ZuDA
1999

April 26, 1999

MEMORANDUM

SUBJECT: Unexploded Ordnance Information

FROM: Chuck Hendrickson, CRH
USEPA Region 6

TO: Ft. Wingate Depot BCT/RAB members and stakeholders

I'm sending the unexploded ordnance (UXO) information, attached, that I brought to the BCT meeting on March 10th, to those of you that expressed an interest.

I've also found and included some more-current information. It is the summary section on the latest Department of Defense testing of UXO remediation effectiveness. As you will read, DoD is trying to find the best ways to remediate UXO sites, but has not found a good solution. The more-recent testing results are mostly better than the 1992 results, some much better. But the new technologies still have some big limitations. And clearance is still routinely done by the "mag and flag" method that's been used for fifty years Unexploded ordnance is a nationwide problem without a clear solution at hand; it seems that we'll need to find a way ourselves to resolve the UXO problems that exist at Ft. Wingate Depot. For the full report, you can go to this Internet site: http://aec-www.apgea.army.mil:8080/ .

Also, the Department of Defense Explosives Safety Board has a website at http://www.acq.osd.mil/ens/esb/esbhompb.html for DoD, DoD contractors, and government agencies. This site has two important UXO documents: the DoD Ammunition and Explosives Safety Standards, and a report by the Defense Science Board Task Force on UXO Clearance. If you want to read these documents (they're not classified), but don't have access to the site or the Internet, I can bring a copy for you to the next BCT & RAB meetings -- just let me know. My phone number is 214/665-2196.

Attachments (2)

ADDRESSEES:

Mr. Jim Enote, Department Head
Pueblo of Zuni
Department of Natural and Cultural Resources
P.O. Box 339
Zuni, NM 87327

Mr. Edward Hansen
Solid Waste Bureau
New Mexico Environment Department
1190 St. Francis Drive

Santa Fe, New Mexico 26110

Mr. Allen Sedik
Bureau of Indian Affairs
Albuquerque Area Office
615 1st Street, NW
Albuquerque, New Mexico 87125-6567

Mr. Larry Fisher
Environmental Management Division
Tooele Army Depot
Tooele, Utah 84074-5000

Ms. Julie Wanslow
Hazardous and Radioactive Materials Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, NM 87502

Mr. Dwayne Ford
U.S. Army Corps of Engineers, Fort Worth District
Attn: CESWF-ED-E
P.O. Box 17300
Fort Worth, TX 76102-0300

Mr. David Sinclair
U.S. DOI-BLM, New Mexico State Office (NM 930)
1474 Rodeo Road
P.O. Box 27115
Santa Fe, NM 87502-7115

Ms. Roseria Duwyenie
U.S. Department of Interior
Bureau of Indian Affairs, Navajo Area Office
Branch of Environmental Quality
P.O. Box 1060
Gallup, New Mexico 87305

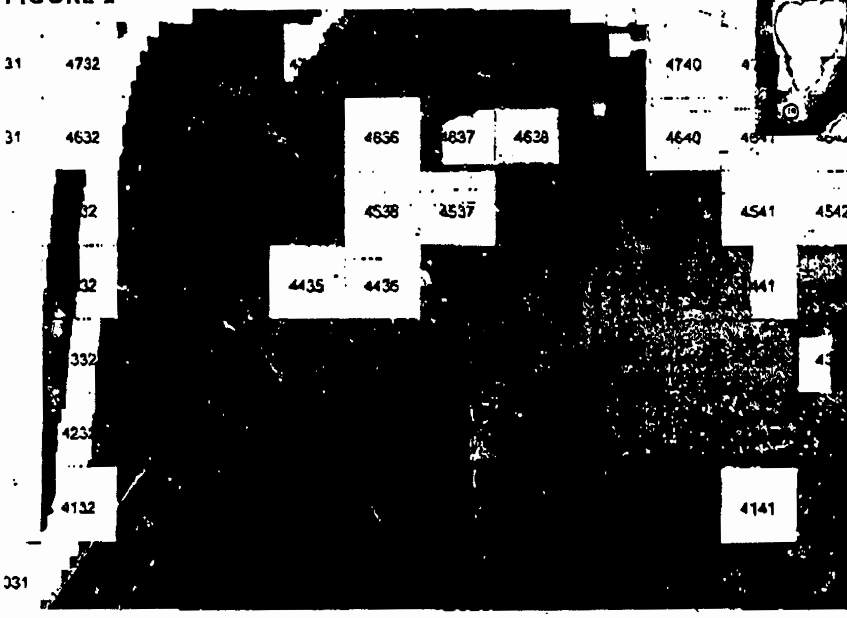
Ms. Sharlene Begay-Platero
Navajo Nation Project Development Department
P.O. Box 663
Window Rock, AZ 86515

FIGURE 1

Navigating

By John C. McIlroth, PE

FIGURE 2



Above, geophysical map of the site in Adak, Alaska.
Left, GIS summary of data at the Adak site.

