DoD Humanitarian Demining Research and Development Program

HANDHELD METAL DETECTORS: NICARAGUAN FIELD TEST REPORT

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Background.

This final technical report details the results of a joint project between the United States Office of the Assistant Secretary of Defense for Special Operations and Low-Intensity Conflict (OASD-SO/LIC), the US Army Communications and Electronics Command (CECOM) Night Vision and Electronic Sensors Directorate (NVESD), the Organization of American States (OAS) (Organizacion de los Estados Americanos [OEA]), the Assistance Mission for Mine Clearance in Central America (la Misión de Asistencia para la Remoción de Minas en Centroamérica, [MARMINCA]), the Program for Demining in Central America (el Programa de Apoyo al Desminado de Centroamérica, [PADCA]), and the Inter-American-Defense Board (IADB) (Junta Interamericana de Defensa, [JID]).

The joint project was an in-country field evaluation of seven commercial off-the-shelf (COTS) handheld metal detectors. It was the result of an earlier Department of Defense (DoD) visit to Nicaragua to provide advice and recommendations on demining equipment as part of DoD's Humanitarian Demining Research and Development (R&D) program. The evaluation took place near Panchito, a high-priority minefield on a former Nicaraguan airbase where the magnetic properties of volcanic soil render conventional mine detectors extremely unreliable. The conduct of the field test was greatly enhanced through the assistance of officers from MARMINCA and experienced Nicaraguan deminers.

The in-country test helped to determine the applicability of results from a recent international assessment of 25 commercial off-the-shelf handheld metal detectors. This previous international effort tested and evaluated commercially available metal detectors suitable for humanitarian demining application. The participating nations for this effort were the United States, Canada, the Netherlands, the United Kingdom, and the European Commission's Joint Research Centre. The effort was called the International Pilot Project for Technology Cooperation (IPPTC). The IPPTC resulted in a final technical report to help agencies, such as MARMINCA, determine which detectors are best suited for a particular geographical set of conditions or operational environments and to narrow down the number of detectors that must be procured for further evaluation [1].

1. Project Overview.

The main objective of the testing was to evaluate the performance of seven different detectors, two of which are presently used in Nicaraguan demining, as well as five other detectors which were shown by the IPPTC to have promise when used in areas with soil that makes it difficult to detect mines. At a minimum, each detector was evaluated against a set of standard metal objects as well as inert landmine targets of concern for Nicaraguan deminers. Targets were buried at 5-cm, 10-cm, 15-cm, 20-cm, and 25-cm as measured from the surface down to the top of each target. The prime factor that was considered in this evaluation was probability of detection (Pd) and, secondarily, the accompanying false alarm rate (FAR).

Each detector's performance was equally compared to determine those that should be considered for use under the particular soil conditions found in Nicaragua. These soil conditions were represented by the red-colored and black-colored soil found near the Panchito airfield located on Las Tinajas peninsula on the northeast edge of Lago de Managua (see **Figure 1**). This report presents all the data and results from the in-country field testing performed during May 2001 in order to assist MARMINCA and the Nicaraguan demining community to identify and acquire the detector or detectors best suited to their needs based on the number of detections and false alarms over the particular soil type in the minefield.

Figure 1. *Map showing Las Tinajas, northeast of Managua. The test site was located near Panchito airfield on the peninsula.*

2. Project Methodology.

The detectors involved in the evaluation were chosen based on their overall performance in the previous IPPTC testing. When used to detect targets buried in soils with extreme magnetic and electrical properties (which made detection very difficult), some detectors showed greater detection capability than others. Of these detectors, five were chosen based on their having some soil compensation techniques and showing the most detections in difficult soils in the previous IPPTC trials. In addition to these five, two other detectors were chosen because they were presently in use by the Nicaraguan deminers. These last two detectors were both versions of the Schiebel AN-19/2 detector. Neither of the two Schiebel detectors had soil compensation techniques.

(NOTE: Since the initiation of the IPPTC project from which the above detectors were selected, several new detector models have entered the market and are currently being offered to the humanitarian demining community. The complete listing of previous models may be found in the final report of the IPPTC [1]. 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 the manufacturers about implications of actual and potential changes prior to acquisition.)

The detectors included in this testing are shown in **Table 1**.

