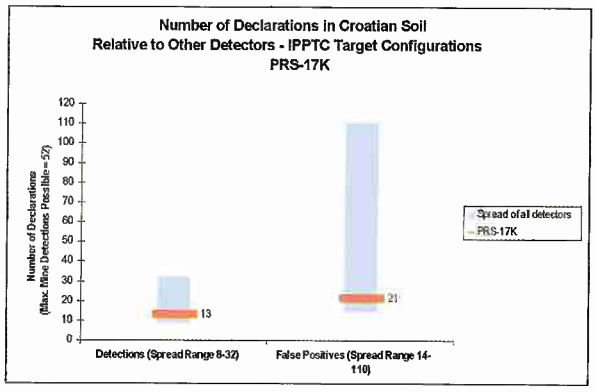
- Versatility of control box location
- Robustness
- Simplicity of controls
- No external speaker
- No field case
- No confidence tone

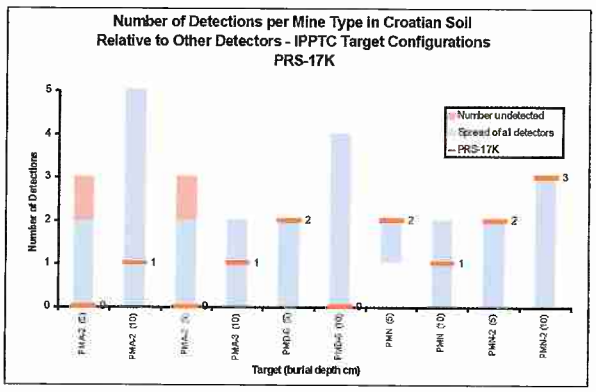
Field Tests – Cambodia





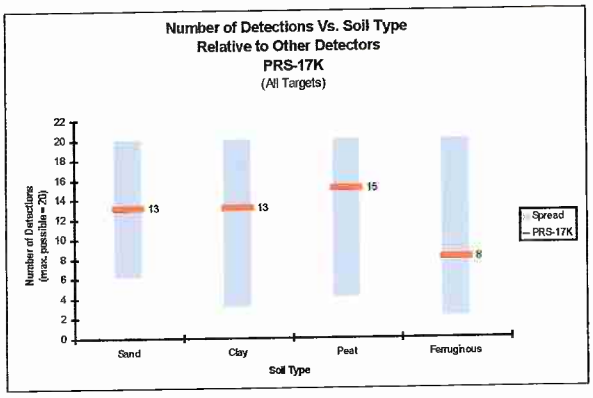
Field Tests – Croatia

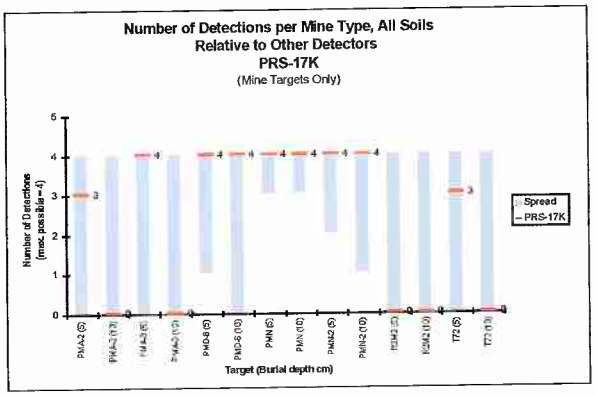




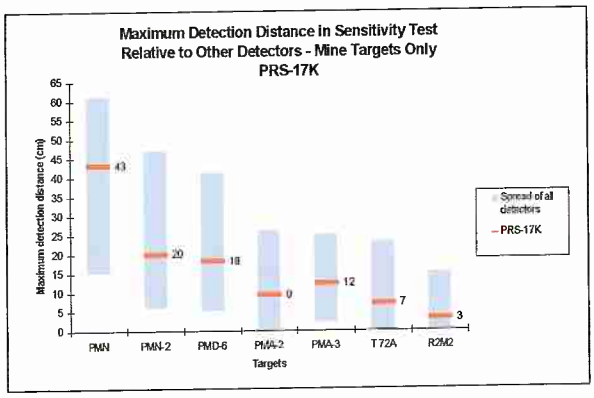
LG PRECISION PRS-17K

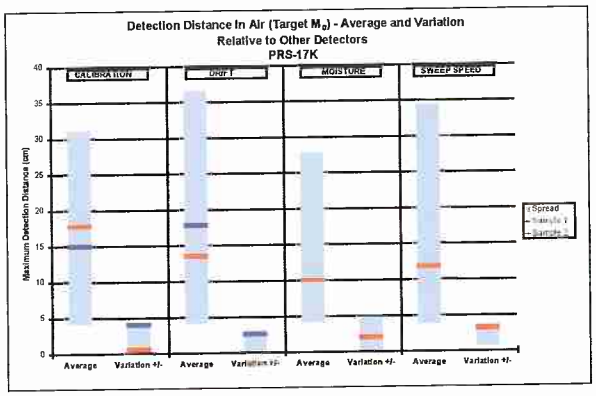
In-Soils Tests

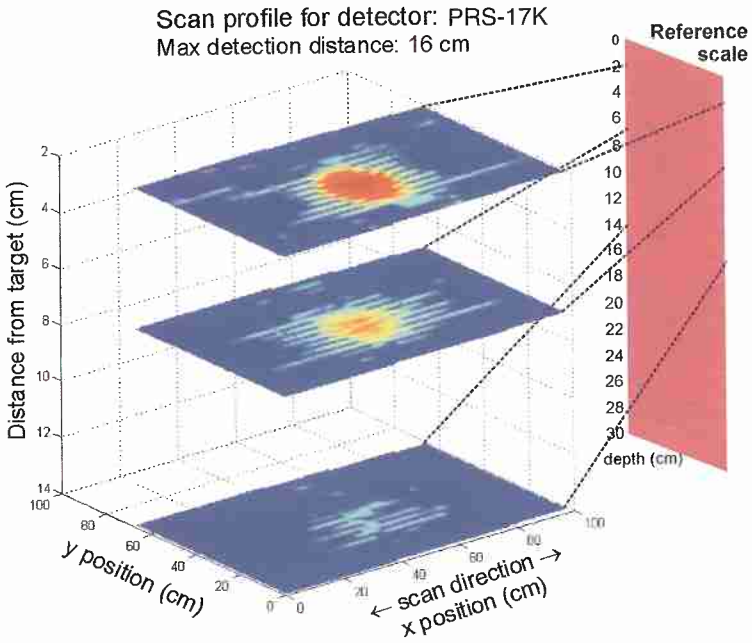




In-Air Tests







MINELAB F1A4 CMAC

Manufacturer Information:
Minelab Electronics Pty Ltd.
118 Hayward Avenue
Torrensville, SA 5031
Australia
Telephone: +618 8238 0888
Fax: +618 8238 0890
http://www.minelab.com

IPPTC Cost: US $2,250

Weight/Dimensions:
Boom/Shaft: 1200 – 1450 mm max.
Control Box: 875 g
Coil and Shaft Assembly: 1326 g
Total Operating Weight: 2900 g

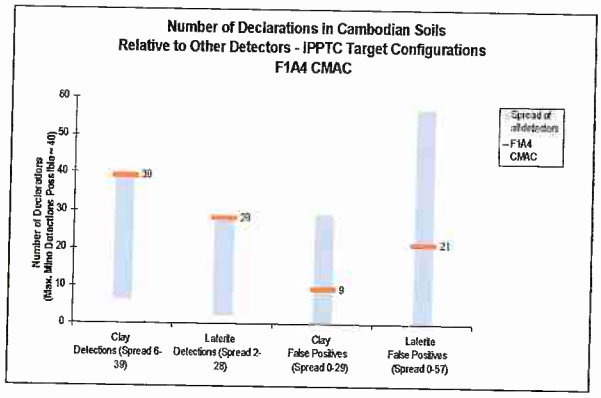
Power Supply: 4 x 1.5V "D" Cell batteries

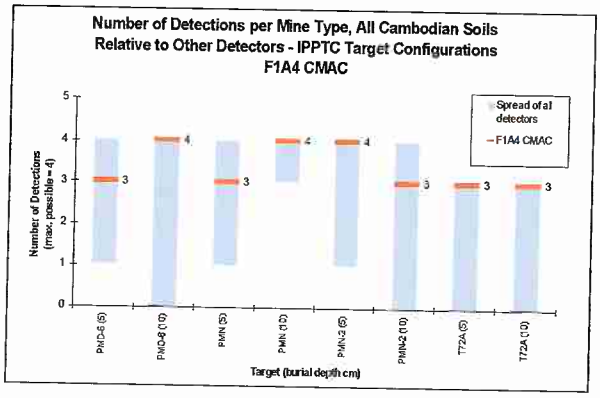
The F1A4 CMAC uses monopolar pulse induction with the added feature of soil compensation. The equipment automatically adjusts Ground Balance, Threshold (audio) and Fine Frequency. The F1A4 CMAC is the standard F1A4 with a different earpiece and carry bag.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

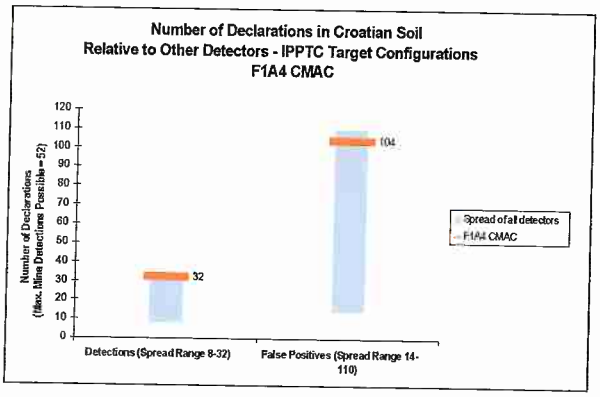
- Choice of earpiece (allows use of speaker at the same time)
- Ease of setup and operating procedure
- Versatility of control box location
- Poor for pinpointing multiple targets
- Weak screws securing the control box and head
- No labeling of alternative earphones

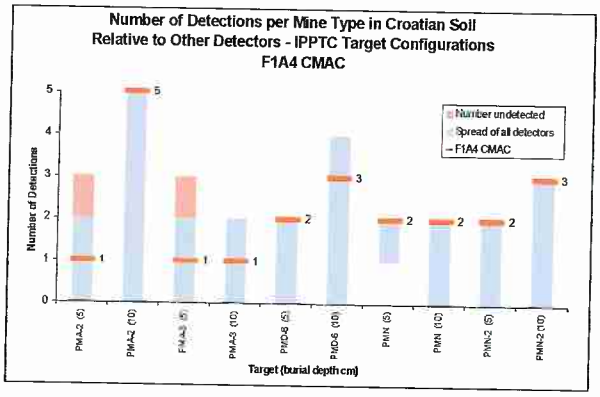
Field Tests – Cambodia





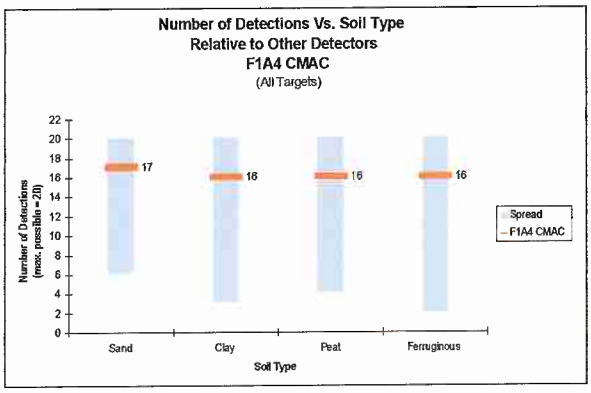
Field Tests – Croatia

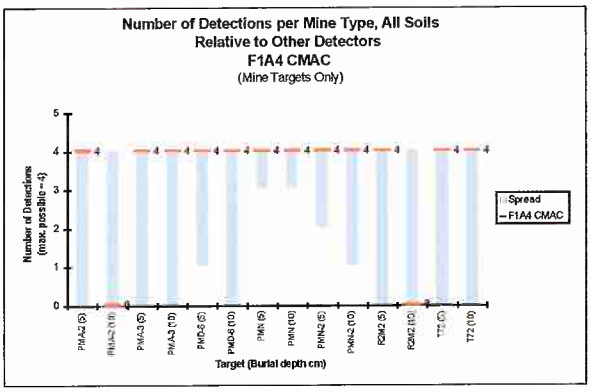




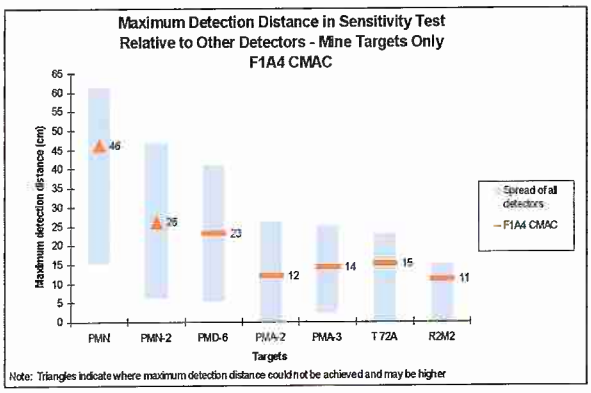
MINELAB F1A4 CMAC

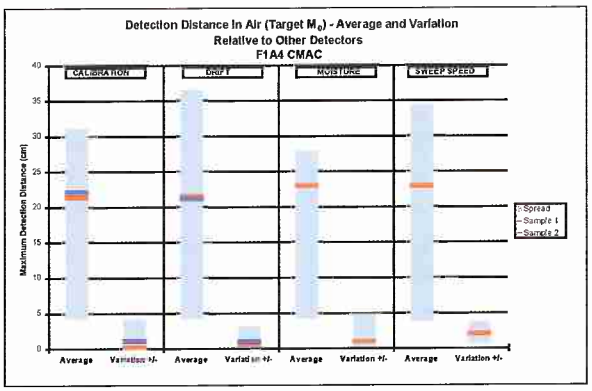
In-Soils Tests

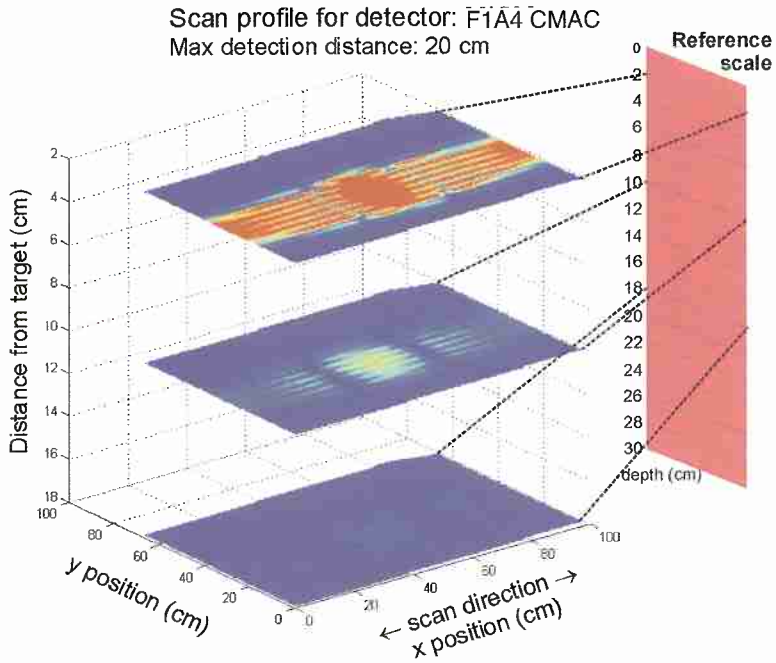




In-Air Tests







MINELAB F1A4 MIM

Manufacturer Information:
Minelab Electronics Pty Ltd.
118 Hayward Avenue
Torrensville, SA 5031
Australia
Telephone: +618 8238 0888
Fax: +618 8238 0890
http://www.minelab.com

IPPTC Cost: US $2,250

Weight/Dimensions:
Boom/Shaft: 1200 – 1450 mm max.
Control Box: 875 g
Coil and Shaft Assembly: 1326 g
Total Operating Weight: 2900 g