Hundreds of both active and former U.S. Department of Defense sites are contaminated with unexploded bombs, rockets, grenades, mortars and cannon projectiles, collectively called unexploded ordnance (UXO). Although nationwide site cleanup estimates start at $7 billion, growth of the UXO remediation industry has been slow. Both the low productivity and high cost of remediation have deterred government agencies from budgeting sufficient money to make any real progress in completing cleanups. In the last two years, some agencies and their contractors have begun a joint attack on the two issues of increasing productivity and reducing cost.

Past problems

Conventional approaches to UXO remediation have involved detection of UXO with hand-held magnetometers, careful excavation to uncover the object, and if it is a UXO, detonating it *in situ* or moving it to another location for detonation. Unfortunately, hand-held magnetometers, even operated by the most skillful technicians, cannot reliably tell the difference between UXO and other iron and steel objects, or between a small object near the surface and a large object several feet below. Detection rates from 35 to 65 percent have been demonstrated by hand-held magnetometers in controlled tests. This poor detection rate leads to missing much of the UXO. Further, hand-held magnetometers cannot distinguish between UXO and other metal objects, resulting in many slow and expensive excavations to recover harmless scrap metal.

The intuition of skilled operators is now supplemented by detection technologies capable of collecting vast amounts of highly precise magnetic and electromagnetic data. This technology also offers the promise of detecting extremely subtle differences and trends in the data that otherwise would be invisible. However, the massive amount of data collected can overwhelm attempts to manipulate it into any useful format.

New technology

Over the last three years, Foster Wheeler Environmental Corp. has developed systems to collect increasingly accurate data, analyze the data to increase the detection rate for UXO without massive excavation, and store and manage the raw and processed data in ways that permit more complete and useful understanding of the data.

The first, and most critical, step to improving UXO detection was more accurate data collection. The ability to locate and visualize objects is dependent on the data's precision and the location of the data measurement.

Initially, developers of the new systems used a number of sensor data collection techniques, including those commonly employed in other parts of the geophysical industry. These techniques involve carefully marking an area into lanes, then collecting data from the middle of the lane while using cross lines to keep track of position. Unfortunately, ground unevenness and obstacles such as trees, roads, fences and rocks created variances in the location accuracy, limiting the clarity and usefulness of the data for further analysis.

Using these conventional techniques, estimations of the approximate size of objects were within 50 percent of the true value. Object location and depth estimations were within 1 to 2 feet. In some areas, the geometry of the grids was so complex, due to buildings, fences, brush, trees and other obstacles, that an alternative technique using an ultrasonic positioning and data collection system was more appropriate.

An alternative technique

The ultrasonic positioning system can measure the location of the data collection point to within about 12 inches of its true location on the grid. Although this technique was initially selected for use in complex terrain not well suited to a conventional grid system, researchers found it also produced a moderate improvement in accuracy. Size estimates improved to approximately 40 percent of the true value, and location and depth improved to 9 to 20 inches of the true location. **Figure 1** shows the detailed geophysical map of the Foster Wheeler test plot for a Navy project in Adak, Alaska.

Additional investigations led to the use of a data collection system based on a differential global positioning system (DGPS), with a data point accuracy of just a few inches. After analysis of data, estimates of object size were within 20 percent of true size, and location within less than 12 inches. This creates two advantages. First, the data can be analyzed with much greater precision. Since the images of each item are much clearer, more meaningful comparisons can be made with images from items already excavated. This has led to improved confidence in the selection of anomalies for excavation. The second benefit is in the excavation itself. The DGPS provides a simple system to determine the exact point where the anomalies are located on the grid, and also predicts an object's depth with great accuracy. This results in the ability to excavate more quickly, using mechanical excavators to within 1 foot of the object, saving substantially in digging time and cost. As geophysicists have gained experience with the higher quality data, they have become more proficient in differentiating UXO from other anomalies. This trend should continue.

Managing vast amounts of data

The volume of data collected is massive. An area of approximately 1,000 acres yielded over 40,000,000 data points. Manual capture and maintenance of this much data would be virtually impossible. Initially, the computerized system captured the data and tagged each data point with its location on the grid. Later, researchers correlated the data point location to the precise latitude and longitude. The DGPS data collection system automatically correlates the data point with its location. A geographic information system (GIS), used in conjunction with DGPS, provides a method to capture, store, retrieve, analyze and display large volumes of spatially related data. This permits researchers to sort or use the data for input to other computer programs that present the data in ways that can be more intuitively interpreted.

