AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9127

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

MOGULS SCORING RECORD NO. 665

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
GEOPHEX, LTD.
605 MERCURY STREET
RALEIGH, NC 27603-2343

TECHNOLOGY TYPE/PLATFORM:
GEM-3 EM REALTIME DISC/HAND HELD

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

NOVEMBER 2005

Prepared for:
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

DISTRIBUTION UNLIMITED, NOVEMBER 2005.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
November 2005

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
See Item 13

4. TITLE AND SUBTITLE
STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE MOGULS SCORING RECORD NO. 680 (GEOPHEX, LTD.)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Overbay, Larry; Robitaille, George
The Standardized UXO Technology Demonstration Site Scoring Committee

5d. PROJECT NUMBER
8-CO-160-UXO-021

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Aberdeen Test Center
ATTN: CSTE-DTC-AT-SL-E
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER
SFIM-AEC-AT-CR-2006052

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Environmental Center
ATTN: SFIM-AEC-ATT
Aberdeen Proving Ground, MD 21005-5401

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Same as Item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution unlimited.

13. SUPPLEMENTARY NOTES
18 through 22 and 25 through 27 April 2005

14. ABSTRACT
This scoring record documents the efforts of Geophex, Ltd. to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Moguls. Scoring Records have been coordinated by Larry Overbay and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include, the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS
Geophex, Ltd., UXO Standardized Technology Demonstration Site, APG, GEM-3 EM Realtime Disc/hand held, MEC

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER *(Include area code)*

(Page ii Blank)

TABLE OF CONTENTS

PAGE

SECTION 1. GENERAL INFORMATION

SECTION 2. DEMONSTRATION

SECTION 3. FIELD DATA

SECTION 4. TECHNICAL PERFORMANCE RESULTS

PAGE

SECTION 5. ON-SITE LABOR COSTS

SECTION 6. COMPARISON OF RESULTS TO OPEN FIELD DEMONSTRATION

SECTION 7. APPENDIXES

SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) – i.e. unexploded ordnance (UXO) and discarded military munitions (DMM) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (AEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 <u>Scoring Methodology</u>

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e. that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. Based on configuration of the ground truth at the standardized sites and the defined scoring methodology, there exists the possibility of having anomalies within overlapping halos and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular ground truth item.

(2) For overlapping R_{halo} situations, ordnance has precedence over clutter. The anomaly with the strongest response or highest ranking that is closest to the center of a particular ground truth item gets assigned to that item. Remaining anomalies are retained until all matching is complete.

(3) Anomalies located within any R_{halo} that do not get associated with a particular ground truth item are thrown out and are not considered in the analysis.

f. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm Heat Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

JPG = Jefferson Proving Ground
HEAT = high-explosive antitank

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

Address: Geophex, Ltd.
605 Mercury Street
Raleigh, NC 27603-2343

2.1.2 System Description (provided by demonstrator)

The hand-held GEM-3 (fig. 1) sensor consists of a concentric sensing coil set having two transmitting coils (Tx) wired such that current flows in opposite directions, a central receiver coil (Rx), an electronic console, and an iPAC® user interface with software for real-time data processing. The GEM-3 coils (fig. 2) create a central magnetic cavity region using two concentric, circular loops that are electrically connected in an opposing polarity. The inner coil typically has half as many turns as the outer (6 and 12 for our current 40 cm diameter version used here).

Figure 1. Demonstrator's system, GEM-3 EM Realtime Disc.