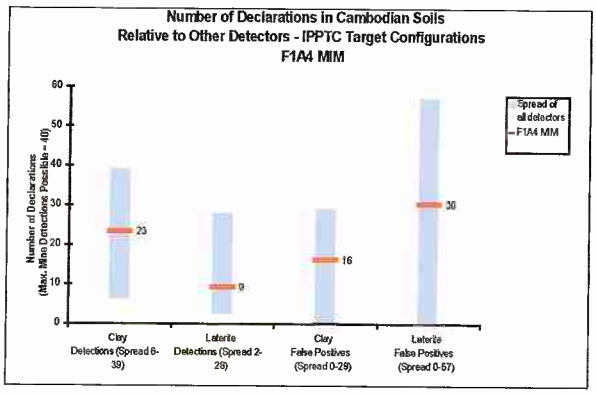
Power Supply: 4 x 1.5V "D" Cell batteries

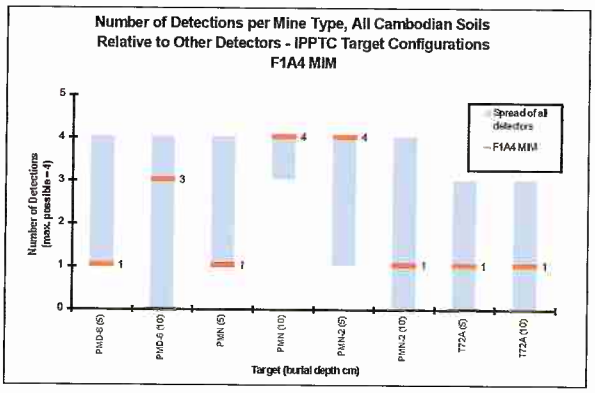
The F1A4 MIM uses bipolar pulse induction with the added feature of soil compensation. It was specifically designed with the intention of not triggering magnetically influenced mines. The equipment automatically adjusts Ground Balance, Threshold (audio) and Fine Frequency.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

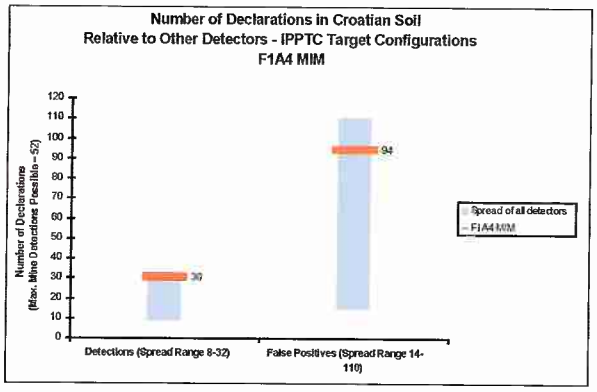
- Lockable, weather-proof, hard case
- Appropriate range of features including low battery indicator
- Light-weight, particularly when control box is detached
- Solid search head obscures direct view of target area
- Risk of damaging central cable when storing the equipment
- Insecure locking on the handle of the detector shaft

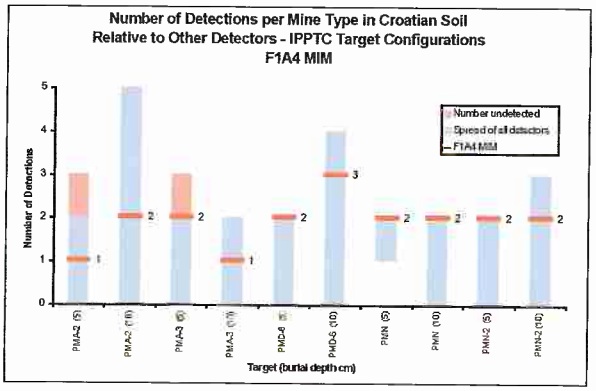
Field Tests – Cambodia





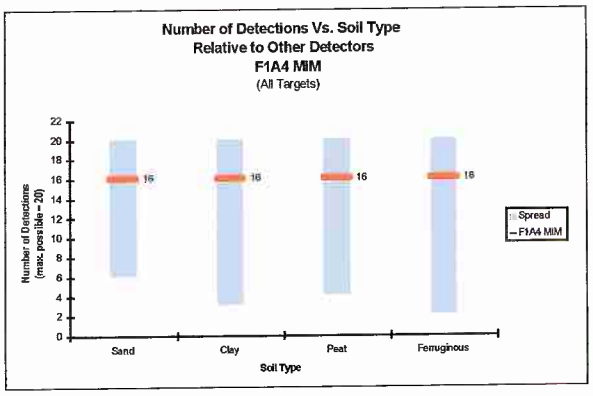
Field Tests – Croatia

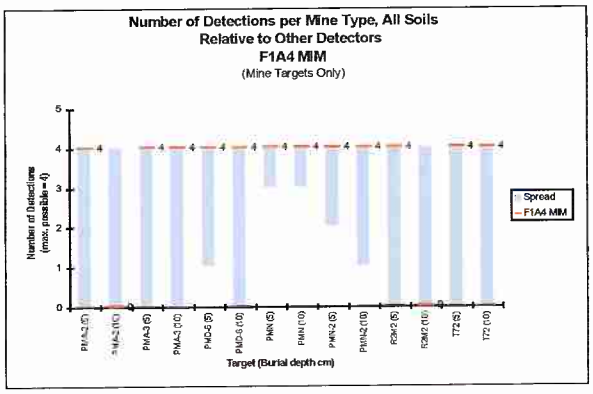




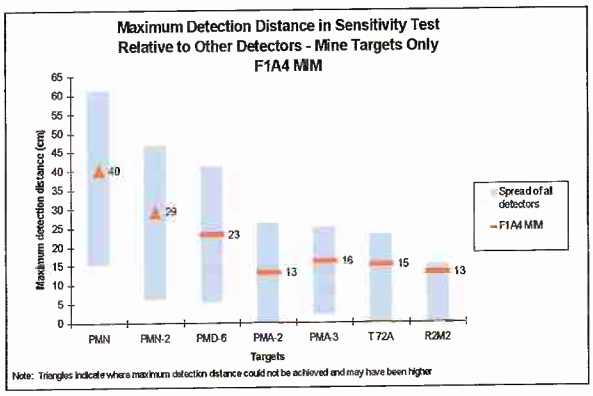
MINELAB F1A4 MIM

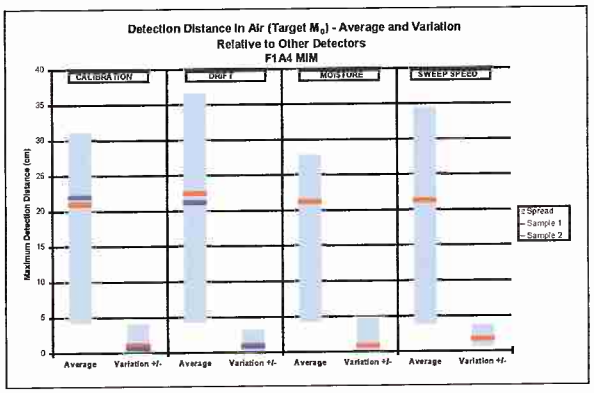
In-Soils Tests

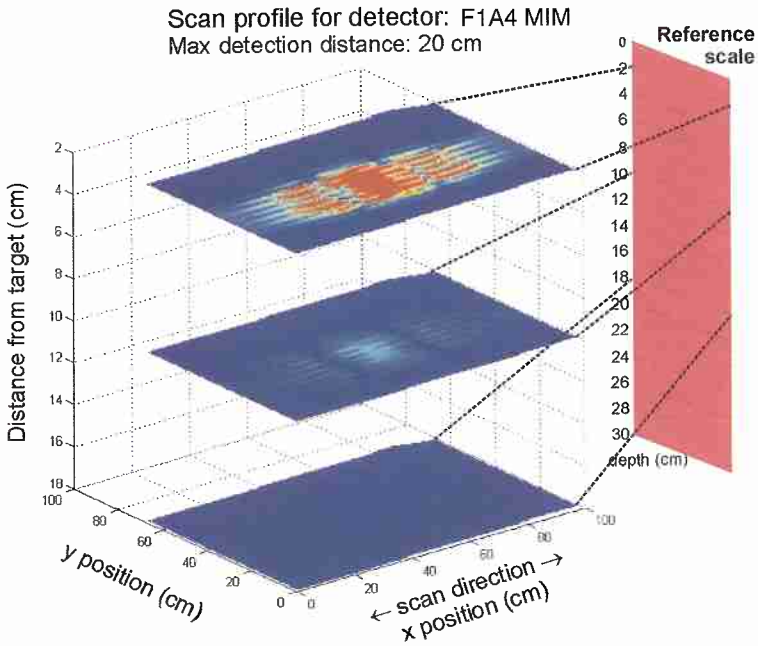




In-Air Tests







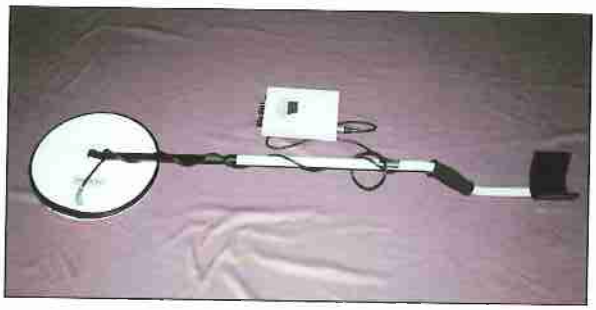
PRO-SCAN MARK 2 VLF

Manufacturer Information:
Pro Scan Ltd
262-266 Pirie Street
Adelaide, SA 5000
Australia
Telephone: +618 8232 5727
Fax: +618 8238 5290

IPPTC Cost: US $1,000

Weight/Dimensions:
Boom/Shaft: unavailable
Search head: 305 mm diameter

Power Supply: 9.6V NiCad rechargeable pack

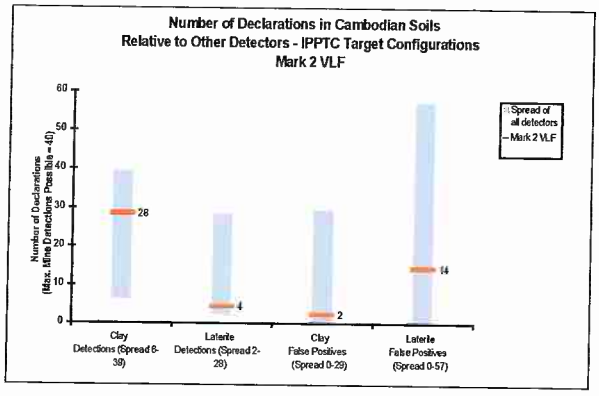


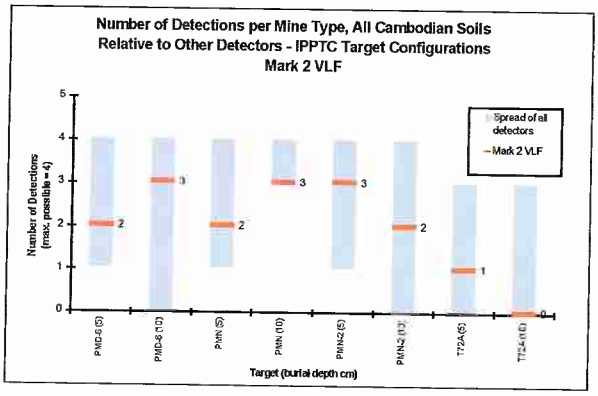
The Mark2 metal detector is designed for the hobbyist. It is simple to use. It features a squelch control for tuning the sensitivity and a ground balance control. It uses a versatile rechargeable battery pack.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

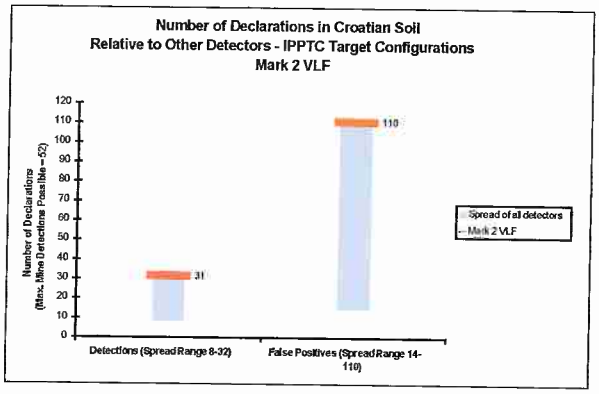
- Extra volume control on head phones
- Versatility of recharge system
- Light and well balanced
- No transit or field case
- Not rugged or weatherized
- Large, closed search head

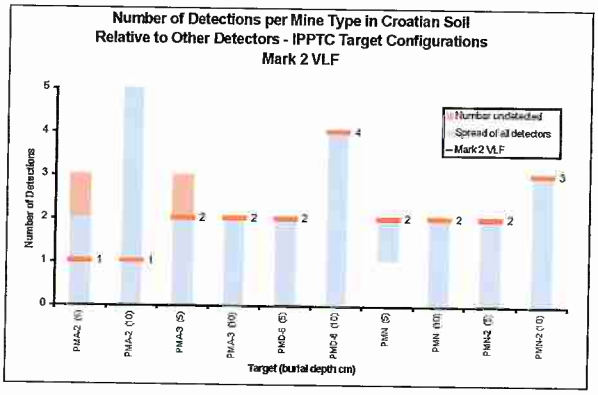
Field Tests – Cambodia





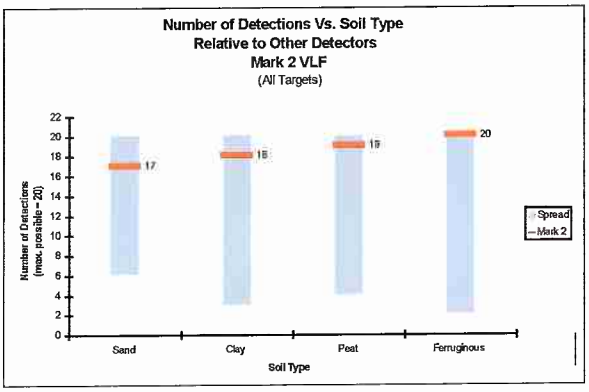
Field Tests – Croatia

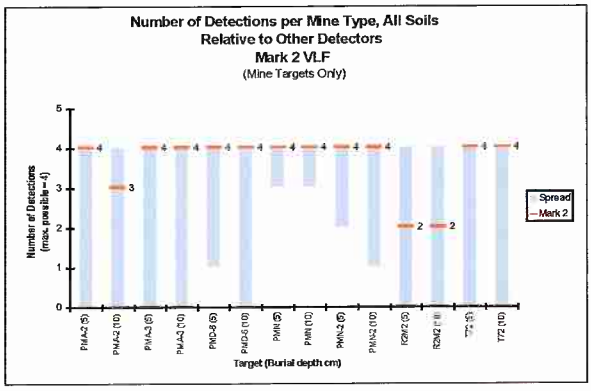




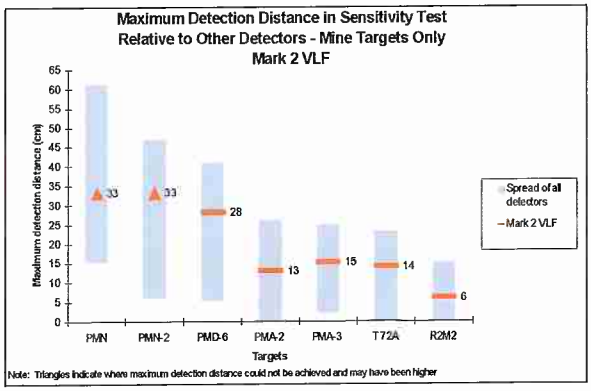
PRO-SCAN MARK 2 VLF

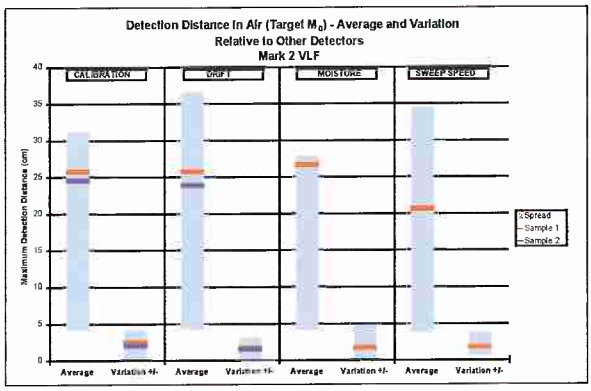
In-Soils Tests

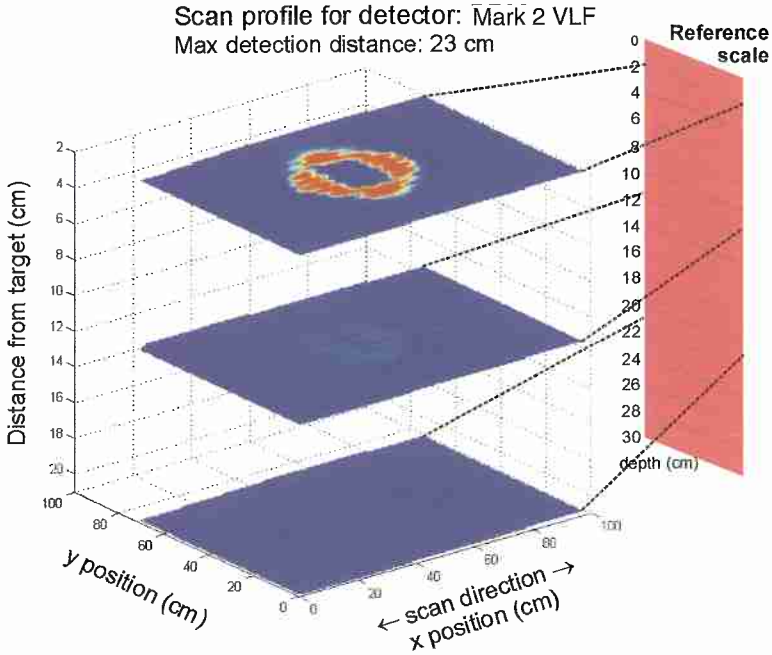




In-Air Tests







REUTECH MIDAS PIMD

Manufacturer Information:
Reutech Defence Industries
PO Box 118
New Germany, Natal 3620
South Africa
Telephone: +27 31 719 5711
Fax: +27 31 719 5707
http://www.esd.co.za/rdihome.htm