Capturing the raw and processed geophysical data on the GIS makes it possible to create some very useful products. Visualizing a summary of raw data over large areas can demonstrate the locations of former targets, or the areas of greatest concentration of anomalies. This is useful when defining homogeneous areas for more detailed sampling and analysis. **Figure 2** shows a GIS summary of data at a project site in Adak, Alaska. It provides a graphic representation of the progress of work, shows where work is actively proceeding and highlights locations where data has not been collected. All of these are valuable tools for planning and managing work. For a project at Rocky Mountain Arsenal, geophysical data is being used in conjunction with geological and hydrogeological data to identify locations for interceptor trenches and cutoff walls that avoid subsurface items that could be UXO.

The data from UXO excavations is also retained in the GIS. This permits visualization of UXO that have been discovered, while providing a database for comparison of new anomalies with the data for confirmed anomalies. Geophysicists use this feedback to improve their skills in evaluating which items are likely to be UXO. The GIS also makes data available in formats that allow the use of other innovative techniques. One of these is risk analysis, where the density of UXO in an area is combined with planned land uses to estimate the risk of UXO exposure. This permits the creation of risk estimates for a number of alternative cleanup approaches, and potential land uses or land use restrictions.

Getting the most bang for your buck

The combination of geophysical detection and analysis technologies has created a remarkable improvement in the speed and cost of UXO removals. Geophysical analysis permits UXO specialists to bypass most of the small, harmless metal pieces that once had to be slowly excavated using conventional approaches. This cuts the time and cost of excavation. In addition, analysis of detailed geophysical data can drastically reduce the areas where detailed sampling is needed to determine the UXO density. When used in conjunction with UXO risk estimating and analysis software, managers can focus attention on areas of greatest risk. The rapid and accurate reduction of the footprint of areas where investigation or remediation is necessary also serves to drive down the cost of UXO remediation.

Government agencies will increase their investments in reducing UXO threats if the cost of the cleanup is equal to or lower than the value of the cleaned property. The future of the UXO remediation business lies in leveraging a number of technologies to speed cleanup, lower costs and provide the government agencies responsible for cleanup activities with assurance that it is not only effective, but economical to protect the public from the dangers of UXO.

minefield

Innovations in data collection, analysis and management can speed up unexploded ordnance cleanup operations and drive down costs

John C. McIlrath, PE, is Foster Wheeler Environmental Corp.'s director of unexploded ordnance programs. He is based in Huntsville, Ala.

For more information circle 73 on card.

HANDHELD GRADIOMETER SURVEY TEST

MARINE CORPS AIR GROUND COMBAT CENTER
TWENTYNINE PALMS, CA

SEPTEMBER 1992

PREPARED BY: NAVAL EXPLOSIVE ORDNANCE
DISPOSAL TECHNOLOGY CENTER
INDIAN HEAD, MD

TABLE OF CONTENTS

HANDHELD GRADIOMETER SURVEY TEST

This report contains the results of a site survey test conducted at MARINE CORPS AIR GROUND COMBAT CENTER(MCAGCC), Magnetic Test Range(MTR), Twentynine Palms, Ca. from 11th-15th August 1992.

Two gradiometers; the FORSTER Model 4.021(military designation, MK26) and the SCHONSTEDT Model GA-72CV were used to conduct a Field Survey Test using known buried ordnance. Four Marines from the MCAGCC Explosive Ordnance Disposal(EOD) Team at Twentynine Palms, Ca. were used as test personnel. The results of these test will also be evaluated, versus the Surface Towed Ordnance Locator System(STOLS) field test previously conducted at the Twentynine Palms MTR.

Two sites approximately one acre in size, at the MTR were used for these tests.

The details of this survey test follow:

BACKGROUND

With many Range Clearance Surveys being conducted it was determined there was a need for a controlled survey using handheld Gradiometers to determine the percentage of targets detected. The MTR at the MCAGCC, a site with a large number of buried ordnance items from a 60mm mortar to a MK84(2000) bomb was selected for this test. The location, depth and orientation of these munitions was known to within a few inches. The MK26 Gradiometer is currently accepted as the standard for range clearance and was chosen to be one of the locators tested. The other Gradiometer would be the

SCHONSTEDT GA-CV72CV believed to have equivalent detection capability but not as rugged and lacking the borehole or underwater capability of the MK26. The SCHONSTEDT however costs considerably less than the MK26 and is lighter in weight.