MANUFACTURER	MODEL	PROJECT CODE
Ebinger	EBEX 420 GC	EB42-2
Foerster	MINEX 2FD 4.400.01	FOMI-1
MineLab	F1A4 CMAC	MICM-1
MineLab	F1A4 MIM	MIMI-1
Pro-Scan	Mark 2 VLF	PRMA-2
Schiebel (older version)	AN-19/2	SCAN-0
Schiebel (newer version)	AN-19/2	SCNN-0

Table 1. *List of detectors tested showing manufacturer and model type and inventory code used for each item during the project.*

The testing evaluated the detectors against inert, empty POMZ anti-personnel (AP) landmines and also landmine simulants: G_0, I_0, M_0 (aluminum tubes). For full descriptions, see **Appendix A**). In one instance, the metal parts from a PMN-2 anti-personnel landmine were available and were also used in the testing. The POMZ and the PMN-2 are the two mines reportedly encountered in the Panchito minefield. The inert POMZs and the PMN-2 components used in this effort were provided by the Nicaraguan Army.

In designing this field test, 5- and 10-cm were chosen as the two depths at which the simulant targets were to be buried, as these targets contained little metal and the signal would quickly be obscured upon burial. 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 commonly 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.

The inert POMZ target mines were buried at a greater range of depths. In Nicaragua, soil crevasses open in the ground surface, due to the actions of heavy rainfall filtering through cracks in the soil that form during dry spells. The POMZ landmines, normally emplaced at or above the ground surface on spikes, have been dislocated and fallen into these crevasses down to a reported depth of 0.5 meters. Although having a significant amount of metal for the metal detectors to find, at these depths the signal is very weak. For the purposes of this test, the inert POMZ targets were emplaced from 10-cm down to 25-cm, measured to the top of the mine, and with the POMZ positioned horizontally.

(*NOTE: Although PMN-2 anti-personnel landmines are also present in the area, the metal parts from only one inert PMN-2 were available for testing. This one set of metal parts was buried at 10 cm.*)

3. Field Test.

3.1. Objective.

The main objective of the field test was to evaluate and demonstrate the ability of detectors with proven soil compensation techniques. The detectors were tested for their ability to detect mines in local soils that already had been proven to make detection difficult. The factors considered in this evaluation included: 1) detection of targets buried at various depths, and 2) the occurrence of false alarms.

3.2. Test Procedures.

In order to adequately train local instructors and deminers on the given set of detectors, without impacting the overall schedule, the training and testing were conducted in the following fashion on a daily basis for five days. Each day, two instructors trained all the deminers on a given type of detector for a period of two hours, which included time to work with the detector over a set of readily visible buried targets in a nearby calibration area. While this may have been a limited period of time compared to the usual training regimen for deminers, it was adequate for the purposes and resources available for this testing and gave the experienced deminers a working knowledge of each detector.

A pair of deminers was then selected to conduct each test run for the detectors. The deminers calibrated a given detector in accordance with the manufacturer's instructional manual, against known targets and soil types to optimize the detector sensitivity. Operators were instructed to operate their equipment in accordance with their standard demining practices. However, they were requested to disregard any visual clues and rely only on the detector signals to ensure that the detectors were given a proper evaluation. It was explained to the deminers that they were testing the detectors and not their personal demining experience. Once the training and practice was complete, the operators began the actual detector evaluation in the test lanes.

Each operator started at the beginning of each test lane (described below) and moved forward as they swept the lane, placing a marking chip at the center of each suspected target location. At the completion of each test lane, support team members measured and recorded the X-Y coordinate of each of these markers. The location of each marker was compared to the ground truth. A target was considered detected when a marker was placed within a 20-cm radius from the center of the target. This radius was used to account for inaccuracy in placing markers precisely in the center of a suspected target as well as to account for any inaccuracies in position measurements. When a marking chip fell outside of the radius, it was considered a false alarm. In this test, no attempt was made to determine the source for each false alarm.

4.3 Test Site.

The test site itself was chosen in coordination with the local Nicaraguan demining team and demining specialists from MARMINCA. It was hoped that the test site would provide results in conditions as comparable to the nearby minefield as possible. This entailed being able to test in two different soil types that were evident in the area, a black, silty type of soil and a red, silt/clay soil (see **Figure 2**).

Figure 2. *Representative views of the two different soil types as differentiated by apparent texture and color: black silty soil (left) and red silt/clay soil (right). (These two pictures were taken within 10–m of each other along a dirt road bed 100-m from the minefield in question.)*

Both soil types were in evidence throughout the area and, from the depths of postholes that had been driven in a nearby roadbed, extended to various depths from surface layer down to at least 0.5 meters. Other soil types, appearing with a silty brown as well as with a white-to-gray clay appearance, were also evident.

According to the local deminers and MARMINCA, the black soil itself generated many signals from a detector without soil compensation, and the red soil yielded even more signals, making detections of actual landmines very difficult. It was determined that to satisfactorily apply the results of the testing to either the black or the red soil for comparison, testing had to proceed in a similar fashion in both soils types. This entailed halving the time and the number of targets available for testing, to cover both soil types. This, in turn, led to a smaller number of target opportunities (samples) than would have been preferred.