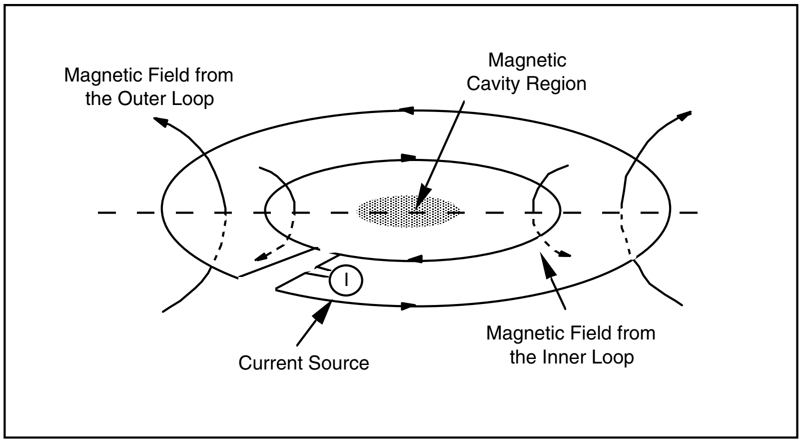

Figure 2. Conceptual representation of the GEM-3 coils.

The GEM-3 electronics includes a digital signal processor (DSP) that performs the transmitter waveform generation and processes samples from the receiver analog-to-digital converter (ADC), including discrete Fourier transform (DFT) math to produce inphase and quadrature measurements (parts per million (ppm) relative to primary field at Rx) at each frequency and data time-stamping with a real-time clock for synchronization to a Differential Global Positioning System (DGPS).

The iPAC® performs the detection and discrimination algorithms using the electronic console inphase and quadrature outputs and provides real-time enunciation to the operator in the form of audio and graphical detection queues, graphical identification, and discrimination results.

Major features of the GEM-3 sensor include:

a. ADC sampling at 96 kHz at 24 bits.

b. Sampling (ppm) at up to 30 times a second regardless of how many frequencies are used, with automatic averaging down to operator selectable rate (typical 5 Hz).

c. Integration with an iPAC® hand-held computer for user interface.

d. iPAC® software with graphical/audio functions and real-time detection and discrimination algorithms.

2.1.3 Data Processing Description (provided by demonstrator)

Target detection is achieved by combining multifrequency data into a single detection channel designed to respond specifically to metal targets and not to geologic anomalies. Data collected included: the sum of all quadrature channels, the difference between high frequency and low frequency inphase channels, the sum of the absolute differences of quadrature channels between all frequency pairs, and the inverse log (frequency) weighted total apparent conductivity. The selected detection channel forms the response stage.

Target identification and classification (clutter discrimination) utilizes a normalized matching of the multifrequency spectra to a library of known unexploded ordnance (UXO) spectral responses. The matching scheme fits an unknown target to the best-fit linear combination of the longitudinal (sensor axis along target long axis) and transverse (sensor axis perpendicular to target long axis) response spectra, allowing for a frequency independent background inphase response for magnetic soils. The goodness-of-fit to the best fitting item is mapped into a confidence ranking from 0 (definite clutter) to 10 (definite UXO) with 5 corresponding to the clutter misfit threshold. The confidence ranking forms the discrimination stage.

2.1.4 <u>Data Submission Format</u>

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

2.1.5 <u>Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)</u>

Overview of Quality Control (QC): daily sensor calibration check with ferrite target; calibration area test.

Overview of Quality Assurance (QA): daily data review.

2.1.6 <u>Additional Records</u>

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org. The counterpart to this report is the Blind Grid, Scoring Record No. 680.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15- and 30-percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator to calibrate their equipment.
Blind Test Grid	Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter or nothing.
Moguls	1.30-acre area consisting of two areas (the rectangular or driving portion of the course and the triangular section with more difficult, non-drivable terrain). A series of craters (as deep as 0.91m) and mounds (as high as 0.91m) encompass this section.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (18 through 22 and 25 through 27 April 2005)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration Lanes	2.50
Mogul	51.08

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2005	Average Temperature, ^{o}F	Total Daily Precipitation, in.
18 April	72.39	0.00
19 April	73.97	0.00
20 April	78.07	0.00
21 April	60.02	0.00
22 April	52.29	0.00
25 April	54.31	0.00
26 April	64.94	0.00
27 April	65.79	0.02

3.3.2 Field Conditions

Geophex surveyed the Moguls from 18 through 22 and 25 through 27 April 2005. The moguls were wet and small areas of standing water were present due to precipitation prior to testing.