DETAILS OF SURVEY TEST

Test Instruments:

The MK 26 is a fluxgate gradiometer used to detect ferrous ordnance. The gradiometer is powered by 6 - 1.5 volt D cells and weights approximately 8 lbs. This locator can be used in the differential(gradiometer) or the absolute(single axis) mode. The absolute mode has 1/10 the sensitivity of the differential mode. A zero-center meter, an external speaker and an ear phone give aural and visual indication of target detections. The detection probe can be separated from the electronics and used underwater or in boreholes. The cable length is 98.4 ft (30 meters). The MK26 has the sensitivity to detect a MK82 bomb(500lb) at depths of 12 feet.(see figure 1)(see appendix A for additional details)

The SCHONSTEDT Model GA-72CV Gradiometer is a fluxgate ferrous ordnance detector with sensitivities equivalent to the MK26.(see figure 2) The GA-72CV Weights approximately 3 lbs (1.36kg), uses 4 alkaline AA-cells and cost less than $1,000.00. The sensor spacings are 20 inches. The system has a zero-center meter, an external speaker and a headset is available as an option; as indicators for target detection.(See appendix B for additional information (model GA-52C is the same gradiometer less meter))

The Surface Towed Ordnance Locator System(STOLS) is a towed array system consisting of an ATV low magnetic tow vehicle; a very low magnetic tow platform with seven cesium vapor magnetometers; a reference station; a micro-fix navigation system, with four transmitter/receivers(T/R); and a command center containing a computer system capable of interpolation and analyzing field data and providing hard copy outputs such as: beacon maps, site maps, mission maps, landmark maps, missed area maps, target maps and target reports. This system is capable of detecting a MK82 bomb (500lb) to depths of fifteen feet.(see appendix C or NAVEODTECHCEN TR-302 for additional details)

Test Site:

The site selected for these tests was an approximately six acre site located at the Marine Corps Air Ground Command Center (MCAGCC) at Twentynine Palms, Ca.. The MTR was developed by the Naval Explosive Ordnance Disposal Technology Center(NAVEODTECHCEN) for previous ordnance locator testing. This site contains over seventy ordnance items ranging in size from a 60mm mortar to a MK84 bomb(2000lb) in various orientations. From this large site two approximately one acre sites were selected for the Hand Survey Tests and test site 1 was further divided in A and B sections. (see figures 3 & 4) The sites contained the following targets:

Site 1A 8 targets

Site 1B 11 targets

Site 1 total 19 targets

Site 2 total 11 targets

Target Location:

Two persons were used for each survey team, one person was the locator operator, the other recorded the target#, size small, medium or large and approximate depth. (see appendix d) Small targets are 60mm mortar to 105mm projectile; medium is 155mm projectile to MK80(100lb) bomb and large is MK81(250lb) and larger. The recorder also flagged the target location determined by the operator. Upon completion of the survey, Electronic Distance Measuring (EDM) Equipment was used to determine the exact location of selected targets. Two prisms were located over each flagged location and EDM from two positions was used to fix the location. (see figures 5 & 6) The MTR was layed out using cartesian coordinates, so each target has an X and Y position. After the flagged distance was calculated, its X and Y positions could be determined and compared to the known target locations. The distance must be 1 meter or less on small and medium targets and 2 meters or less on large targets. When a flagged target met these parameters, the target# was compared with the recorder's log to determine the flagged target was of the approximate size and depth of the actual target. If both these criteria was met it was considered a detection.

Test Personnel:

It was determined that personnel with training and experience in the use of the MK26 would be best suited to conduct the Gradiometer Survey Testing. The Marine Corps EOD Teams use the MK26 as its authorized ordnance locator and are trained on its use while attending The Naval Explosive Ordnance Disposal School. So four marines from the MCAGCC EOD Team at Twentynine Palms were selected to participate in the testing. In addition Training was given to the test participants the day before the tests began. Training was given in Magnetic Theory, Gradiometer operation and Search techniques.

TWENTYNINE PALMS SURVEY TEST:

10August92: The Survey Team met at the EOD Building to outline the schedule for conducting the Test Survey. Following this meeting training for the four test personnel(Marines) was conducted by the Navy Explosive Ordinance Disposal Technology Center(NAVEODTECHCEN).