The test site was set up to include two test lanes (one for each soil type) plus a small training /calibration area. Each test lane was 1-m wide, and 20-m long, containing a total of 15 targets three of each of G_0, I_0, and M_0 tubes simulants and six each of the inert POMZ mines. (In one lane - red soil - the metal parts from the single PMN-2 were used, replacing one of the inert POMZ mines.)

The metal content of the simulants determined the range of burial depths. Given the low metal content of the simulants and desiring to detect them with some of the detectors, the G_0, I_0, and M_0 simulants were buried at 5-cm and 10-cm depths. The inert mines, having much more metal content, and so being more readily detected, were buried at a greater range of depth, from 10-cm down to 25-cm. All depths were measured from the surface of the ground to the highest point of the target when emplaced. One copy each of each target (except the metal parts of the PMN-2) was buried in the nearby training/calibration area. Here, each target was buried with its top visible at the soil surface in order to facilitate the training by allowing the deminers being trained to see the object as they heard a signal when passing the detector over each target. The deminers were trained to compensate for burial depth in the calibration lane by raising the head of the detector to the required height with the understanding that this was being done in air versus through the soil.

(NOTE: To keep those deminers who are being trained from witnessing the locations picked by those deminers who were testing at the same time, the training/calibration area was situated far enough apart so that those who were testing could not easily be seen by those training.)

Before burying the targets, the calibration area and test lanes were certified as clear of extraneous metal, using one of the MineLab F1A4 CMAC detectors. Two signals were detected in the red soil lane. For this reason, no targets were buried within one meter of the locations of these signals. After burial, the area was scuffed (and, ultimately, rained upon), so that any traces of target locations were not apparent to the naked eye.

Figure 3. *Construction of the 1-m by 20-m test lanes, the black soil lane (left) and the red soil lane (right). (NOTE: The black soil lane can be seen further down the road in the red soil lane picture (right), showing the near proximity of the lanes.)*

4.4 Test Targets and Test Lane Description.

Prior to testing, the lanes in an area containing both soil types were laid out. Both test lanes were clear of vegetation other than grass and their surface was flush with the ground. As stated before, the lanes were swept with a MineLab F1A4 CMAC to determine any already-existing signals. Two signals were found in the red lane and no targets were buried within one meter of these signals. Each test lane was 1-m wide, and 20-m long (**Figure 4**). A combined total of 30 targets were buried in both test lanes.