IPPTC Cost: US $2,025

Weight/Dimensions:
Weight: 4.3 kg
Search head: 305 mm diameter
Boom/Shaft: 1640 – 2110 mm max.

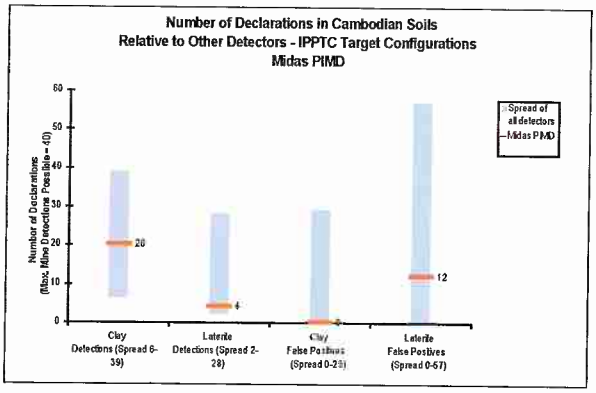
Power Supply: 11 x 1.5V "AA" batteries

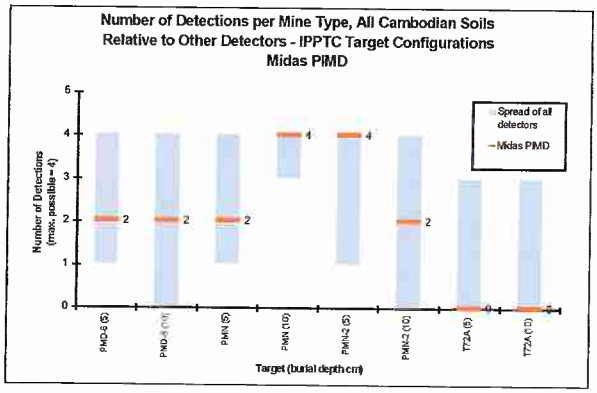
The Midas PIMD operates on the pulse induction method. It has two operational modes: Locate, which gives an alarm only when the detection head moves past a metallic object; and Pinpoint, which provides a continuously varying tone output intended to be proportional to the size and position of the metallic object.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

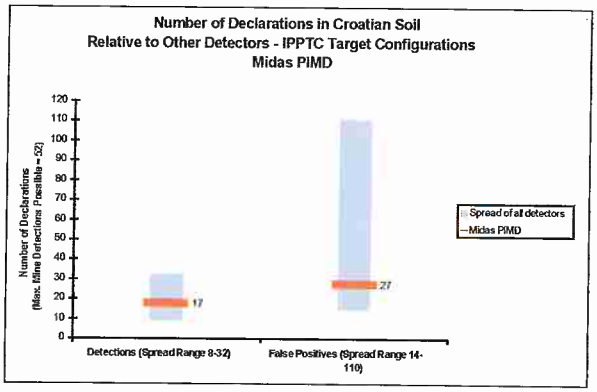
- Simple design
- Robust construction
- Versatile field and transit case
- Absence of volume control or external speaker
- Long length
- Awkward position of controls

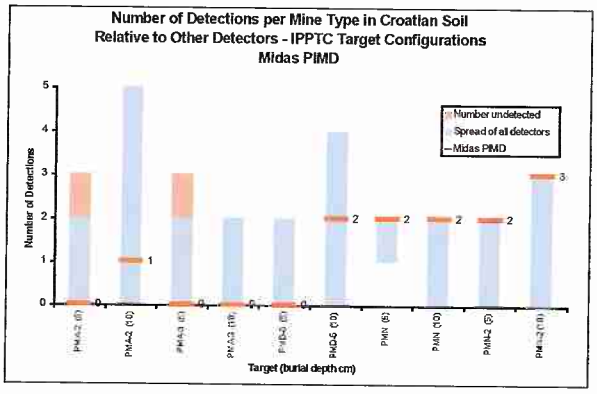
Field Tests – Cambodia





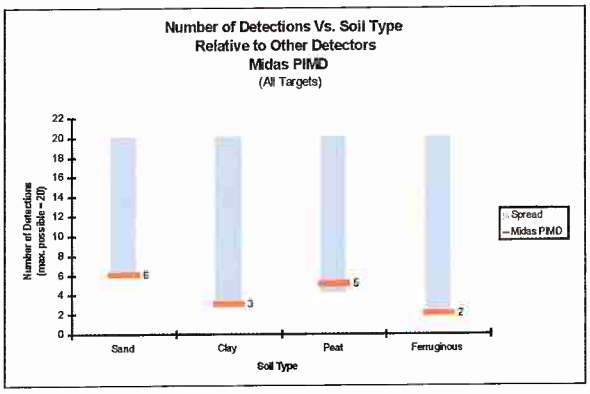
Field Tests – Croatia

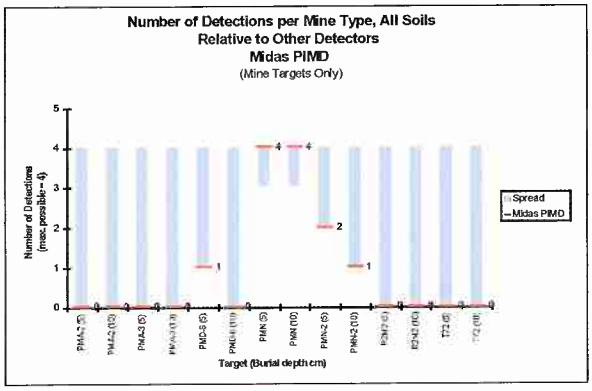




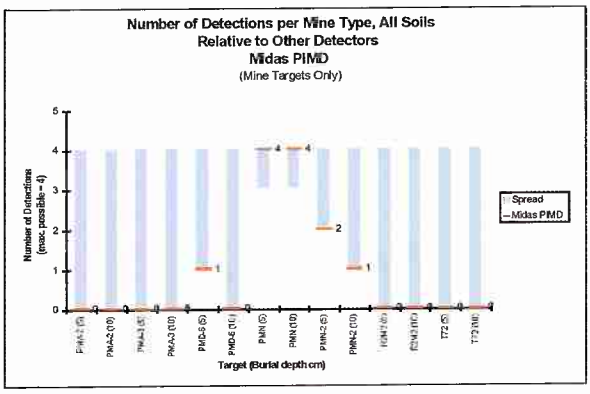
REUTECH MIDAS PIMD

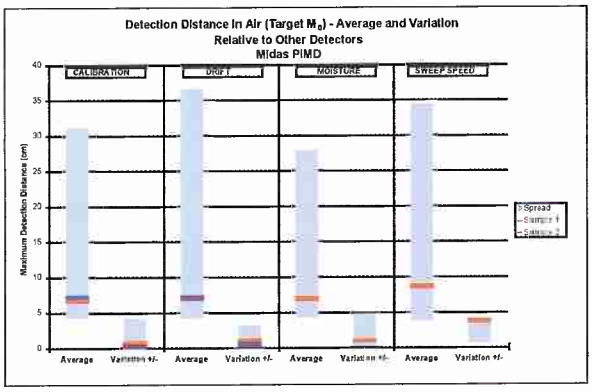
In-Soils Tests

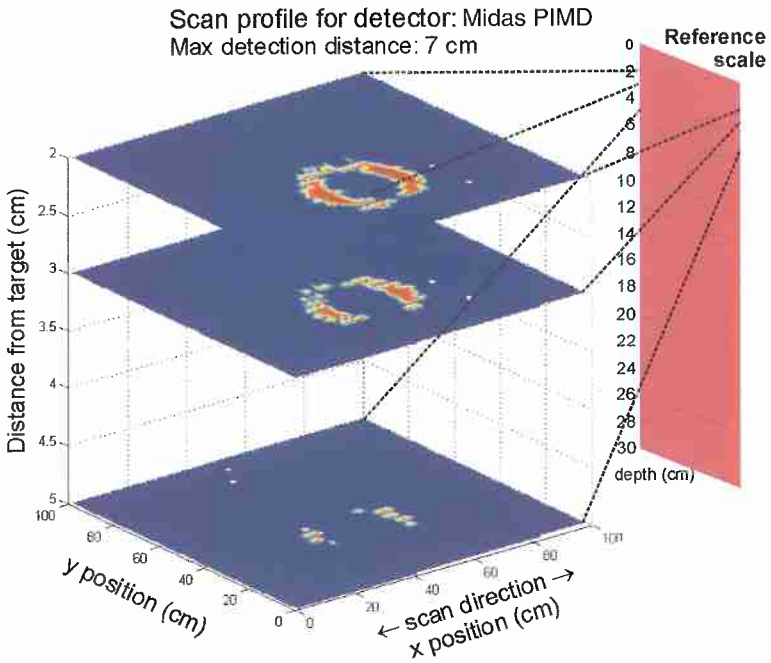




In-Air Tests







SCHIEBEL AN-19/2

Manufacturer Information:
Schiebel GmbH
Margaretenstrasse 112
A-1050 Vienna
Austria
Telephone: +43 1 546 26-0
Fax: +43 1 545 23 39
http://www.schiebel.com

IPPTC Cost: US $2,300

Weight/Dimensions:
Electronics unit: 1100 g; 185 x 80 x 150 mm;
Boom/Shaft: 700 g; 3 fixed positions – 1400 mm, 1500 mm, 1600 mm
Search head: 600 g, 270 mm diameter

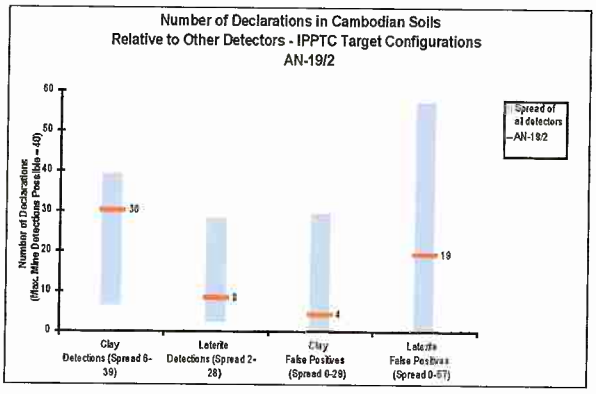
Power Supply: 4 x 1.5V "D" cell batteries

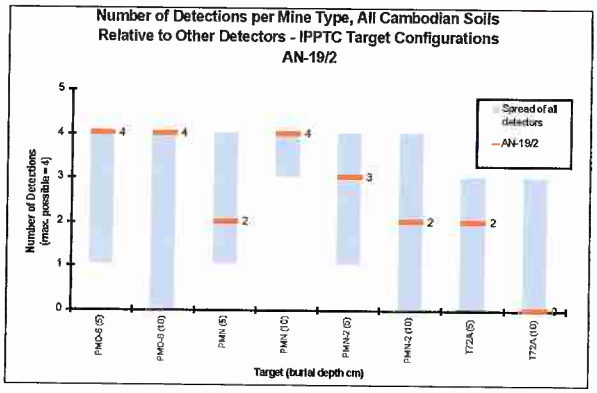
The AN-19/2 is designed for military use. The AN-19/2 operates on the pulse induction principle and is made up of concentric transmitting and receiving coils. Sensitivity can be controlled manually during operation. It features a ticking confidence tone every 1-2 seconds.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

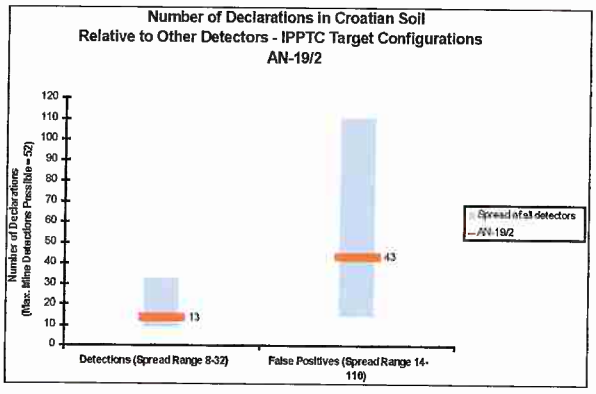
- Light-weight
- Rugged and weather-proof
- Easy to use
- No external speaker
- Exposed cable
- Lack of ability to mount electronics box on detector shaft