Following the training two test sites were selected at the MTR. One site was selected with small and medium targets, the other site was selected to include large targets. The first site was designated site 1, the other site 2.(see figure 6A)

11August92: Three surveys were conducted at the MTR. Two tests were conducted at site 2 using the SCHONSTEDT (see figures 7 & 8) with different operators and one test at Site 1 using the MK26. One SCHONSTEDT S/N 105355 was defective and the MK26 survey was delayed because of a lose cable. The results of the survey are as follows:

Test#	Site#	Locator	Survey Time	Targets Flagged
1	1	MK26	5hr,50min	10
2	2	SCHON	2hr,40min	21
3	2	Schon	2hr,30min	19

12August92: Three surveys were conducted. Two tests were conducted at site 1 using the SCHONSTEDT with different operators and one test at site 1 using the MK26. The SCHONSTEDT S/N 105354 had a sticking needle. The results of the survey follow:

Test#	Site#	Locator	Survey Time	Targets Flagged
4	1	SCHON	2hr,40min	19
5	2	MK26	9hr,15min	29
6	1	SCHON	2hr,10min	18

13August92: Three surveys were conducted(two surveys were one half site surveys), Therefore two site surveys were completed. Site 1 was surveyed using the SCHONSTEDT and the MK26 was used on site 2. (see figure 9 & 10)

The results follow:

Test#	Site#	Locator	Survey Time	Targets Flagged
7	2	MK26	5hr,55min	28
8	1B	SCHON	4hr,55min	3
9	1A	SCHON	4hr,40min	18

14August92: One survey was conducted at site 1 using the MK26. Following the survey the equipment was packed for shipment to NAVEODTECHCEN. One SCHONSTEDT was given to the MCAGCC EOD for additional evaluation. Survey results follow:

Test#	Site#	Locator	Survey Time	Targets Flagged
10	1B	MK26	3hr,5min	3
11	1A	MK26	2hr	14

RESULTS OF SURVEY TEST:

Test#	Operator#	Site#	Locator	Survey Time	Targets Flagged (actual)	Detections (sm,med,Lg)
1	1	1	MK26	5hr,50min	10(19)	0
2	2	2	SCHON	2hr,40min	21(11)	2sm
3	3	2	SCHON	2hr,30min	19(11)	2sm,2med 3Lg
4	2	1	SCHON	2hr,40min	19(19)	2sm,1Lg
*5	1/4	2	MK26	9hr,15min	29(11)	2sm,1med 2Lg
6	3	1	SCHON	2hr,10min	18(19)	3sm,3Lg
7	2	2	MK26	5hr,55min	28(11)	1Lg
8	1	1A	SCHON	4hr,55min	3(8)	1sm,2Lg
9	4	1B	SCHON	4hr,40min	18(11)	3sm,2med
10	2	1A	MK26	3hr,5min	3(8)	1sm,2Lg
11	3	1B	MK26	2hr,	14(11)	4sm

* all targets detected by operator 4

Percent of Targets Detected(all locators):

Test#	Site#	Targets(actual) sm med Lg	Targets(detected) sm med Lg	% Detected sm med Lg
1	1	10, 3, 6	0, 0, 0	0%, 0%, 0%
2	2	5, 2, 4	2, 0, 0	40%, 0% 0%
3	2	5, 2, 4	2, 2, 3	40%,100%,75%
4	1	10, 3, 6	2, 0, 1	20%, 0%,17%
5	2	5, 2, 4	2, 1, 2	40%, 50%,50%

Test#	Site#	Targets(actual) sm med Lg	Targets(detected) sm med Lg	% Detected sm med Lg
6	1	10, 3, 6	3, 0, 3	30%,0%,50%
7	2	5, 2, 4	0, 0, 1	0%,0%,25%
8	1A	1, 1, 6	1, 0, 2	100%,0%,33%
9	1B	9, 2, 0	3, 2, 0	33%,100%.na
10	1A	1, 1, 6	1, 0, 2	100%, 0%,33%
11	1B	9, 2, 0	4, 0, 0	44%, 0%,na

Total Percentage of Targets Detected(all locators):

Small - 29%

Medium - 22%

Large - 30%

Total percentage of targets detected(by locator):

	MK26	SCHONSTEDT
Small	23%	33%
Medium	10%	31%
Large	25%	35%
overall	22%	33%

Survey Time(average by locator)

Site#	Mk26	SCHONSTEDT
1	5hr,28min	4hr,48min
2	7hr,35min	2hr,35min

STOLS:

While the STOLS was not included in this test the results of a test previously conducted are being included in this report for comparison.