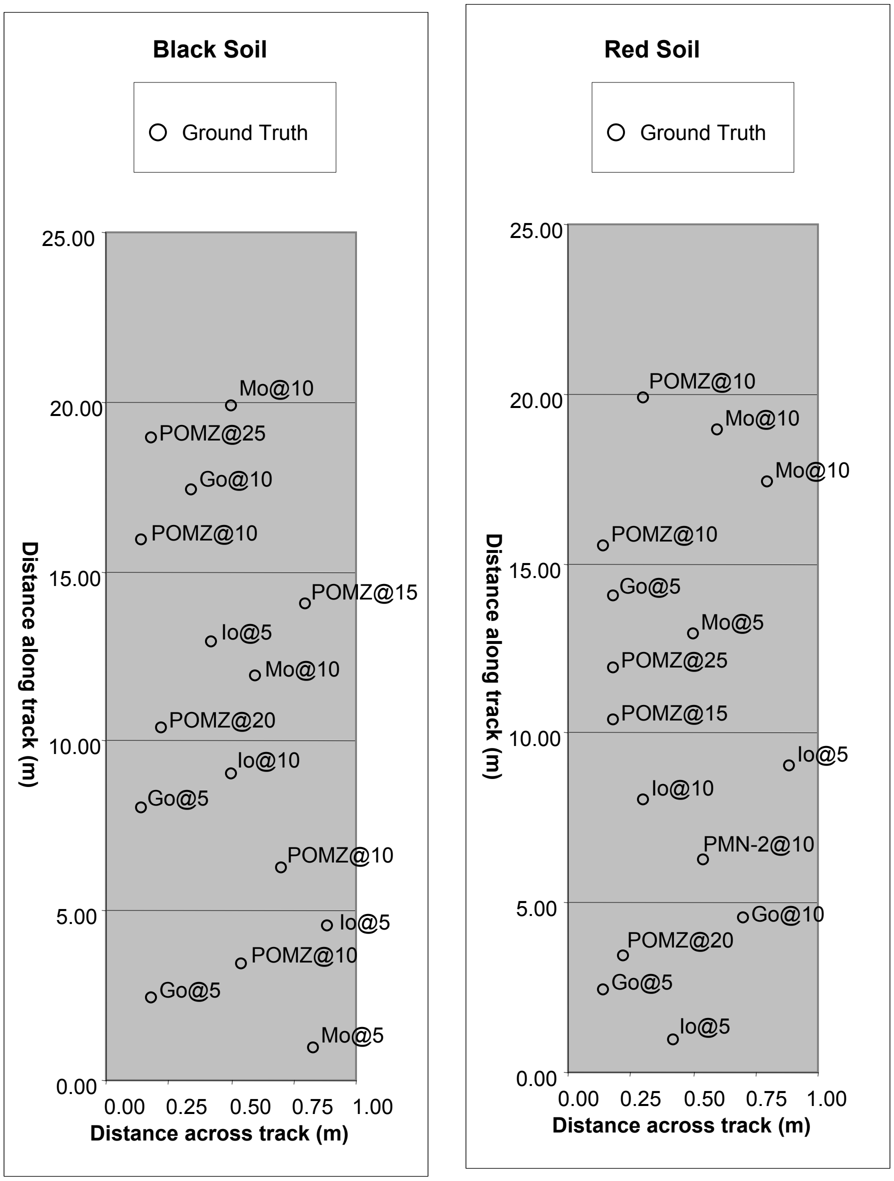

Figure 4. *Layout of the black soil lane and red soil lane (not to scale) showing positions and distribution of ground truth (e.g., "POMZ@10" = POMZ inert mine target at 10 cm depth).*

Target Type	X-Coordination, meter	Y-Coordination, meter	Depth, cm
AL Tube	0.82	0.86	6.00
Go	0.21	1.99	8.00

POMZ	0.55	3.39	8.00
Io	0.89	4.51	7.00
POMZ	0.70	6.22	9.00
Go	0.15	7.95	6.00
Io	0.53	9.03	10.00
POMZ	0.24	10.35	19.00
AL Tube	0.62	11.87	15.00
Io	0.47	12.87	5.00
POMZ	0.82	14.05	16.00
POMZ	0.18	15.86	10.00
Go	0.36	17.33	16.00
POMZ	0.15	18.89	22.00
AL Tube	0.48	19.95	13.00

Table 2. *Ground truth locations of targets for the black soil lane upon removal.*

Target Type	X-Coordination, meter	Y-Coordination, meter	Depth, cm
Io	0.41	0.90	6.00
Go	0.15	2.44	9.00
POMZ	0.18	3.47	19.00
Go	0.73	4.50	11.00
PMN-2	0.52	6.27	12.00
Io	0.29	7.89	12.00
Io	0.91	9.06	6.00
POMZ	0.20	10.41	17.00
POMZ	0.18	11.91	23.00
AL Tube	0.50	12.92	5.00
Go	0.18	14.06	6.00
POMZ	0.13	15.53	10.00
AL Tube	0.79	17.39	7.00
AL Tube	0.54	18.94	10.00
POMZ	0.29	19.94	10.00

Table 2. *Ground truth locations of targets for the red soil lane upon removal.*

Tables 2 and 3 show the actual X and Y coordinates for the targets shown in **Figure 4** along with their depths.

4.5. Test Site Conditions.

The weather at the site was reported to be typical for the beginning of the local rainy season. There were episodes of precipitation almost daily for the duration of our test. This left the ground very moist for the testing, to the extent that puddling was common on the edges of the test lanes (refer back to **Figure 3, left**). The temperature, during testing, was measured between 37 and 41 degrees Celsius (99 and 106 degrees Fahrenheit). Outside of taking temperature measurements, no measurements were made of the high humidity throughout the trial, nor were any soil measurement data taken.

4.6 Test Procedure.

One sample of each detector was tested in the test lanes with the other sample being on-site as a backup. Each detector was tested over both lanes in a serial fashion, with a different operator for each lane. In the training area at the beginning of each test day, each operator reviewed with the instructors the standard method of setting up the detector according to the manufacturer's specifications. Prior to each test, the operator then calibrated the detector in accordance with the operating manual in the training/calibration area. Once calibration was completed, the operators were required to spend some time working with the detector to increase their familiarization with its signals. After this period of familiarization, they began the actual test in the test lane. The search procedure used was a slow back-and-forth sweep with the sensor head as close as possible to the ground as the detector carefully moved forward.

The first copy of each detector was used for the testing with the following exceptions:

Ebinger EBEX 420GC:	Sensitivity/compensation knob was loose.
Pro Scan Mark 2 VLF:	Possibly not fully charged

In these cases, another copy was used in the test instead. Test incident reports (TIRs) were filed for each of these detectors (see **Appendix B**).