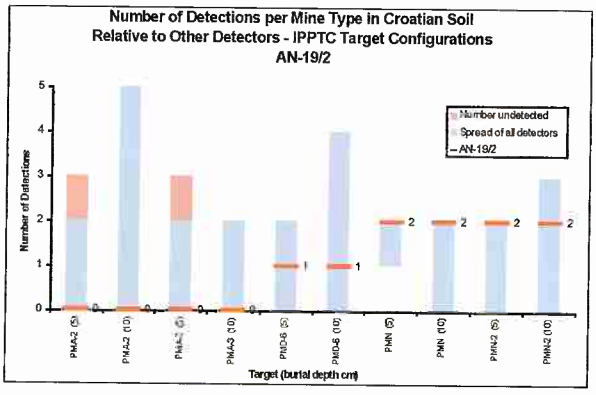
Field Tests – Cambodia





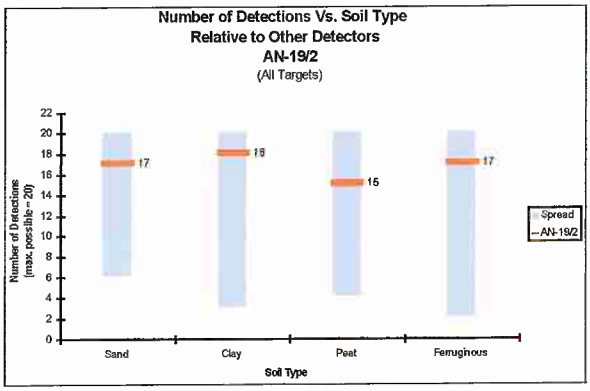
Field Tests – Croatia

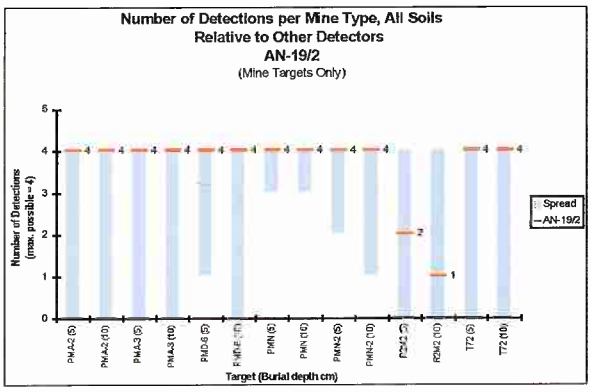




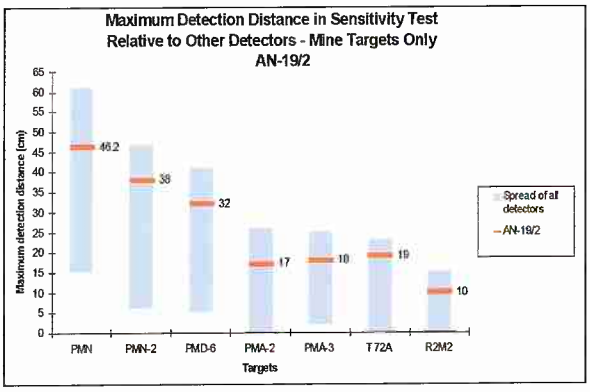
SCHIEBEL AN-19/2

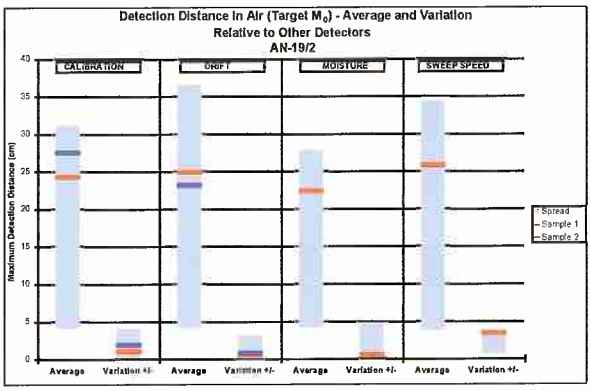
In-Soils Tests

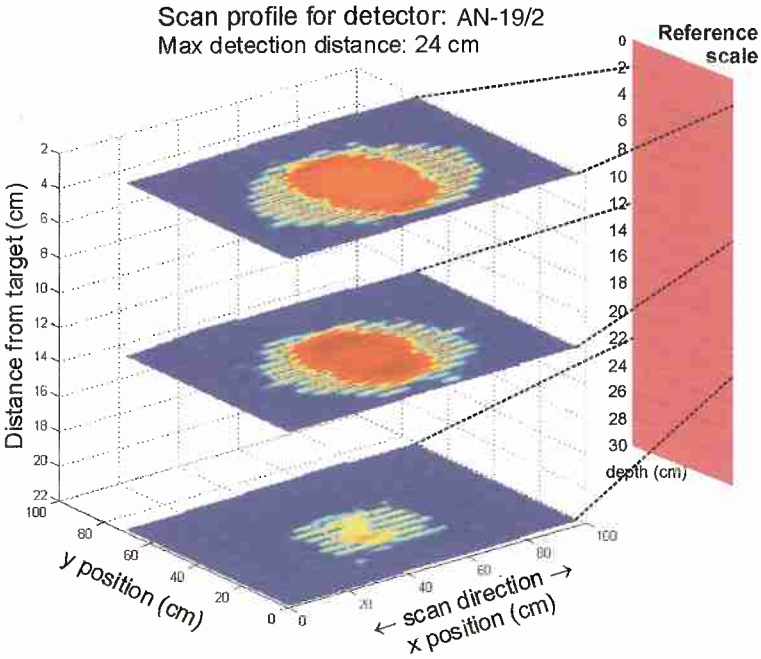




In-Air Tests







SCHIEBEL ATMID

Manufacturer Information:
Schiebel GmbH
Margaretenstrasse 112
A-1050 Vienna
Austria
Telephone: +43 1 546 260
Fax: +43 1 545 2339
http://www.schiebel.com

IPPTC Cost: US $2,300

Weight/Dimensions:
Electronics unit: 1100 g; 185 x 80 x 150 mm
Boom/Shaft: 700 g; 770-1620 mm
Search head: 270 mm diameter

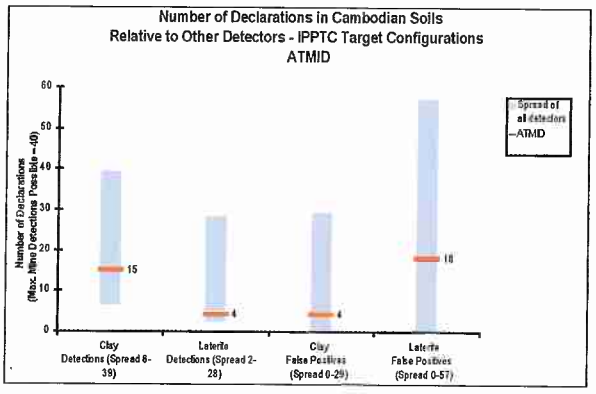
Power Supply: 4 x 1.5V "D" cell batteries

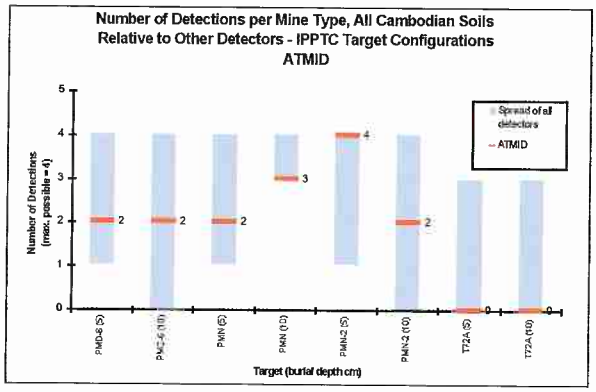
The ATMID (All Terrain Mine Detector) is based on the AN-19/2, but it is specifically intended for use in all soil types and terrain. Digital spectral detection algorithms have been added to the AN-19/2 design with the intention to compensate for ground and soil effects.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

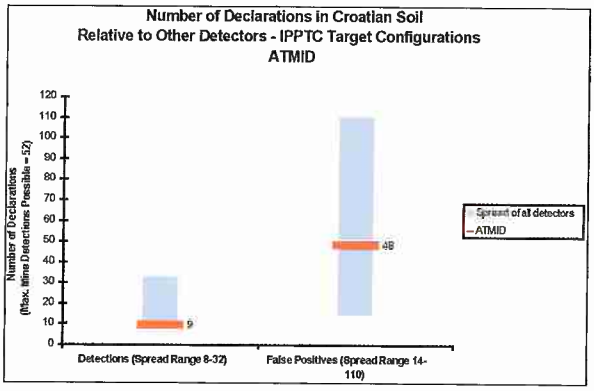
- Light-weight and easy to use
- Rugged and weather-proof
- Versatile
- No external speaker
- Exposed cable
- Lack of documentation for search head use

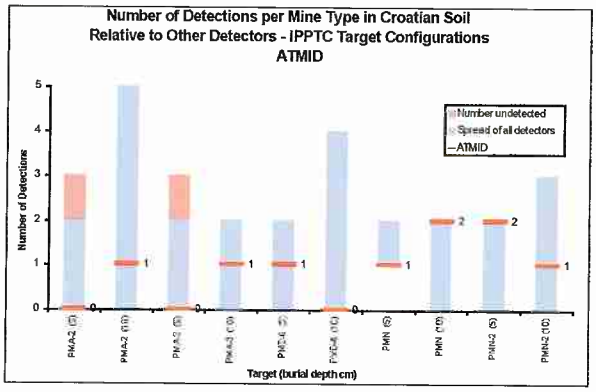
Field Tests – Cambodia





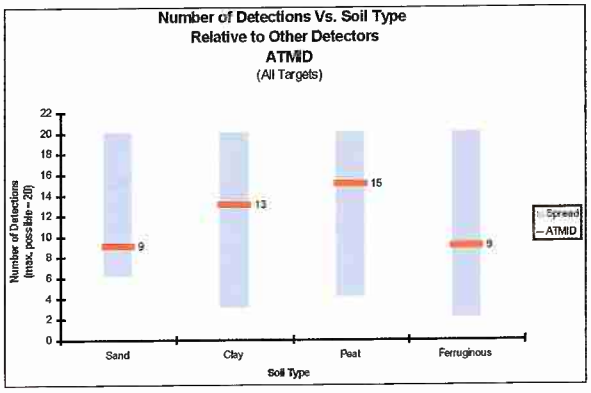
Field Tests – Croatia

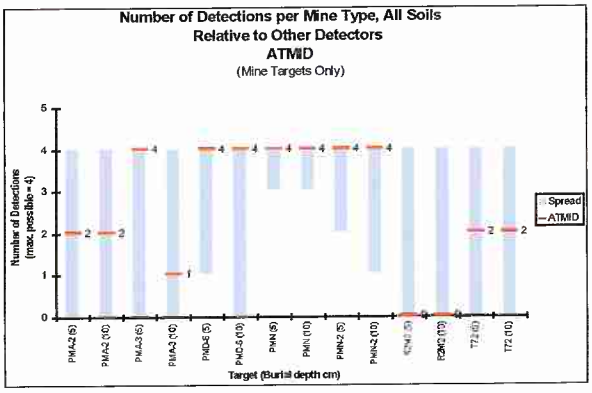




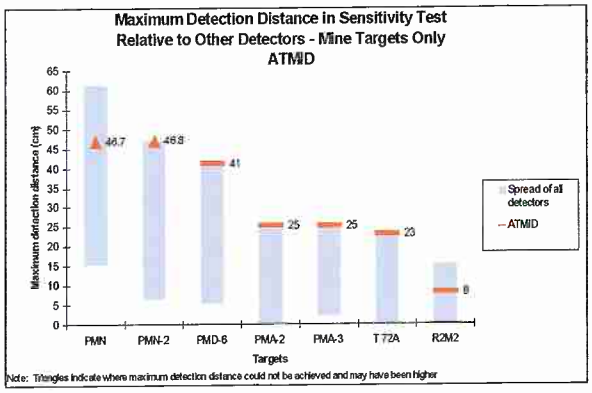
SCHIEBEL ATMID

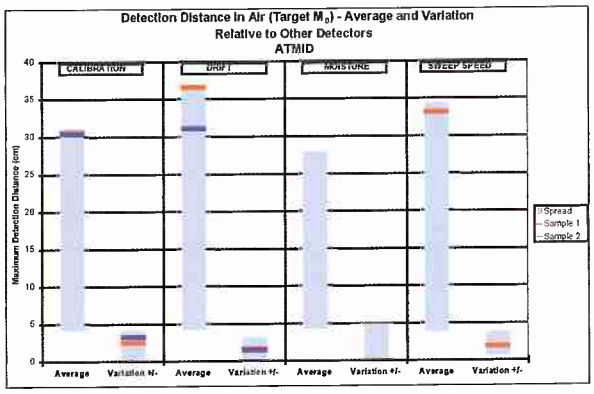
In-Soils Tests

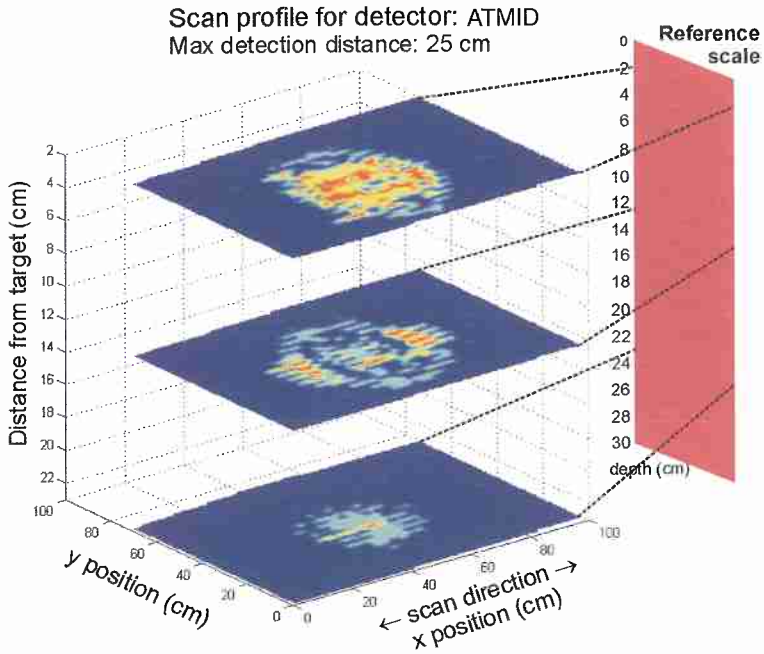




In-Air Tests







SCHIEBEL MIMID

Manufacturer Information:
Schiebel GmbH
Margaretenstrasse 112
A-1050 Vienna
Austria
Telephone: +43 1 546 260
Fax: +43 1 545 2339
http://www.schiebel.com

IPPTC Cost: US $3,590

Weight/Dimensions:
Total Weight: 1.37 kg
Folded: 325 x 55 x 95 mm
Fully extended: 1250 mm

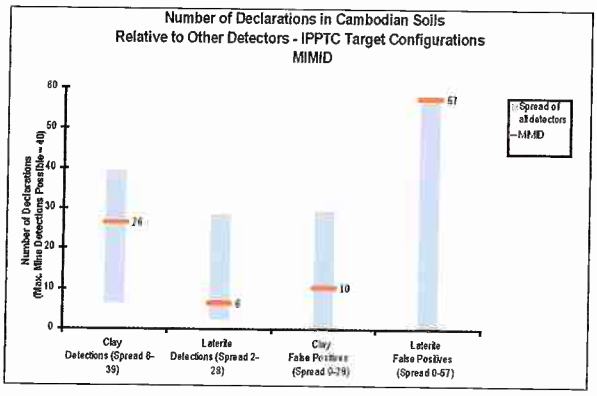
Power Supply: 4 x 1.5V "D" cell batteries

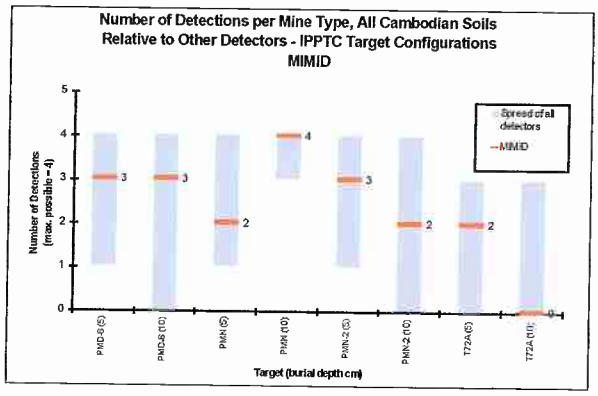
The MIMID (Miniature Mine Detector) is based on AN-19/2 technology. Its compact, collapsible, one-piece design makes it easy to transport and set up. It can be quickly transformed for use in the standing, kneeling, or prone positions by adjusting the length of the telescopic pole. The MIMID has a built-in speaker and can be used with or without headphones.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

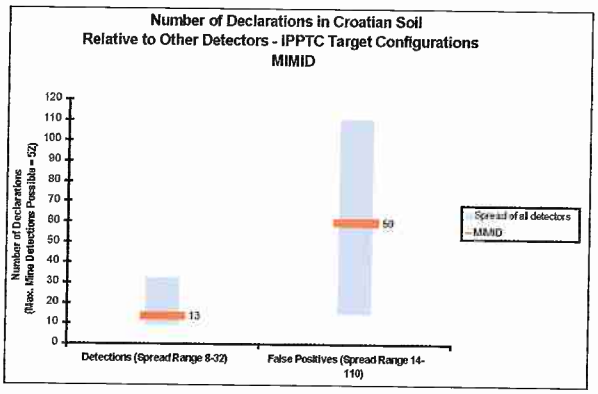
- Light-weight and compact
- Weather-proof
- Pre-assembled
- No transit case
- Handle does not lock down
- Elbow restraints and shaft latches are weak