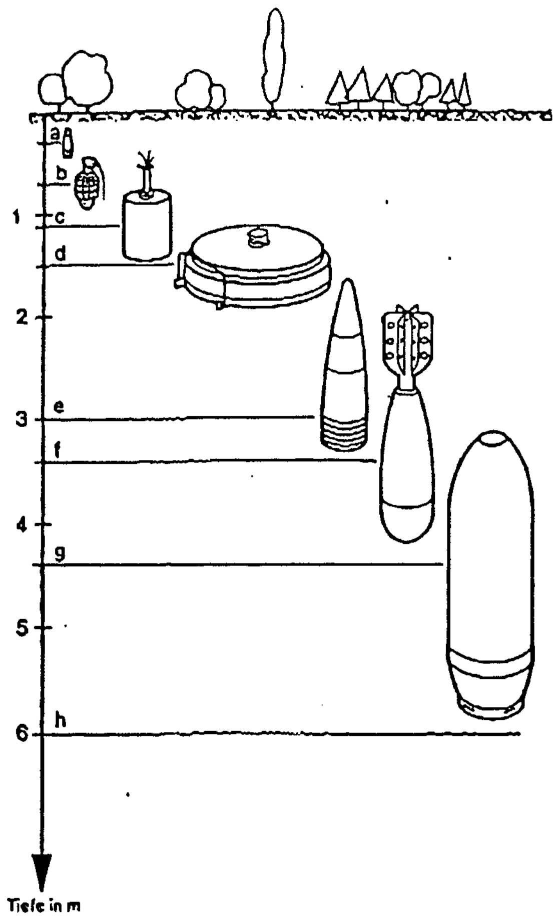
From 5-14 June and 4-13 December 1989 tests were conducted at MCAGCC MTR Twentynine Palms, Ca. using the STOLS. The results of those tests follow:

Size	Ordnance item	Depth	Detection Confidence
small	60mm mortar	2 ft.	84%
small	81mm mortar	2.5 ft.	95%
small	105mm projectile	3.0 ft.	95%
medium	155mm projectile	4.0 ft.	84%
medium	8 in. projectile	7.0 ft.	84%
large	MK81(250lb) bomb	9.0 ft	84%
large	MK82(500lb) bomb	13.0 ft	95%

For additional information see appendix E

CONCLUSION:

While it should be remembered the survey test was limited, Of particular concern is the low detection percentage for a handheld gradiometer survey. If you analysis the test site the clutter was largely very small targets such as: "c" ration can openers, "c" ration cans and small pieces of comm wire. These targets would not obscure the munitions the operators were told was present on the site. The munitions were buried well within the detection capabilities of the gradiometer as shown in the figure 11 from the MK26 users manual.



a 13-mm shell (Fe)
b Mills-bomb (Fe)
c anti-personnel mine (Fe)
d flat anti-tank mine (Fe)
e 8.8-cm tank shell (Fe)
f 10-cm projectile (Fe)
g 250-kg-bomb (Fe)
h 500-kg-bomb (Fe)

Figure 11 The detection depth of the FEREX 4.021(MK26)

So there is no obvious reason for the low detection rate . You would believe this survey test would favor the operator, who knew there were targets but did not know the location or number of targets. In a real survey the operator does not even know if there are any targets.

The SCHONSTEDT Gradiometer outperformed the MK26 in both detection and survey time. These Gradiometers have similar sensitivities so it is believed the difference was because of the weight and ease of use of the SCHONSTEDT, reducing operator fatique. All operators preferred to use the the SCHONSTEDT over the MK26.

The STOLS array system far outpeformed both handheld locators. There are probably three reasons for this; the STOLS uses a magnetometer with about 20-25% greater sensitivity, the STOLS also generates a total magnetic signature while the handheld operator uses discrete points and must generate the image in their head and last operator fatique. The STOLS performs the same at the end of the day as it does in the beginning, the same cannot be said for the handheld operator.

CONTROLLED SITE

ADVANCED TECHNOLOGY DEMONSTRATION PROGRAM

PHASE III

U.S. ARMY JEFFERSON PROVING GROUND
MADISON, INDIANA

Prepared for U.S. Army Environmental Center

EXECUTIVE SUMMARY

The U.S. Army Environmental Center (USAEC) has an established program to assess technologies suitable for the detection, identification, and excavation of unexploded ordnance (UXO). This report presents the results of the third series (Phase III) of UXO Advanced Technology Demonstrations (ATD) completed at Jefferson Proving Ground (JPG) in Madison, Indiana. The analysis documents the performance capabilities of 15 demonstrators who participated in the Phase III ATD, and compares their overall performance to what was achieved in two earlier Phases. Demonstrators in all three Phases were required to either search/detect/characterize or excavate inert ordnance that was deliberately emplaced for the ATD. The performance data define the capabilities and limitations of UXO technologies, as demonstrated under the JPG test conditions and evaluated by the ATD methodology. This data will be useful to those who wish to better understand the challenges posed by UXO, and to those who may have to respond to those challenges.

The need...

UXO technology deficiencies came to the forefront of our nation's newspapers with the public's realization that the base realignment and closure (BRAC) process would not result in the immediate turnover of formerly used, Department of Defense (DoD) properties. A legacy of bombs, missiles, and rockets decades old, and even cannonballs from the past century restricts unlimited public use or access to these lands. In addition, active DoD installations considering alternative land uses must face unknown hazards, as record keeping of past ordnance usage was nonexistent or incomplete. Installation managers need to know the capabilities of UXO technologies. There is an enormous demand to characterize properties just so the extent of the UXO hazard can be defined. In addition, there is a demand for lands to be returned to the public domain through UXO remediation efforts. UXO cleanup efforts are estimated to cost in the tens of billions of dollars.