Since there were only two lanes, but only one copy of each detector being tested, the following method was utilized:

1) One operator from a team tested Detector Type 1 in Lane 1, while an operator from the other team tested Detector Type 2 in the other lane.

2) When each operator was done, the second operator from each team took the detector and switched to the other lane. That way, a detector covered both lanes with two different operators, averaging operator effects between the two members of the team. Further, to reduce memorization, each operator only covered one lane a day and, on the next day, with a new detector, went over the other lane.

In the lanes, the operators placed markers (a standard plastic "poker chip") where a signal was heard and then pinpointed. The operator swept the 1-m width of the test lane and continued to move forward until he had covered the entire test lane. One to two hours were required for each lane.

As the operator neared completion of each test lane, two engineers/support staff measured the distance in the X and Y axes where the poker chip was placed and recorded these measurements on a data collection sheet. The positions of the poker chips were measured using the same tape measure along the lane (with offset noted) and a meter stick across the lane that was used to measure the locations of the targets upon burial. Test personnel documented the test by completing the data collection sheets, and any pertinent TIRs (see **Appendix B**). The results of each test run were recorded electronically each day in Excel spreadsheets. Preliminary checks of these results were made by comparing them to the positions of the targets measured at the time of burial.

The testing was completed in under a week. At that point, the targets were excavated and their positions were re-measured using the tape measure and meter stick for comparison to the original readings for quality assurance. As discussed below, the final measurements of the target positions were used for the ground truth against which the detector declarations were scored.

4.7 Ground Truth, Detections, and False Alarms.

The definition of what constituted a detected target was a given declaration made by the deminer (by placing a marker on the ground) that was collocated with one of the buried. The means for doing this collocation was to measure the positions of the targets and the positions of the markers and correlate them in the scoring. With any such system, there will be some inherent error in positioning. To allow for this error, as well as to give the benefit of the doubt to the detectors being evaluated, a simple method was to allow some leeway in the positioning of the detections. This leeway took the form of a +/- radius or "halo" around the measured center of each target. To give an adequate halo that would a) subsume any positional errors, b) give each detector type the benefit of the doubt, and c) minimize the introduction of spurious determinations of detected targets, a halo of 20-cm around the center of each target was used. When the targets were put in the ground, their positions as well as depth were measured using: 1) a meter stick, with left-to-right (facing down the lane) across the 1-meter track to get the X-coordinate, 2) a tape measure stretched from the beginning left corner along the length of the track to measure the Y-coordinate, and 3) a vertical ruler held against a straight-edge level with the ground surface down to the center top of each target to obtain the Z-coordinate. Each lane had its own relative coordinate system. This procedure was performed for each target upon burial, as well as upon removal for quality assurance on the position of the targets. The comparison of the burial and removal coordinates showed that for the cross track measurements (X-coordinates), there was agreement to within 5- to 6-cm for each position except for two agreeing within 8-cm and another at 10 cm. One other exception was adjusted when it was discovered that the coordinate was read at burial. This was adjusted by using the measurements at removal that revealed the offset (see **Tables 4 and 5**).

	Difference		
Target Type	**X-Difference, cm**	**Y- Difference, cm**	**Depth, cm**
AL Tube	1.00	8.00	-1.00
Go	-3.00	adjusted	-3.00
POMZ	-1.00	2.00	2.00
Io	-0.10	5.00	-2.00
POMZ	0.00	4.00	1.00
Go	-1.00	4.00	-1.00
Io	-3.00	2.00	0.00
POMZ	-2.00	4.00	1.00
AL Tube	-2.00	2.00	-5.00
Io	-5.00	5.00	0.00
POMZ	-2.00	1.00	-1.00
POMZ	-4.00	8.00	0.00
Go	-2.00	6.00	-6.00
POMZ	3.00	3.00	3.00
AL Tube	2.00	-6.00	-3.00

Table 4. *Difference in measured positions of targets between burial and removal for the black soil lane.*

	Difference		
Target Type	**X- Difference, cm**	**Y- Difference, cm**	**Depth, cm**
Io	1.00	4.00	-1.00
Go	-1.00	0.00	-4.00
POMZ	4.00	-6.00	1.00
Go	-3.00	6.00	-1.00
PMN-2	2.00	-1.00	-2.00
Io	1.00	10.00	-2.00
Io	-2.10	-1.00	-1.00
POMZ	-2.00	-2.00	-2.00
POMZ	0.00	-2.00	2.00
AL Tube	0.00	0.00	0.00
Go	0.00	0.00	-1.00
POMZ	1.00	-4.00	0.00
AL Tube	1.00	0.00	3.00
AL Tube	6.00	-2.00	0.00
POMZ	1.00	-5.00	0.00

Table 5. *Difference in measured positions of targets between burial and removal for the red soil lane.*

4.8 Test Data Analysis and Results.

The major results from the analyses of all the detectors tabulated for all targets were examined for the black soil and the red soil individually, as well as combined.