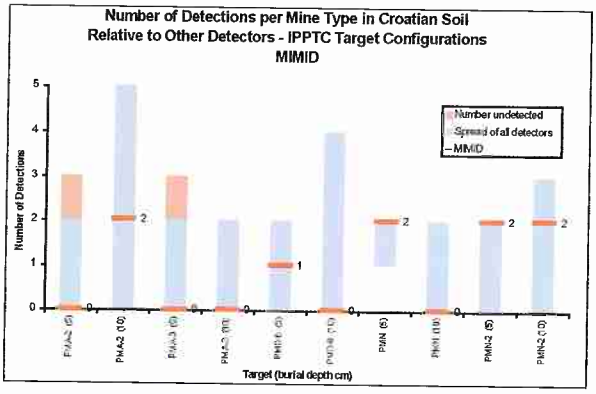
Field Tests – Cambodia





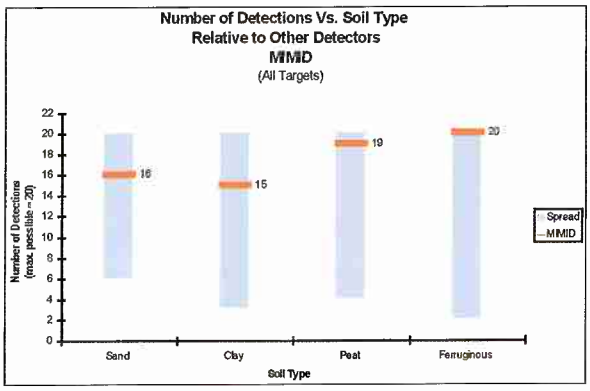
Field Tests – Croatia

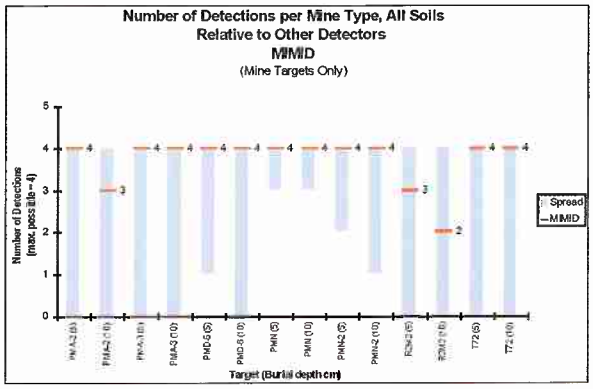




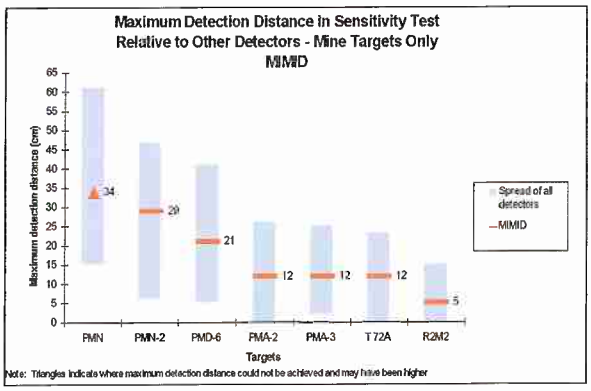
SCHIEBEL MIMID

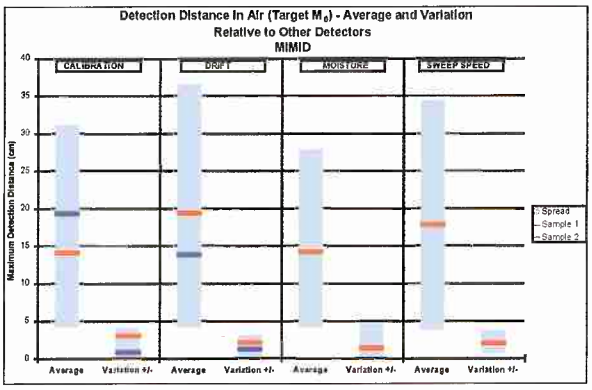
In-Soils Tests

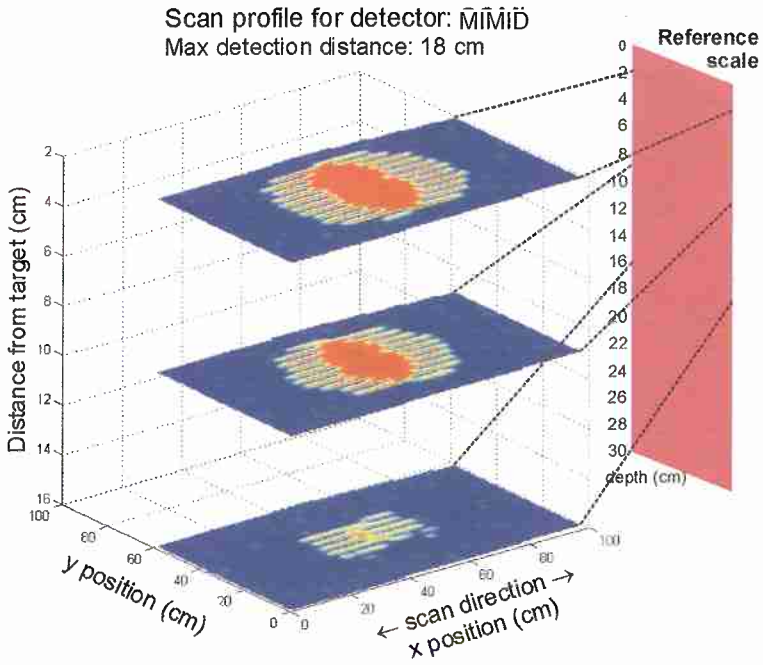




In-Air Tests







VALLON ML 1620 C

Manufacturer Information:
Vallon GmbH
Postfach 12 52
D-72795 Eningen
Germany
Telephone: +49 7121 98550
Fax: +49 7121 83643
http://www.vallon.de

IPPTC Cost: US $4,160

Weight/Dimensions:
Search head: 1300 g (incl. Shaft); 170 x 305 mm
Electronics box: 1550 g; 95 x 75 x 205 mm;
Boom/shaft: 960-1900 mm

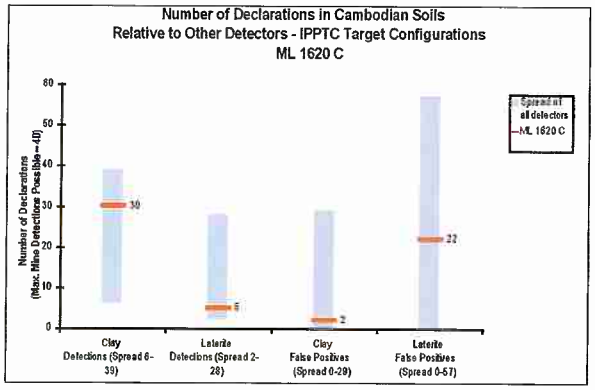
Power Supply: 4 x 1.5V "D" cell batteries

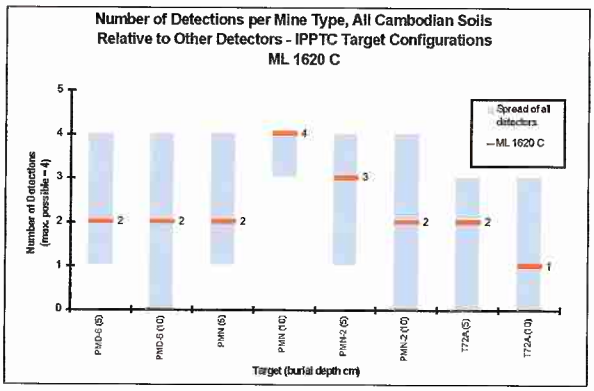
The ML 1620 C uses the pulse induction principle for metal detection. It features 4 different soil programs to compensate for varying soil types, as well as programs to reduce interference from nearby power lines. The detector adapts itself automatically to the ambient ground conditions.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

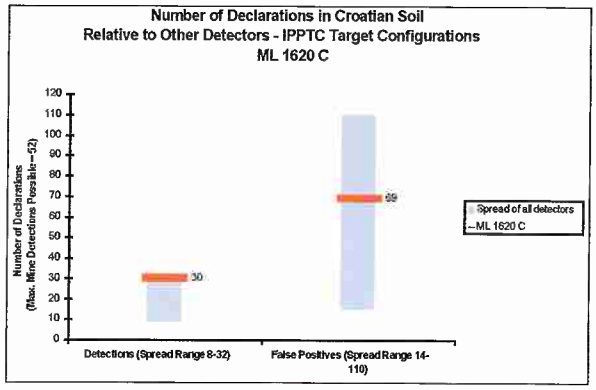
- Range of functions offers a wide capability
- Choice of electronics box position
- Range of length adjustment
- Complex
- Lack of confidence indicator
- Incomplete guidance for setting of functions

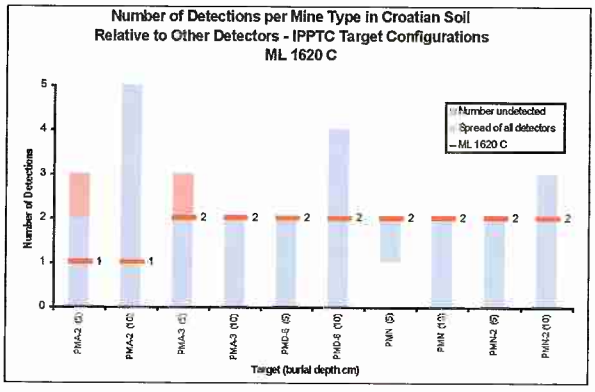
Field Tests – Cambodia





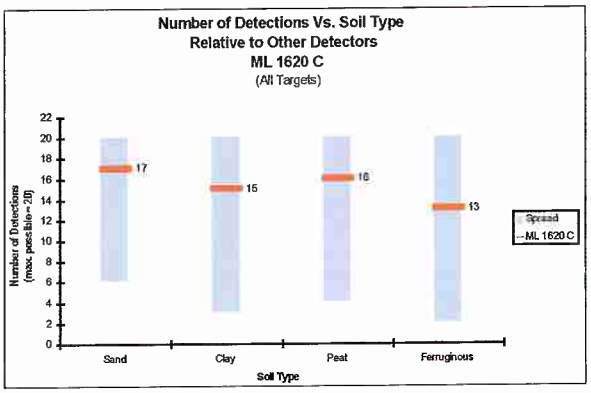
Field Tests – Croatia

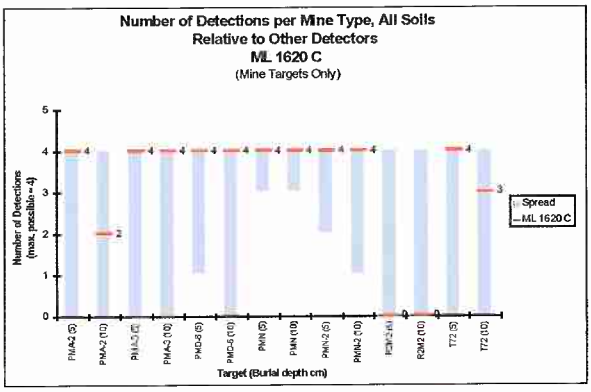




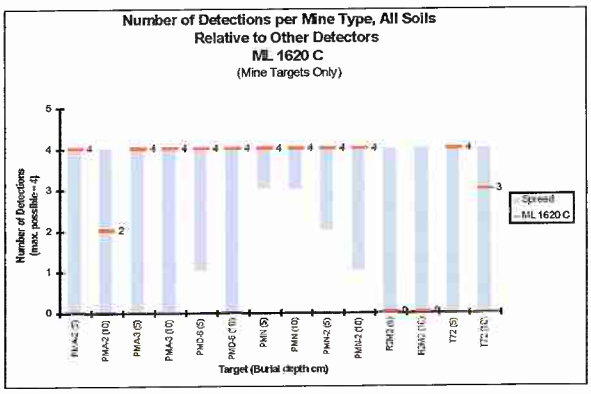
VALLON ML 1620 C

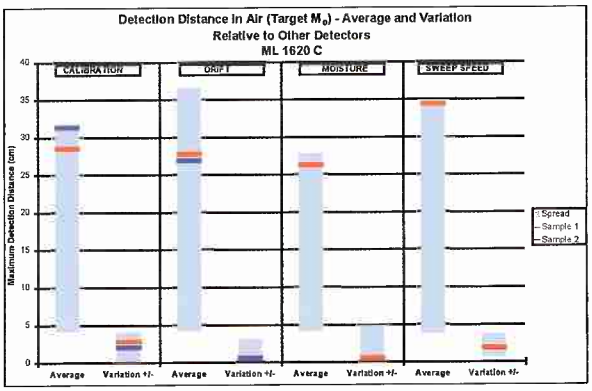
In-Soils Tests



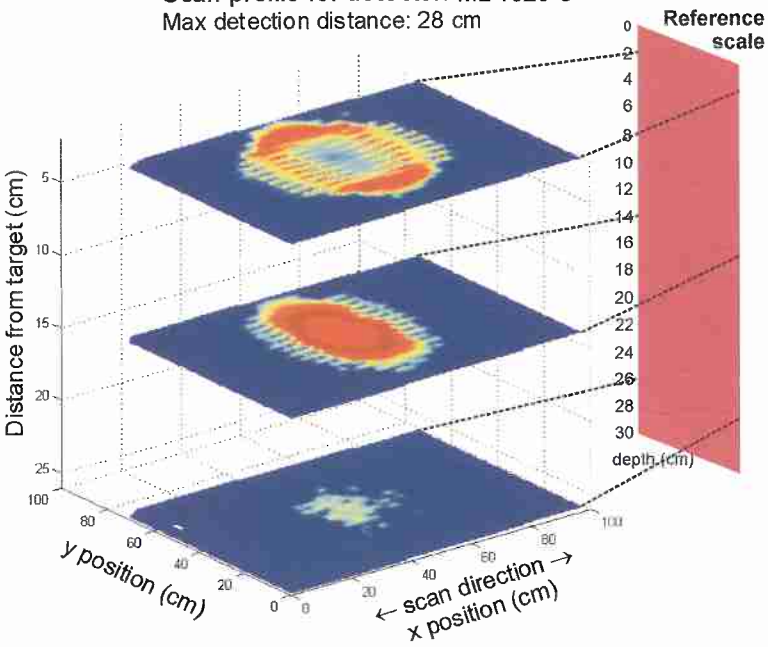


In-Air Tests





Scan profile for detector: ML 1620 C
Max detection distance: 28 cm



VALLON VMH2

Manufacturer Information:
Vallon GmbH
Postfach 12 52
D-72795 Eningen
Germany
Telephone: +49 7121 98550
Fax: +49 7121 83643
http://www.vallon.de

IPPTC Cost: US $2,750

Weight/Dimensions:
Search head: 1500 g (incl. Shaft); 170 x 305 mm
Electronics box: 1600 g; 95 x 80 x 2195 mm
Boom/shaft: 810-1360 mm

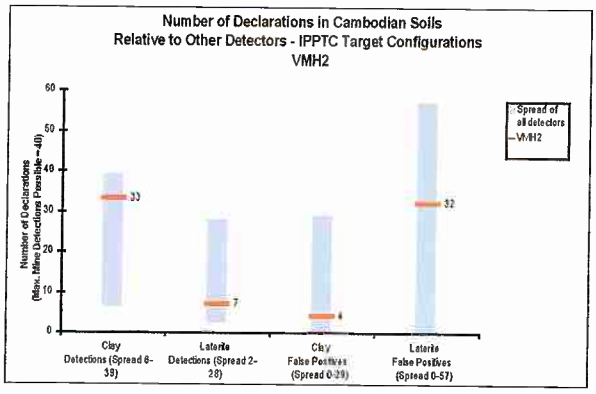
Power Supply: 4 x 1.5V "D" cell batteries

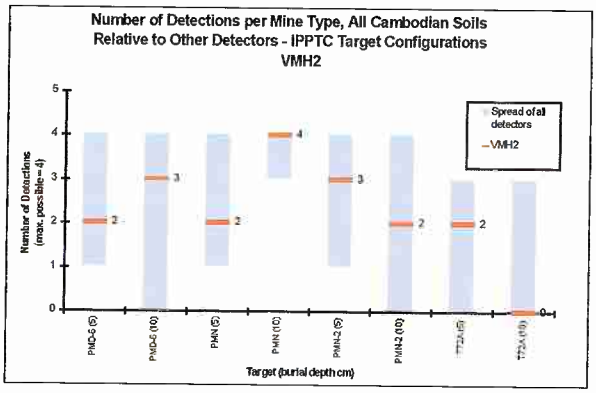
The VMH2 uses the pulse induction principle for metal detection. It features 4 different soil programs to compensate for varying soil types, as well as programs to reduce interference from nearby power lines. The VMH2 is the same as the VMH1 with the addition of a 60-cm diameter UXO search head (not evaluated).