The response...

The U.S. Congress established the UXO-ATD program to focus technology on reducing the unfunded liability and the time needed to characterize and remediate property. Congress recognized the need for more cost-effective and safer technologies. The USAEC manages the ATD program at JPG under the Congressional mandate to demonstrate advanced and innovative UXO technologies. A meaningful framework for understanding UXO technology performance was established by publishing public criteria and metrics. The ATD program would not only benefit restoration managers, who need to know more than just how to spell "ordnance" correctly, but also technology developers who would have quantifiable goals to seek against published performance.

Phases I and II...

In the first two phases, conducted in 1994 and 1995 respectively, ordnance was emplaced that was representative of different UXO conditions. Two sites, 16 and 32 hectares, were established for ground-based and airborne technology demonstrations. There were 29 demonstrations in Phase I and 17 demonstrations in Phase II. These demonstrations showed that airborne platforms and ground penetrating radar (GPR) sensors did not perform well under the test conditions at JPG. Demonstrators who used a combination of sensors (electromagnetic induction and magnetometry) had the best performance. The better performers in Phase II detected over 80 percent of the ordnance, but they also reported three to twenty times more targets (false alarms) than actual ordnance. The inability to distinguish ordnance from the prevalent farming debris at the site was noted, because this would likely be a major cost factor in remediating UXO properties. Excavation demonstrations of remotely operated systems were also demonstrated at the two Phases. Excavators could unearth ordnance at only a fractional rate (<5%) of how fast demonstrators could detect it.

Phase III ...

In Phase III, the ordnance layout was changed from the earlier Phases to represent geographically-defined UXO scenarios. An Aerial Gunnery Range (1), Artillery and Mortar Range (2), Grenade and Submunition Range (3), and Interrogation and Burial Area (4) were established on the 16 hectare site. Demonstrators were allowed to select the scenarios that best represented their system's capabilities for detection, localization and or characterization of the UXO. Remote excavation technologies were also solicited. Fifteen proposals were funded at a maximum of $75K. One company, Sanford Cohen and

Associates (SC&A) formed a teaming arrangement with three survey demonstrators (ADI, Geo-Centers Inc., and Geometrics) to apply SC&A's advanced data processing to their data. Geophysical Research Institute (GRI) reported their magnetometer (Mag), electromagnetic induction (EM), and combined sensor (Combined) target data separately. ADI used a Mag in (1) and (2) and EM and Mag in (3). The overall detection performance of the Phase III demonstrations is summarized in **Table ES-1**, as categorized by sensor technology.

TABLE ES-1

DEMONSTRATOR ORDNANCE DETECTION BY SENSOR TECHNOLOGY COMBINED SCENARIOS (1, 2, AND/OR 3)

Sensor Type	Demonstrator (Scenario #)	P_D	False Alarm (FA) Rate (#/Hectare)	FA Ratio (#/Ordnance Detected)
Electromagnetic Induction (EM)	CHEMRAD (1,2)	0.50	12.90	1.91
	GRI (EM) (1,2,3)	0.87	123.89	8.46
	GeoPotential (1,2,3)	0.06	9.04	8.54
Gradiometer (Grad)	Foerster (1)	0.60	36.46	4.85
Magnetometer (Mag)	Battelle (2)	0.12	1.71	1.00
	GRI (Mag) (1,2,3)	0.70	223.68	18.82
	Rockwell (1,2)	0.34	25.93	5.70
EM & Grad	Geophex (1,2)	0.77	32.44	3.11
EM & Mag	ADI (3; Mag only in 1,2)	0.78	109.48	8.30
	GRI (Combined) (1,2,3)	0.93	240.53	15.23
	Geo-Centers (1,2,3)	0.93	81.80	5.18
	Geometrics (2)	0.90	38.44	3.00
	NAEVA (1,2)	0.94	24.84	1.96
	SCA_ADI (3; Mag only in 1,2)	0.63	46.80	4.36
	SCA_Geo-Centers (1,2,3)	0.76	43.55	3.36
	SCA_Geometrics (2)	0.96	41.86	3.06
Ground Penetrating Radar & EM & Grad	ENSCO (1,2)	0.70	48.66	5.14
	Averages [illegible]	[illegible]	[illegible]	[illegible]

P_D

Note: Detection probabilities are based on detecting all the ordnance within a given Scenario. Battelle, CHEMRAD, Foerster, Geo-Centers, and GRI did not survey their entire Scenario(s).