4.8.1 Black Soil.

Examination of **Table 6** indicates the number of detections for each detector in the black soil lane. The six POMZ targets were buried from 10 to 25 cm, and the G_0, I_0, and M_0 simulants were buried at 5-cm and 10-cm depths. An initial look seems to indicate that all the detectors were able to detect all the POMZ targets, even down to 25 cm. This indicates that the depths used in the black soil were not sufficient to place the targets beyond the detection range of any of the detectors. As for the low-metal targets, only two detectors (Ebinger EBEX 420 GC and the Pro-Scan Mark 2 VLF) showed consistent results in detecting these targets, although they did not detect all of them in the black soil.

Detector	Number of POMZs Detected (max=6)	(No PMN2s)	Number of Mo AL Tubes Detected (max=3)	Number of Io Detected (max=3)	Number of Go Detected (max=3)
EB42-2	6		1	2	1
FOMI-1	6		2	0	0
MICM-1	6		1	0	0
MIMI-1	6		0	0	0
PRMA-2	6		1	1	1
SCAN-0	6		1	0	0
SCNN-0	6		2	0	0

Table 6. *In the black soil lane, the number of targets of each type detected by each detector. (Maximum number of targets to detect for each type is indicated.).*

4.8.2 Red Soil.

Examination of **Table 7** indicates the number of detections for each detector in the red soil lane. The five POMZ targets and one PMN-2 target were buried from 10 to 25-cm, and the Io and Go targets were buried at 5-cm and 10-cm depths. An initial look seems to indicate that only four of the detectors (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, MineLab F1A4 CMAC, Pro-Scan Mark2 VLF) were able to detect all 5 POMZ targets and the PMN-2, even down to 25-cm. As for the low-metal targets, none of the detectors did very well on the I_0 and G_0 targets and only three detectors (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, and MineLab F1A4 CMAC) showed any detection of the M_0 tubes in the red soil, although they did not detect all of them.

Detector	Number of POMZs Detected (max=5)	Number of PMN2s Detected (max=1)	Number of Mo AL Tubes Detected (max=3)	Number of Io Detected (max=3)	Number of Go Detected (max=3)
EB42-2	5	1	1	0	0
FOMI-1	5	1	1	0	0
MICM-1	5	1	2	0	0
MIMI-1	4	0	0	0	0
PRMA-2	5	1	0	1	0
SCAN-0	4	0	0	0	0
SCNN-0	4	0	0	0	0

Table 7. *In the red soil lane, the number of targets of each type detected by each detector. (Maximum number of targets to detect for each type is indicated.)*

5. Summary of Test Results.

The main purpose of this field test was to evaluate the performance of detectors shown to have good soil compensation capability in the soil near Panchito airfield, which has made detection of mines difficult. This evaluation would help Nicaraguan authorities decide on the acquisition of metal/mine detectors as one of the suggested methods to clear this particular minefield. Two soil types with different properties were found at the site, one being black and one red, each making mine detection difficult, especially in the case of the red soil. The five detectors with known soil compensation capability, and two detectors without, were tested in both soil types. The summary of detection results for both soil types is shown in **Table 8.**

Examination of **Table 8** indicates the number of detections for each detector in both the black and the red soil lanes. The eleven POMZ targets and one PMN-2 target were buried from 10 to 25 cm, and the M_0, I_0, and G_0 targets were buried at 5-cm and 10-cm depths. Four of the detectors (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, MineLab F1A4 CMAC, Pro-Scan Mark2 VLF), all of which having soil compensation capability, detected all the POMZ targets in both the black and red soils as well as a good number of the low-metal simulant targets. Three of the detectors (MineLab F1A4 MIM, Schiebel AN-19/2 (older version), Schiebel AN-19/2 (newer version), detected all the POMZ targets in the black soil and almost all of the POMZ targets and PMN-2 target in the red soil, but only detected a few of the low-metal simulant targets (M_0, I_0, G_0).