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

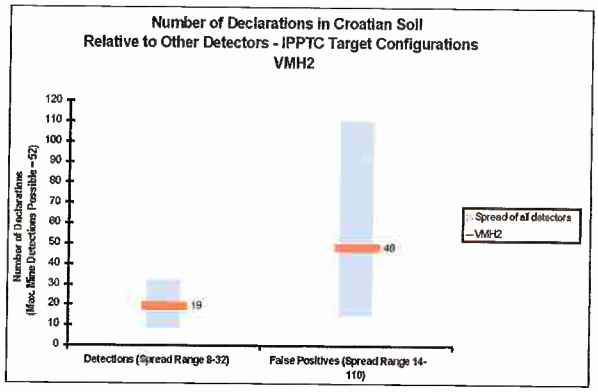
- Rugged
- Good field case
- Pre-assembled
- Complex ground balancing
- Lack of extras (transit case and earphones)
- No confidence tone

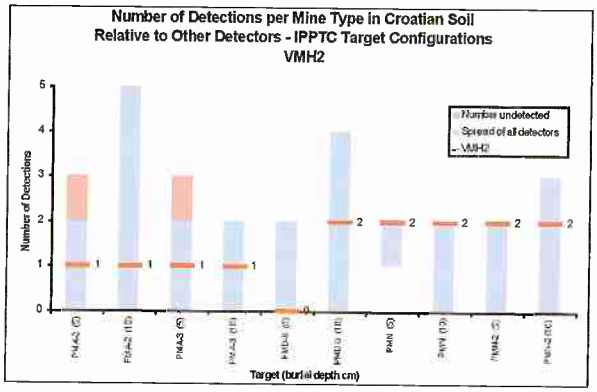
Field Tests – Cambodia





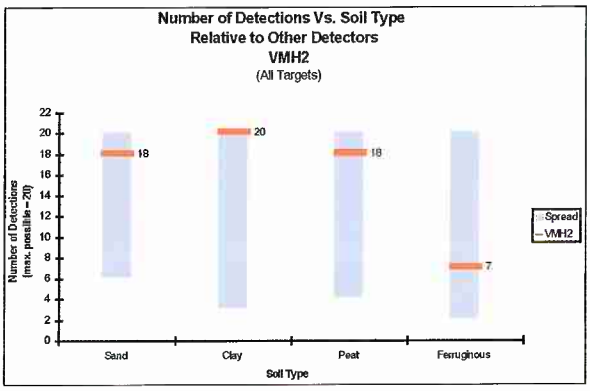
Field Tests – Croatia

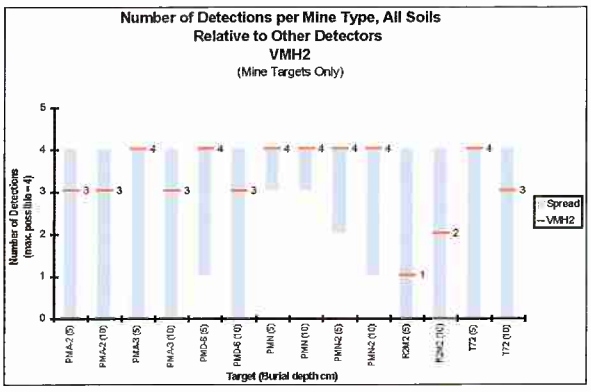




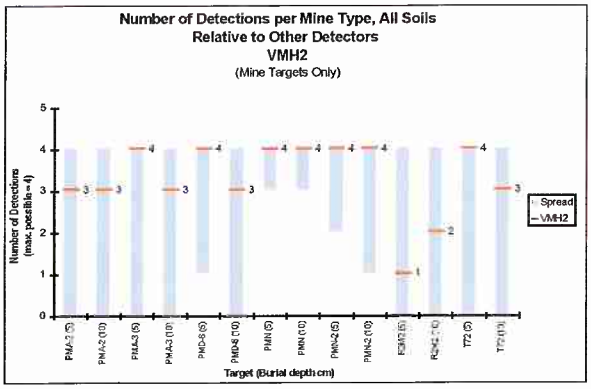
VALLON VMH2

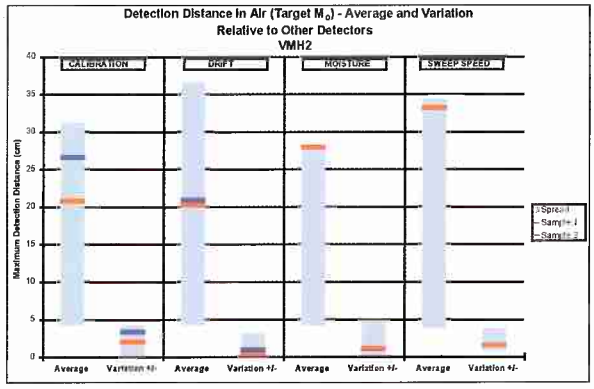
In-Soils Tests

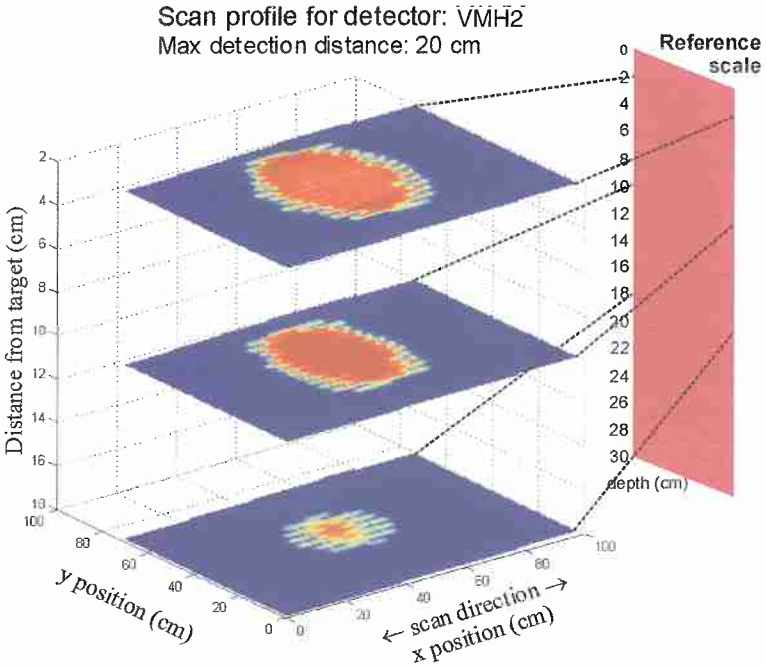




In-Air Tests







WHITE'S DI-PRO 5900

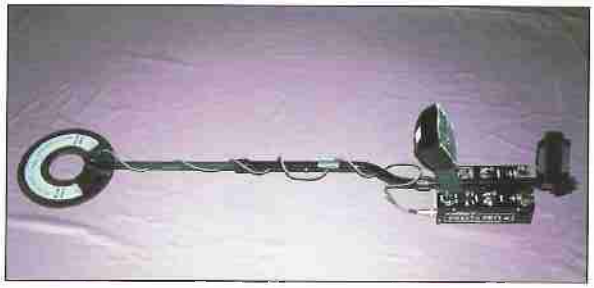
Manufacturer Information:
White's Electronics Inc.
1011 Pleasant Valley Road
Sweet Home, OR 97386
USA
Telephone: +1 800 547 6911 (Distribution)
+1 541 367 6121 (Factory)
Fax: +1 541 367 2968

Email: whites@halcyon.com

IPPTC Cost: US $500

Weight/Dimensions:
Not available

Power Supply: 4 x 1.5V "C" cell batteries

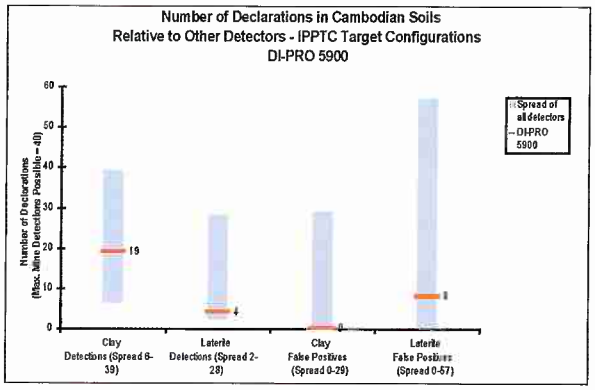


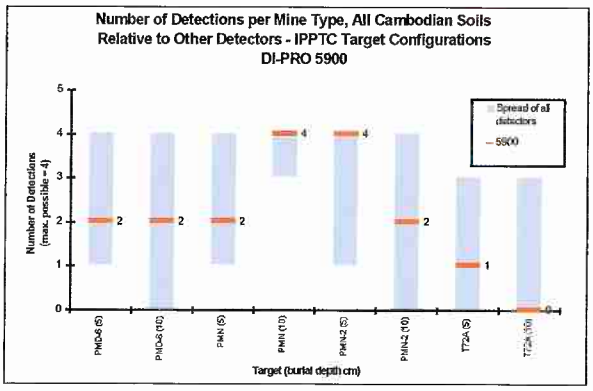
The DI-PRO 5900 is designed for the hobbyist and its features are geared towards the treasure hunter. These features include target identification and depth readings.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

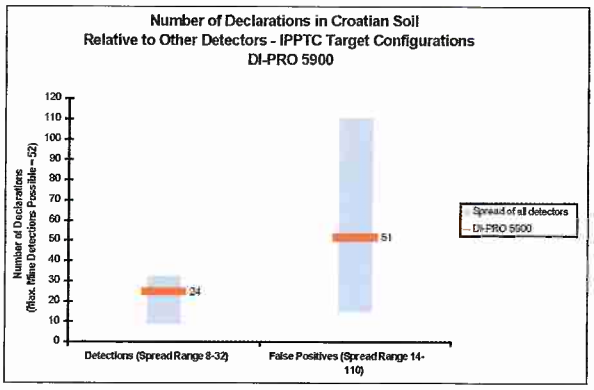
- Lightweight
- Socket for headphones
- Visual dial display (back-up to audible alarm)
- Many complex settings and options
- Lack of ruggedness
- Manual explanations are confusing

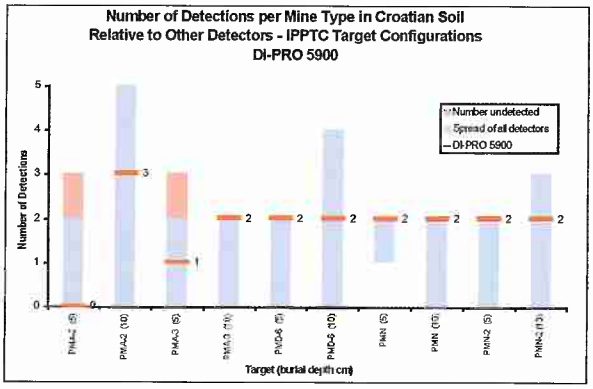
Field Tests – Cambodia





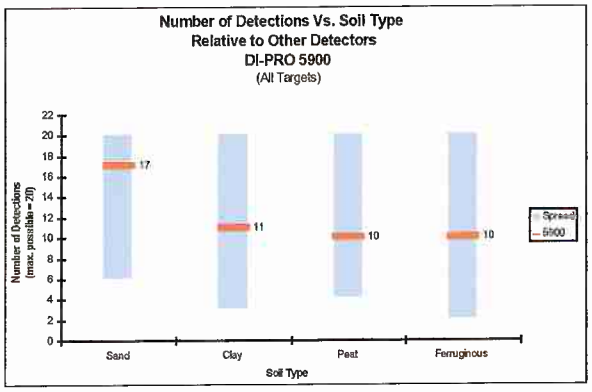
Field Tests – Croatia

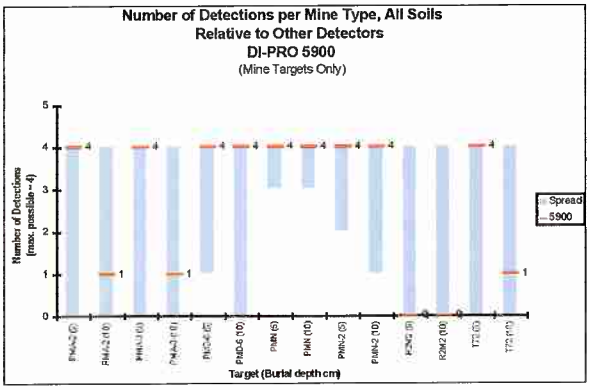




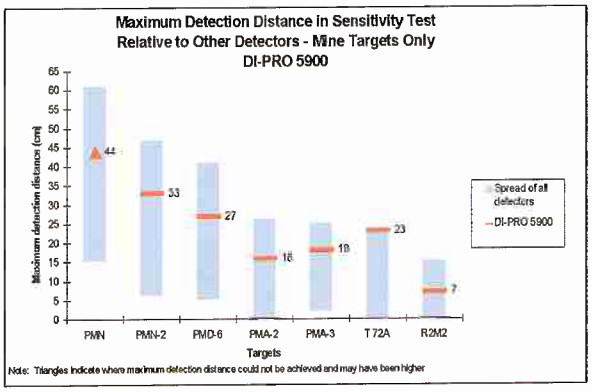
WHITE'S DI-PRO 5900

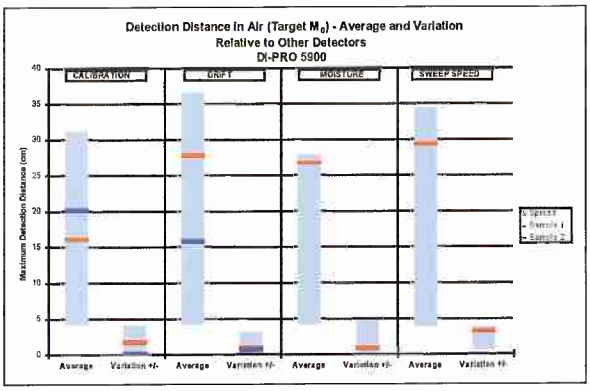
In-Soils Tests

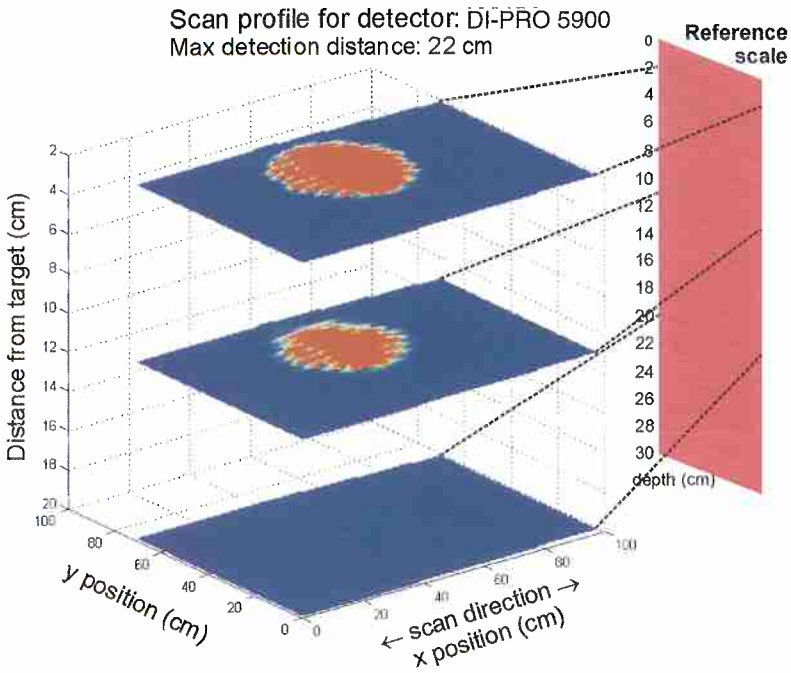




In-Air Tests







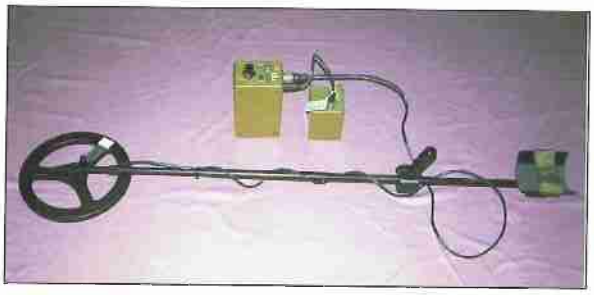
WHITE'S AF-108

Manufacturer Information:
White's Electronics Ltd
35J Harbour Road
Inverness IV1 1UA
Scotland
Telephone: +44 (0)1463 223 456
Fax: +44 (0)1463 224 048
http://www.whites.co.uk

IPPTC Cost: US $2,025

Weight/Dimensions:
Search head: 280 mm diameter
Boom/shaft: 596 - 1600 mm max.