3.3.3 <u>Soil Moisture</u>

Three soil probes were placed at various locations within the site to capture soil moisture data: Blind Grid, Calibration, Open Field, and Wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. A five-person crew took 4 hours and 50 minutes to perform the initial setup and mobilization. There was 4 hours and 30 minutes of daily equipment preparation and end of the day equipment break down lasted 1 hour and 5 minutes.

3.4.2 Calibration

Geophex spent a total of 2 hours and 30 minutes in the calibration lanes, of which 2 hours and 10 minutes was spent collecting data.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, Demonstration Site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to Demonstration Site issues. Demonstration Site issues, while noted in the Daily Log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total Site Survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for 1 hour and 55 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. Geophex spent an additional 5 hours and 30 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. No time was needed to resolve equipment failures that occurred while surveying the Mogul.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Geophex spent a total time of 51 hours and 5 minutes in the Mogul area, 38 hours and 5 minutes of which was spent collecting data.

3.4.5 <u>Demobilization</u>

The Geophex survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 27 April 2005. On that day, it took the crew 50 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Geophex submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was provided on 26 July 2005.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

Geophex began identifying targets in the southwest corner of the Mogul area, covering the area in a north/south direction. A second hand-held sensor was then utilized in the southeast corner of the Mogul area, covering it in a south/north direction. When targets were identified, a pin flag was placed in the ground, GPS equipment was then placed at the flag to give Geophex exact positioning of the target.

3.7 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive. Figure 3 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

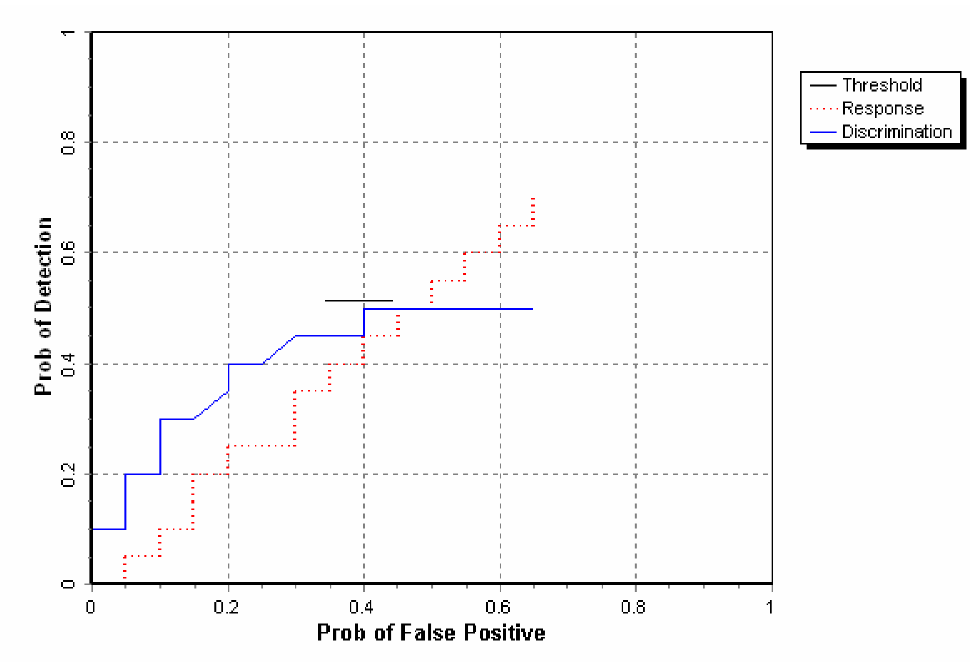

Figure 2. GEM-3 Realtime Disc/hand held mogul probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