Detector	Number of POMZs Detected (max=11)	Number of PMN2s Detected (max=1)	Number of AL Tubes Detected (max=6)	Number of Io Detected (max=6)	Number of Go Detected (max=6)
EB42-2	11	1	2	2	1
FOMI-1	11	1	3	0	0
MICM-1	11	1	3	0	0
MIMI-1	10	0	0	0	0
PRMA-2	11	1	1	2	1
SCAN-0	10	0	1	0	0
SCNN-0	10	0	2	0	0

Table 8. *In both soil lanes, the number of targets of each type detected by each detector. (Maximum number of targets to detect for each type is indicated.)*

It can be seen that the results for the detection of the low-metal simulant targets (M_0 = 0.66 g, I_0 = 0.172 g, G_0 = 0.33 g) are the determining factor in maximum detection since only 18 targets were detected out of a possible 30, showing that most of these low-metal objects were largely ignored. But these same low-metal objects also become the discriminator in separating out the group of four detectors (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, MineLab F1A4 CMAC, Pro-Scan Mark2 VLF) that detected some of these objects from those detectors that did not (MineLab F1A4 MIM, Schiebel AN-19/2 (older version), Schiebel AN-19/2 (newer version)).

Of the three that could not detect the low-metal objects, two of the detectors (Schiebel AN-19/2 (older version), Schiebel AN-19/2 (newer version)) did not have soil compensation and should not be expected to fare as well as the others when in difficult soil of this type.

The third detector (MineLab F1A4 MIM) did have soil compensation but did not do well. This result is surprising in that the closely related model MineLab F1A4 CMAC did better. The deminers noted this discrepancy in compensatory capabilities during training with these two MineLab detectors. While the CMAC version could be adjusted for soil compensation in both the black and red soils, a suitable calibration of the MineLab F1A4 MIM in the red soil could not be performed, as the properties of the soil seemed to exceed the compensatory capabilities of the detector. The reason for the difference in their capabilities was not investigated in this field report but according to later personal communications from MineLab, these two models have significant differences.

The summary of the detection results is presented along with the number of false alarms in **Figure 5**. The results show that, while some detectors performed better than others, no single detector was capable of finding all the targets in both soils. This was interpreted as an indication of the difficulty of the soil conditions for detection.

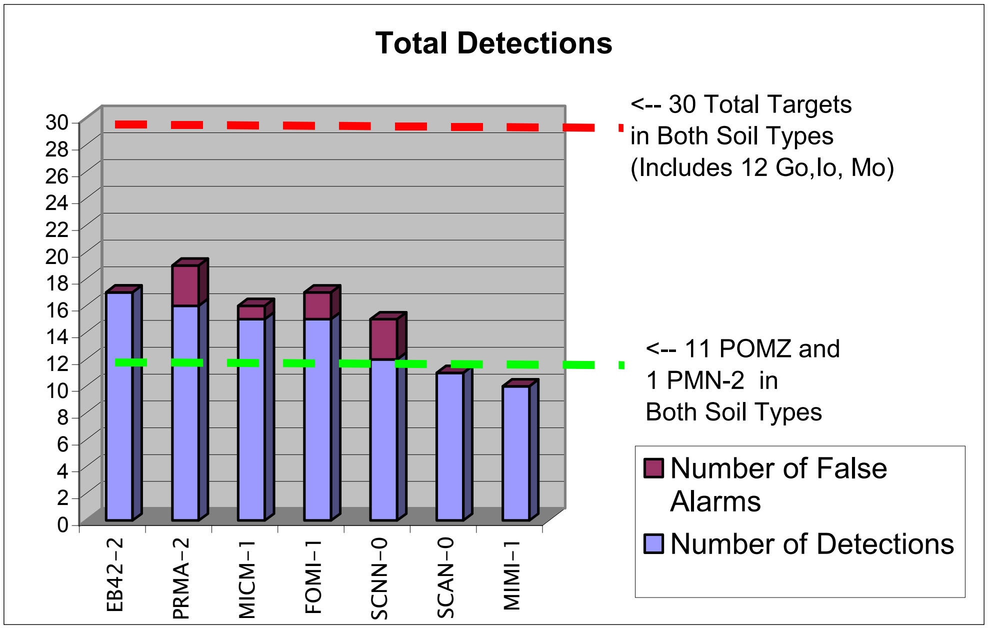

Figure 5. *In both soil lanes, the number of targets of each type detected by each detector along with the number of false alarms.*

6. Conclusions.

Based on the analyses of the test results from the Nicaraguan field test, the following conclusions can be made (see **Figure 5**).

- Among the seven detectors, there is a simple breakout of performance determined by four that detected all the POMZ and the PMN-2 targets and also some of the low-metal targets (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, MineLab F1A4 CMAC, Pro-Scan Mark2 VLF). Given the somewhat uncontrolled nature of any field test, fine distinctions between detectors on the order of a single detection are unwarranted. But these four detectors performed better than the remaining three.