Power Supply: 4 x 1.5V "D" size batteries

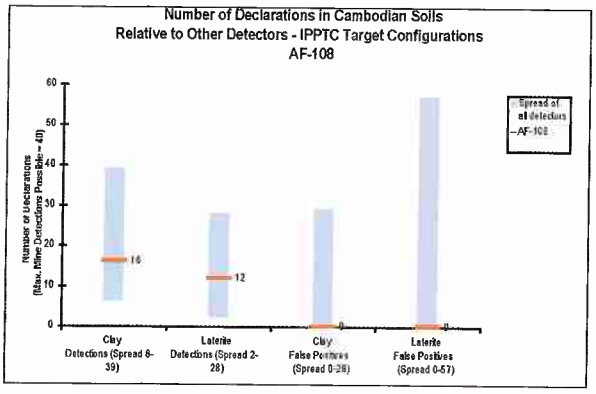


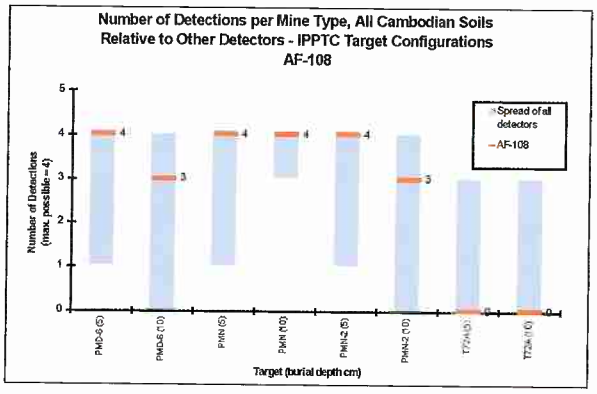
The AF-108 is White's military detector, and it operates on the pulse induction principle. It features both audio and visual indication (on the control box and search head) of targets. The rod, search head, headphones, control box and battery box of all AF-108s are interchangeable with each other should there be failure in one of the components.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

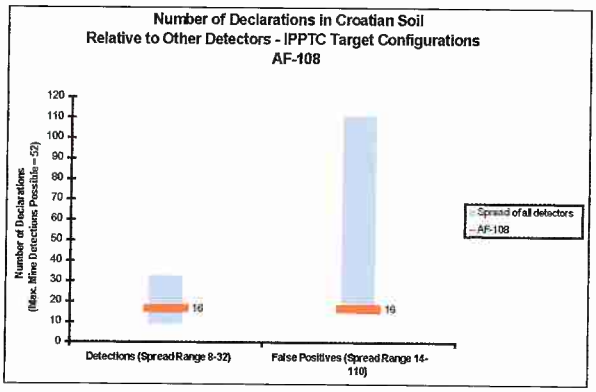
- Rugged
- Simple operation
- Good fault warnings
- Front-heavy leading to potential discomfort
- No separate external speaker
- Many cable connections

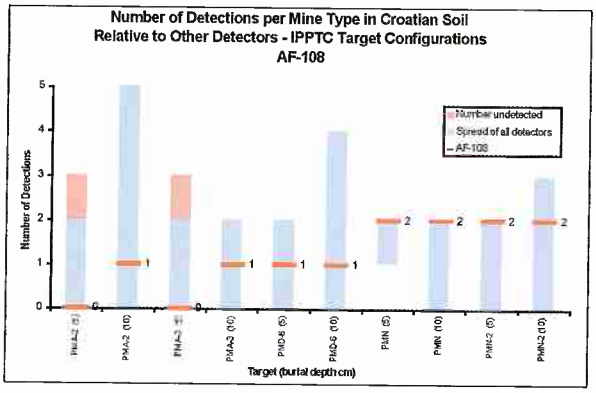
Field Tests – Cambodia





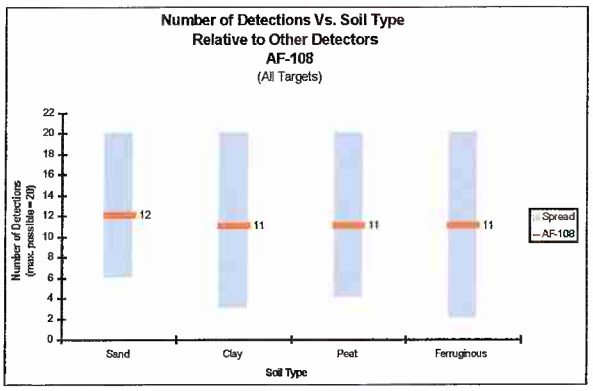
Field Tests – Croatia

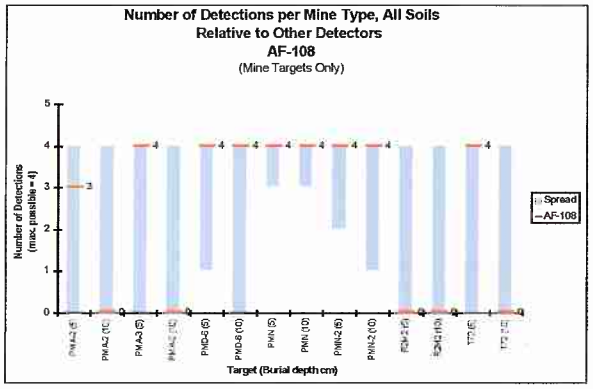




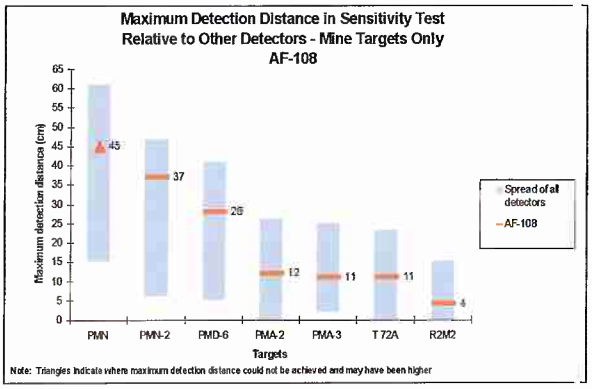
WHITE'S AF-108

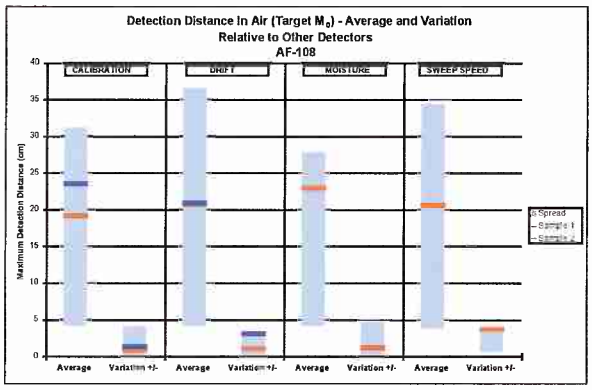
In-Soils Tests

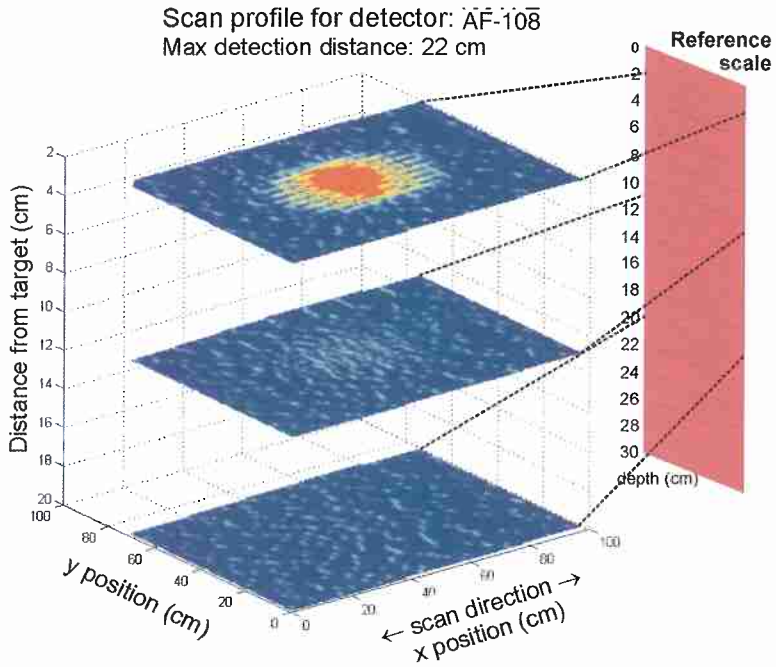




In-Air Tests







WHITE'S SPECTRUM XLT

Manufacturer Information:
White's Electronics Inc.
1011 Pleasant Valley Road
Sweet Home, OR 97386
USA
Telephone: +1 800 547 6911 (Distribution)
+1 541 367 6121 (Factory)
Fax: +1 541 367 2968
Email: whites@halcyon.com

IPPTC Cost: US $680

Weight/Dimensions:
Total Weight: 1.8 kg
Dimensions not available

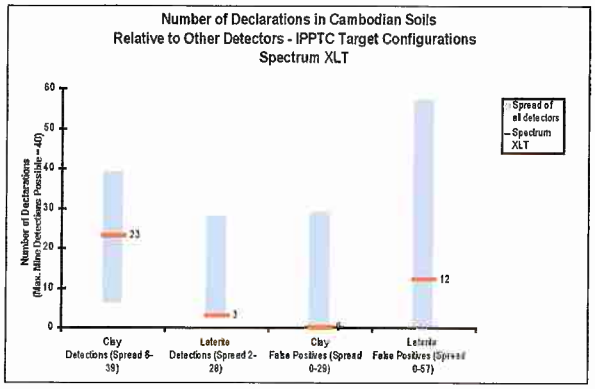
Power Supply: 8 x 1.5V "AA" cell batteries

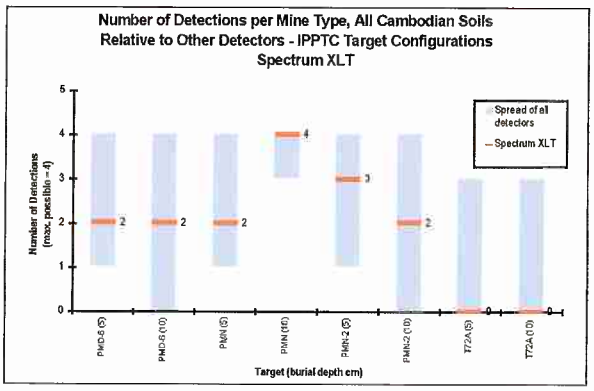
The Spectrum XLT is designed for the hobbyist and its many complex features are geared toward the treasure hunter. It features ground balance, variable audio tone, and a menu-driven LSD display. It can be used with standard or rechargeable batteries.

Strengths and Weaknesses Identified by IPPTC Human Factors Assessment:

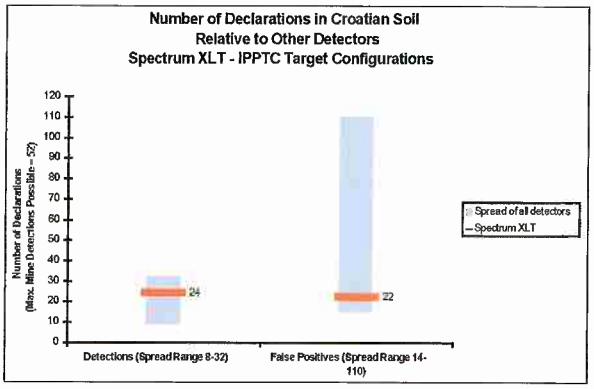
- Light and well balanced
- Choice of standard or rechargeable batteries
- Easy set up
- Many complex settings and options in a menu-driven display
- No weatherproofing
- Difficult menu leads to potential errors