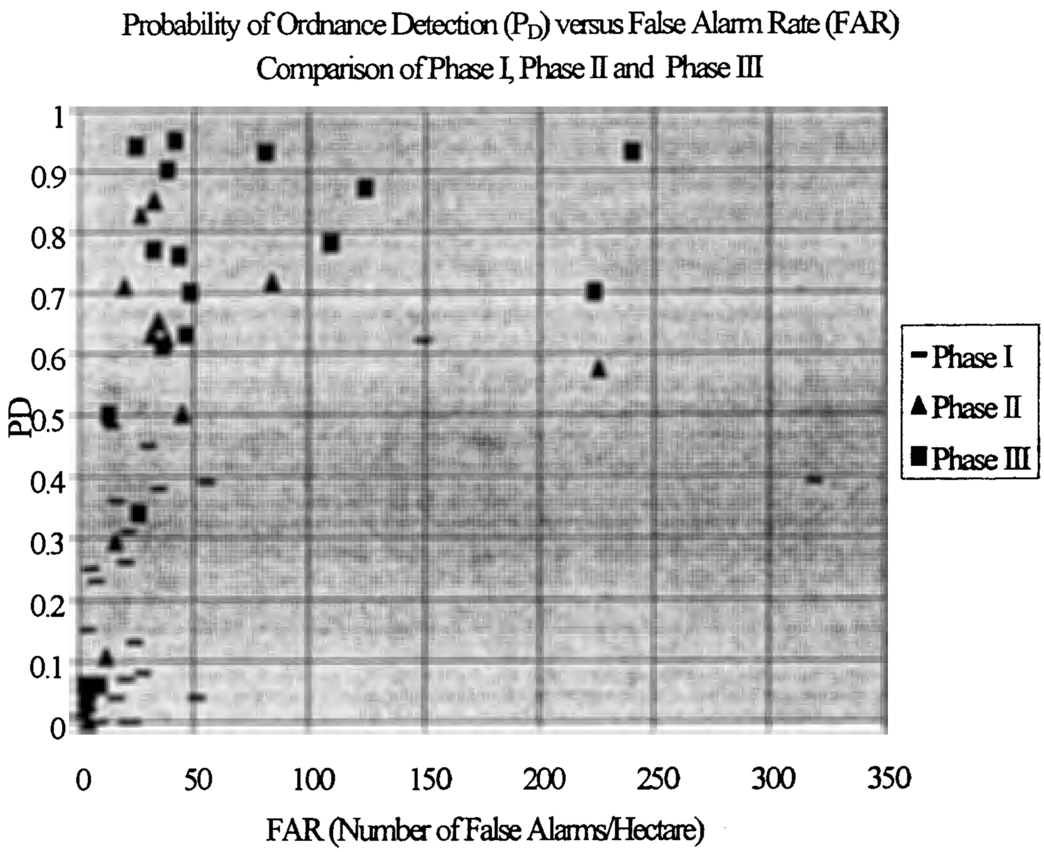
The table shows that overall performance was satisfactory, as many demonstrators found more than 90 percent of the baseline ordnance. The comparison of these results to the earlier Phases is shown in **figure ES-1**, the probability of ordnance detection versus the false alarm rate in false alarms per hectare. Good performance is in the upper-left hand corner of the plot. The general trend is that detection is improving (movement up the plot) but target discrimination (false alarm rate) has not changed (no movement to the left edge of the plot). Localization performance for ground-based demonstrators continues to improve since Phase I as shown in **figure ES-2**. Remote target excavation feasibility was shown, but target excavation can take one half hour or better per target.

In Summary...

The strengths and capabilities of UXO technologies were demonstrated to show continued and satisfactory improvement in detection performance. Because there has been no substantial change in the ability of demonstrators to discriminate UXO from the clutter at JPG, a focused effort is needed to resolve this issue. A poor target discrimination capability means remediation efforts will likely suffer from excessive expenditures of time and money. A strong initiative is needed to encourage the further development of advanced data processing and new approaches that can address this technology deficiency. It is recommended that:

- Target discrimination goals be established.
- Standard formats for raw sensor data be established.
- Factors that affect ordnance and nonordnance discrimination be identified.
- Raw sensor data with ground truth be made available to the developers of discrimination algorithms.
- Innovative and high-risk technologies be funded for further development.
- Facilities and a test area at JPG be made available to those who wish to use it for technology development.

Figure ES-1



Probability of Ordnance Detection (P_D) versus False Alarm Rate (FAR)
Comparison of Phase I, Phase II and Phase III
PD
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
FAR (Number of False Alarms/Hectare)
Phase I
Phase II
Phase III