- The low-metal objects became the discriminator in separating out the group of four detectors (Ebinger EBEX 420 GC, Foerster Minex 2FD 4.400.01, MineLab F1A4 CMAC, Pro-Scan Mark2 VLF) that detected some of these objects from those detectors that did not (MineLab F1A4 MIM, Schiebel AN-19/2 (older version), Schiebel AN-19/2 (newer version)). It is significant that any of these objects were detected in either the black and red soil type as they contain very little metal ($M_0 = 0.66$ g, $I_0 = 0.172$ g, $G_0 = 0.33$ g).

- The results show that, while some detectors performed better than others, no single detector was capable of finding all the targets in both soil types. This was interpreted as an indication of the difficulty of the soil conditions for detection.

- All of the detectors did well against the POMZ and PMN-2 targets at the depths of 10-cm to 25 cm. Due to limited resources, there were not enough targets or time to bury more down to 50-cm. Future testing should attempt to include these objects at greater depths.

- At least the leading four detectors show, through their detections of the low-metal targets, the advantages of soil compensation capability in negating soil effects while still retaining signals from buried metal targets.

- This report only assessed the detection rates and false alarms of the detectors. Other factors such as ease of use, reliability, maintainability, and other human factors such as ease of operation, size, weight, etc. should be included in further evaluations of these detectors.

REFERENCES

[1] International Pilot Project for Technology Cooperation (IPPTC) Final Report: A multinational technical evaluation of commercial off the shelf metal detectors in the context of humanitarian demining." Editors: Y. Das (CA), J.T.Dean (EC), D. Lewis (UK), J.H.J. Roosenboom,(NL), G. Zahaczewsky (US)

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And to the Nicaraguan Army Officers and deminers stationed in the Panchito Front of Operations for their support in the execution of the evaluation. Without their support the evaluation would not have been possible.

APPENDIX A

Target Descriptions

Landmine Simulants

G_0	Very small copper tube, 0.5-inch length x 0.125-inch O.D x 0.015-inch wall thickness [0.393 g].
I_0	Small aluminum tube, 0.5-inch length x 0.187-inch O.D. x 0.015-inch wall thickness [0.172 g].
M_0	Large aluminum tube, 1.5-inch length x 1/4-inch diameter x 0.015-inch wall thickness [0.66g]

Adapted from "Scientific and Technical Report, Simulant Mines (SIMs), October 21, 1998 Updated 02/19/99", published by US Army TACOM Project Manager's Office for Mines, Countermine and Demolitions (Countermine Division), ATTN: AMSTA-LC-AD-C, 10221 Burbeck Road, Fort Belvoir, VA 22060-5806.

Inert Landmines

POMZ	The POMZ-2 is a fragmentation stake mine consisting of a serrated cylindrical cast-iron sleeve, a 75-gram TNT charge, a MUV-type tripwire fuze, and a wooden stake. Only the empty cast-iron sleeve was used for this testing. This sleeve is made of cast iron, 60 mm in diameter, and massing 2.3 kg
PMN-2	This testing only used the blast resistant pressure fuze in the PMN-2, 3 inches in length and mass not known.

Adapted from "ORDATA II, Version 1.0: Enhanced International Deminers' Guide to UXO Identification, Recovery, and Disposal (CD-ROM), Naval Explosive Ordnance Disposal Technology Division, ATTN: Code 602, 2008 Stump Neck Road, Indian Head , MD, 20640-6945.

APPENDIX B

TEST INCIDENT REPORTS

Test Incident Report	**Date Incident Occurred:**
Test Title: Nicaraguan Field Test	29 May 01

SYSTEM DATA	
Model Number: EBEX 420GC	**IPPTC Code: EB42-2**
Manufacturer: Ebinger	

INCIDENT DATA	
Date: 29 May 01	**Time: 9 AM**
Operator's Name: Denis Reidy	**Test Lane #: Training Area**
Incident Status: Broken	
Incident Description: ON/OFF sensitivity switch is loose.	
Action Taken: Not used, replaced with EB42-3 copy instead.	
Name of Preparer: Denis M. Reidy	

Test Incident Report	**Date Incident Occurred:**
Test Title: Nicaraguan Field Test	Original TIR missing

SYSTEM DATA	
Model Number: ProScan Mark 2 VLF	**IPPTC Code: PRMA-1**
Manufacturer: ProScan	

INCIDENT DATA	
Date:	**Time:**
Operator's Name: Denis Reidy	**Test Lane #: Training Area**
Incident Status: No power	

Incident Description:

Possibly not fully charged.

Action Taken:

Not used, replaced with PRMA-2 copy instead.

Name of Preparer: Denis M. Reidy