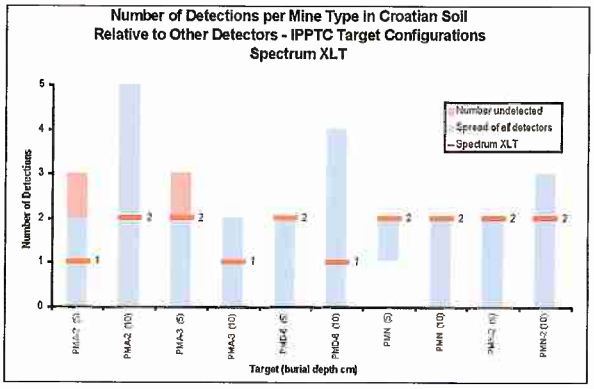
Field Tests – Cambodia





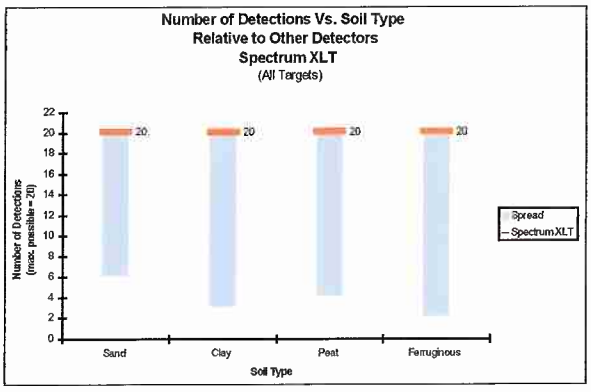
Field Tests – Croatia

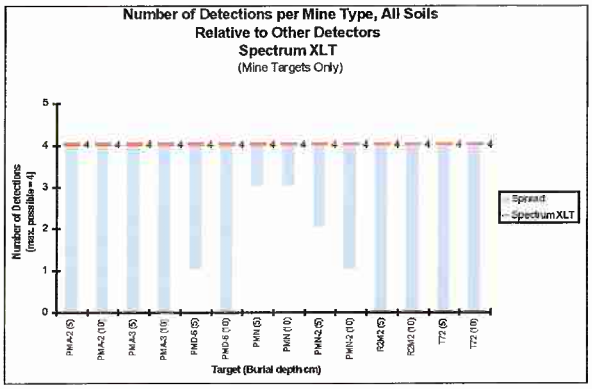




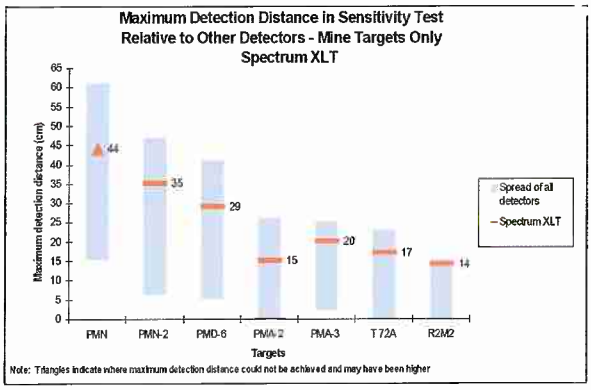
WHITE'S SPECTRUM XLT

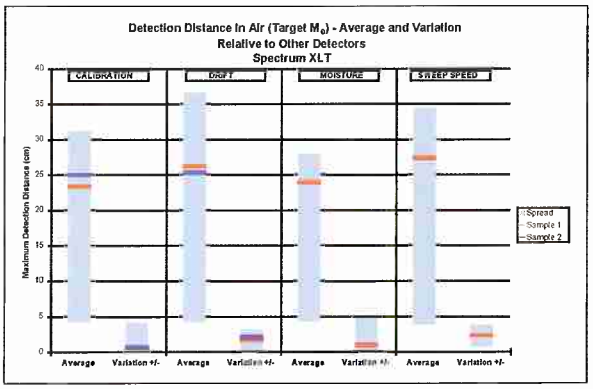
In-Soils Tests

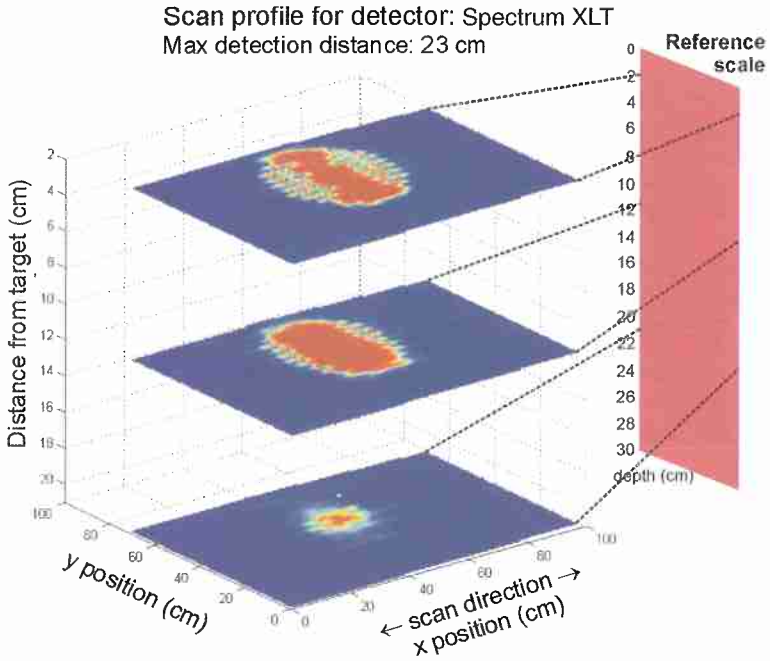




In-Air Tests







ANNEX B - Soil Measurements

Two environmental parameters have been identified having particular relevance to metal detector performance; electrical conductivity and magnetic susceptibility of soil. It is also known that magnetic susceptibility of a soil affects metal detector performance more than its electrical conductivity. Ideally, one would want to measure these soil properties over the frequency range of operation of metal detectors. However, such instruments are not readily available for field use at this time. For this project an approximate but achievable readily approach was adopted, and the relevant parameters were measured using the readily available survey instruments listed the table.

Ground conductivity: Geonics EM38, a well-known instrument in geophysical applications.

Magnetic susceptibility: Bartington MS2 - a susceptibility meter routinely used to measure magnetic susceptibility in fields such as environmental magnetism, soil science and geophysics. An MS2 with a D-coil sensor, designed for in-situ measurements, was used to measure volume susceptibility of the test lanes.

LOCATION	*Conductivity EM38 (horizontal) mS/m*			*Conductivity EM38 (vertical) mS/m*			*Susceptibility MS2 ($x10^{-5}$)*		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
TNO-FEL Test lanes									
Lane 1 – Sand	5.6 -10.4	3	4	10.7 6.9	8	1	9 1	3	2
Lane 2 – Clay	25.6 14.6	22	3	27.5 10.6	20	5	11 7	9	1
Lane 3 – Peat	28.4 17.9	23	3	26.5 10.5	18	6	24 11	16	3
Lane 4 – Ferruginous	3.3 -2.1	2	1	6.4 3.6	4	1	48 13	27	9
CROATIA									
Lane 1	18.9 0.4	12	4	12.5 -18.4	-7	5	264 3	140	63
Lane 2	25.3 -6.9	15	5	8.5 -19.8	-7	5	224 31	99	51
CAMBODIA									
Clay Lane	8.4 3.4	5	1	11.7 5	8	2	15 5	11	2
Laterite Lane	15.6 8	12	2	15.7 5.6	12	3	133 62	90	15

Soil conductivity and susceptibility measured on the IPPTC test locations.

For details of the measurement steps using these instruments, the approximations and errors involved, the reader should consult the relevant operational manuals [8, 9, 10].

At the Cambodia Field Test site, conductivity (mS/m) and susceptibility (MKS units) were measured every 1 meter along a straight line over the center of each of the two test lanes. Similar measurements were carried out over the soil lanes at TNO-FEL and over the Croatian test lanes. The mean values and their standard deviations are summarized in the table.

As seen from the table, the EM38 electrical conductivity is measured in two modes (vertical and horizontal). The horizontal mode is most sensitive at the surface and decreases with depth. The vertical mode is less sensitive to surface material (zero at the surface) and more sensitive at depth. The results for all the lanes are quite small (less than 24 mS/m) and are thought to have had no influence on detector performance.

Magnetic susceptibility varied significantly among the lanes – from a small value of 3 for the TNO-FEL sand lane to a value of 140 in the Croatian Lane 1. A value of the order of 140 will have an effect on metal detectors. The soils, listed in order of difficulty of detection of the targets for metal detectors, with most difficult soil first, are:

1. Croatia Lane 1
2. Croatia Lane 2
3. Cambodia Laterite Lane
4. TNO-FEL Lane 4 – Ferruginous
5. TNO-FEL Lane 3 – Peat
6. Cambodia Clay Lane
7. TNO-FEL Lane 2 – Clay
8. TNO-FEL Lane 1 – Sand

ANNEX C - Invitations to Participants

Examples of IPPTC Communications to Product Manufacturers and Test Facility Providers

This annex contains copies of three letters, sent by the US Department of Defense, relating to the initiation and in-country test phases of the IPPTC project.

1) Letter, dated 25 March 1999, requesting information from a manufacturer (White's of Mid-Atlantic) on Commercial Off the Shelf metal detector that could be suitable for the IPPTC action.
   An individual version of this letter was sent to each of the manufacturers of metal detectors that could be identified by the project team. The purchase of 29 examples of metal detector, used in the Pilot Project, resulted from these solicitation letters.

2) Letter, dated 19 January 2000, to Mr Khem Sophoan of the Cambodian Mine Action Center requesting support to the Pilot Project from CMAC.

3) Letter, dated 19 January 2000, to the Scientific Council of the Croatian Mine Action Center requesting support to the Pilot Project from CroMAC.

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301-2500

SPECIAL OPERATIONS/
LOW-INTENSITY CONFLICT

JAN 19 2000

Mr. Khem Spphoan
Cambodian Mine Action Center
Building 10+12, Road 528, Quarter Boeng kak 1
1 District Tuol Kok, P.O. Box 116
Phnom Penh
Cambodia

Dear Mr. Spphoan:

I am writing to inform you of an international initiative to foster cooperation in the development and testing of technology for humanitarian demining applications. The purpose of this project is to evaluate all existing, commercial-off-the-shelf metal detectors that are used for mine detection and may be potentially suitable for humanitarian demining. The intent of this evaluation is to identify which detectors are best suited for a particular geographical set of conditions or operational environment. This will enable demining organizations, or their donors, to narrow down the number of detectors that must be procured for further evaluation within their own unique operational requirements or parameters.

Representatives from government agencies in Canada, the Netherlands, the United Kingdom and the United States, as well as the Joint Research Centre of the European Commission, are conducting this project. Thus far, equipment evaluation has been conducted in the Netherlands and Canada. The purpose of this letter is to follow up on a previous visit by Mrs. Christine Lee who had discussions with Major Walker, and formally request that the Cambodian Mine Action Center (CMAC) play an active role in this project by offering to host the next phase of the project. The next step in the project will consist of field testing in several countries with mine problems, hopefully including Cambodia, to validate the previous laboratory testing.

Your cooperation in this project would be greatly appreciated. If you have any questions pertaining to this project, please contact me directly at (1) 703-693-5222, or by facsimile at (1) 703-693-3039.

Respectfully,

George Zalnaczewsky
Colonel, United States Army

cc:
Mr. Bou Puthy, CMAC

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301-2500

SPECIAL OPERATIONS/
LOW-INTENSITY CONFLICT

MAR 25 1999

Mr. A.K. Zorger
White's of Mid-Atlantic
4307 Derry Street
Harrisburg, PA 17111

Dear Mr. Zorger:

I am writing to inform you of a recent international initiative to foster cooperation in the development and testing of technology for humanitarian demining applications. I am sure you are aware of the daily threat posed by the past irresponsible use of antipersonnel landmines, and therefore recognize the value of a concerted international effort to ensure that the best tools available are placed in the hands of personnel engaged in the extremely hazardous task of detecting these "hidden killers."

The purpose of this international cooperative effort is to evaluate all existing, commercial-off-the-shelf metal detectors that are used for mine detection and may be potentially suitable for humanitarian demining. The intent of this evaluation is to identify which detectors are best suited for a particular geographical set of conditions or operational environment. This will enable demining organizations, or their donors, to narrow down the number of detectors that must be procured for further evaluation within their own unique operational requirements or parameters. For example, factors that will be considered in the evaluation include: detection ability in highly mineralized soil and in areas of high humidity; ergonomic factors such as weight and ease of use; reliability, maintainability and sustainability; and other factors including cost and ruggedness.

Representatives from government agencies in Canada, the Netherlands, the United Kingdom and the United States, as well as the Joint Research Center of the European Commission, are conducting this project. Actual equipment evaluation will be conducted in the Netherlands and Canada, with field validation testing of laboratory results planned for Bosnia-Herzegovina, Cambodia and Mozambique. A final evaluation report will be released to all interested parties in September 2000.

It is the intention of the project team that suitable metal detectors will be purchased from manufacturers to undergo the evaluation. Manufacturers will also be invited to provide their standard new equipment training packages for their detectors. The final report will not attempt to provide an overall ranking or, in any way, certify the detectors tested. The evaluation will tabulate each detector's performance against a specific list of criteria under a range of defined conditions, thereby highlighting those that should be considered for use under those specified conditions. The report will be

presented in a manner to assist the consumers, or users, of humanitarian demining mine detectors – governments, mine action centers, non-governmental organizations and donors -- in identifying the detectors that best suit their needs.

Your cooperation in this effort would be greatly appreciated. Initially, the project organizers request you provide the following information: (1) identify the detectors that you currently manufacture that are available now for retail sale and are suitable for use in humanitarian demining operations – please, no research and development prototypes; (2) highlight any technical concerns relating to the equipment that may impact on recording detector headphone output with an analog or digital interface; and (3) identify the appropriate sales representative that should be contacted to purchase three copies of each unit for subsequent evaluation.

Please respond no later than two weeks after receipt of this letter. Also, please be aware that our desire is to receive this equipment at the first test site in The Netherlands no later than May 24, 1999. Any equipment received after that date will not be included in the evaluation. Your sales representative will be contacted at a later date to arrange for appropriate equipment training after the detectors have been received.

Please provide the requested information to Mrs. Beverly Briggs at (1) 703-704-1073, or e-mail bbriggs@nvl.army.mil. The alternate POC is Mr. Sean Burke at (1) 703-704-1047, or e-mail sburke@nvl.army.mil. If you have any questions pertaining to this project, please contact me directly or the project coordinator, Colonel George Zahaczewsky, at (1) 703-693-5222, or by facsimile at (1) 703-693-3039.

Sincerely,

Robert C. Doheny
Director
Requirements, Technology and Acquisition

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301-2500

SPECIAL OPERATIONS/
LOW-INTENSITY CONFLICT

JAN 19 2000

Croatian Mine Action Center
ATTN: Scientific Council
Ulicia I. Mestrovica 30
44000 Zagreb
Croatia

Dear Sirs:

I am writing to inform you of an international initiative to foster cooperation in the development and testing of technology for humanitarian demining applications. The purpose of this project is to evaluate all existing, commercial-off-the-shelf metal detectors that are used for mine detection and may be potentially suitable for humanitarian demining. The intent of this evaluation is to identify which detectors are best suited for a particular geographical set of conditions or operational environment. This will enable demining organizations, or their donors, to narrow down the number of detectors that must be procured for further evaluation within their own unique operational requirements or parameters.

Representatives from government agencies in Canada, the Netherlands, the United Kingdom and the United States, as well as the Joint Research Centre of the European Commission, are conducting this project. Thus far, equipment evaluation has been conducted in the Netherlands and Canada. The purpose of this letter is to follow up on a previous visit by Dr. Denis Reidy, who had discussions with Dr. Milan Bajic, and formally request that the Croatian Mine Action Center play an active role in this project by offering to host and participate in the next phase of the project. The next step in the project will consist of field testing in several countries with mine problems, hopefully including Croatia, to validate the previous laboratory testing.

Your cooperation in this project would be greatly appreciated. If you have any questions pertaining to this project, please contact me directly at (1) 703-693-5222, or by facsimile at (1) 703-693-3039.

Respectfully,

George Zahaczewsky
Colonel, United States Army

References

1. Das Y., Toews J. D. Russell K., and Lewis S., Results of In-Air Testing of Metal Detectors (U), Technical Report TR-2000-185, Defence Research Establishment Suffield, Ralston, Alberta, Canada, December 2000.

2. Das Y., and Toews J. D., A Plan for In-Air Testing of Metal Detectors (U), Technical Memorandum TM-2000-184, Defence Research Establishment Suffield, Ralston, Alberta, Canada, December 2000.

3. Veer, Maj. Ir. P.J. de, Schoolderman Dr. A.J., In-Soil tests International Pilot Project for Technology Co-operation, TNO-report FEL-99-C253, (IPPTC) in metal (mine) detection (Commercial Confidential), Technical Report ABWM/18082 & FEL-00-A246, Royal Netherlands Army & TNO Physics and Electronics Laboratory, Netherlands, October 2000.

4. Schoolderman, Dr. A.J., Wolf F.J. de, Test Plan for Soil Tests, International Pilot Project for Technology Co-operation, TNO-report FEL-99-C253, TNO Physics and Electronics Laboratory, The Hague, Netherlands, December 1999.

5. Lee Christine J., International Pilot Project for Technology Co-operation, Cambodia Field Test Report, U.S. Army Communications and Electronics Command, Night Vision and Electronic Sensors Directorate, Fort Belvoir, VA, USA.

6. Reidy, D. M., International Pilot Project for Technology Co-operation: Croatia Field Test Report, U.S. Army Communications and Electronics Command, Night Vision and Electronic Sensors Directorate, Fort Belvoir, VA, USA.

7. Hooper A. and Mead R., IPPTC Humanitarian Mine Detection: Human Factors Assessments; DERA\LWS\LSAA\TR000599\1.0; DERA, Chertsey, UK, Nov. 2000.

8. EM-38 Ground Conductivity Operating Manual, Geonics Ltd., 8-1745 Meyerside Drive, Mississauga, Ontario, Canada, L5T 1C6, March 1999.

9. Dearing J., Environmental Magnetic Susceptibility: Using the Bartington MS2 System, Bartington Instruments Ltd., 10 Thorney Leys Business Park, Witney, Oxford, OX8 7GE, England, 1994.

10. Bartington MS2 Operation Manual.

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I-21020 ISPRA (Va), Italy

Mr. Steve Lewis
EC Joint Research Centre

(Please note that where addresses are similar, the full mail address is given only for the first participant from each center.)

Acknowledgements

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Defence Research Establishment Suffield:

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Warrant Officer Dirk Keij

Royal Netherlands Embassy, Washington, DC

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