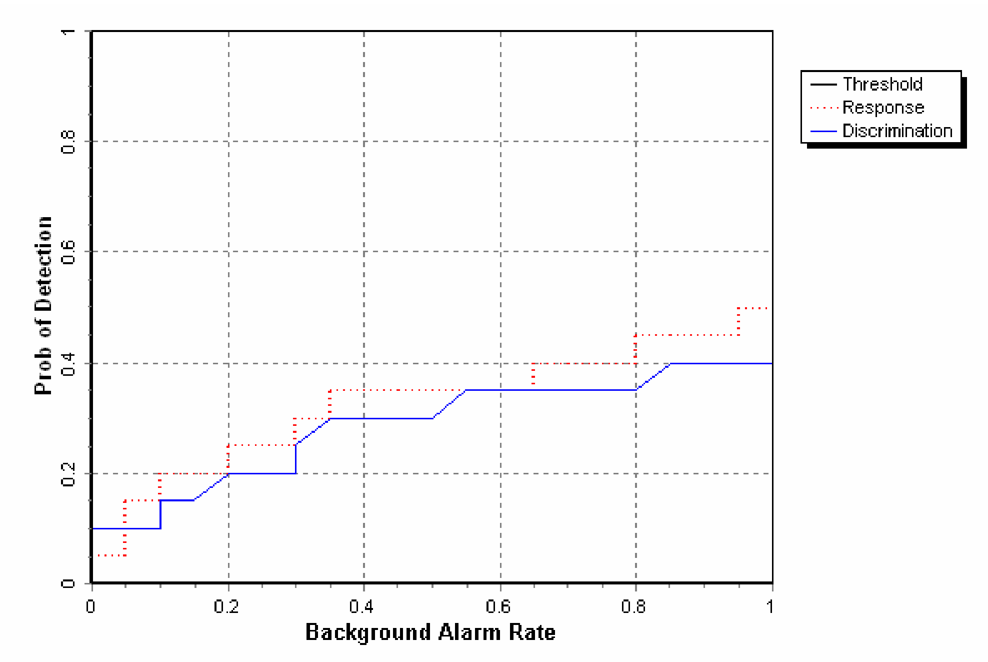

Figure 3. GEM-3 Realtime Disc/hand held mogul probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 4 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored. Figure 5 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

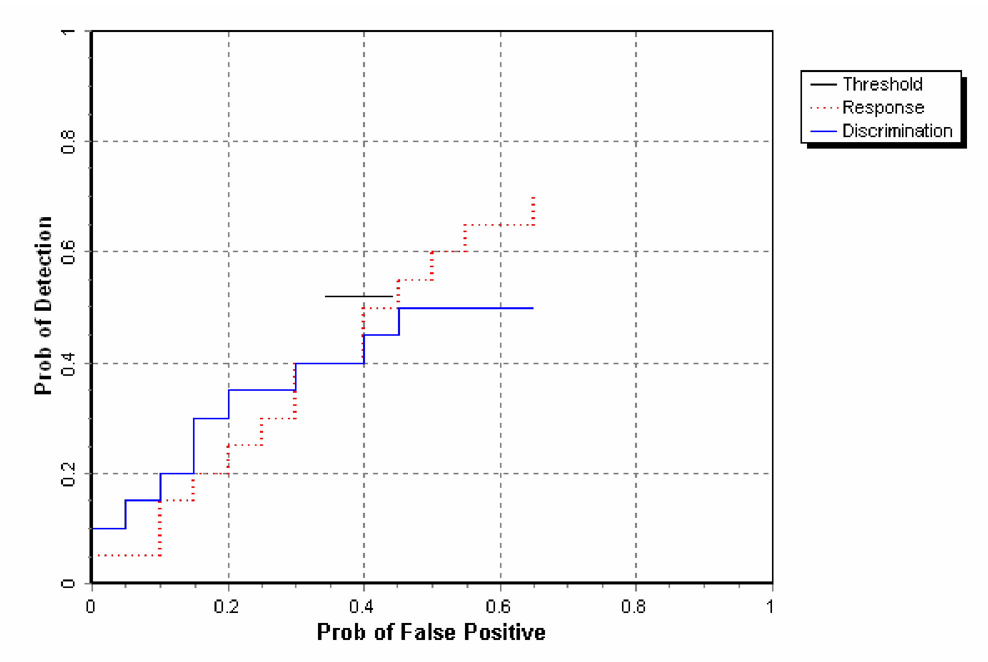

Figure 4. GEM-3 Realtime Disc/hand held mogul probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

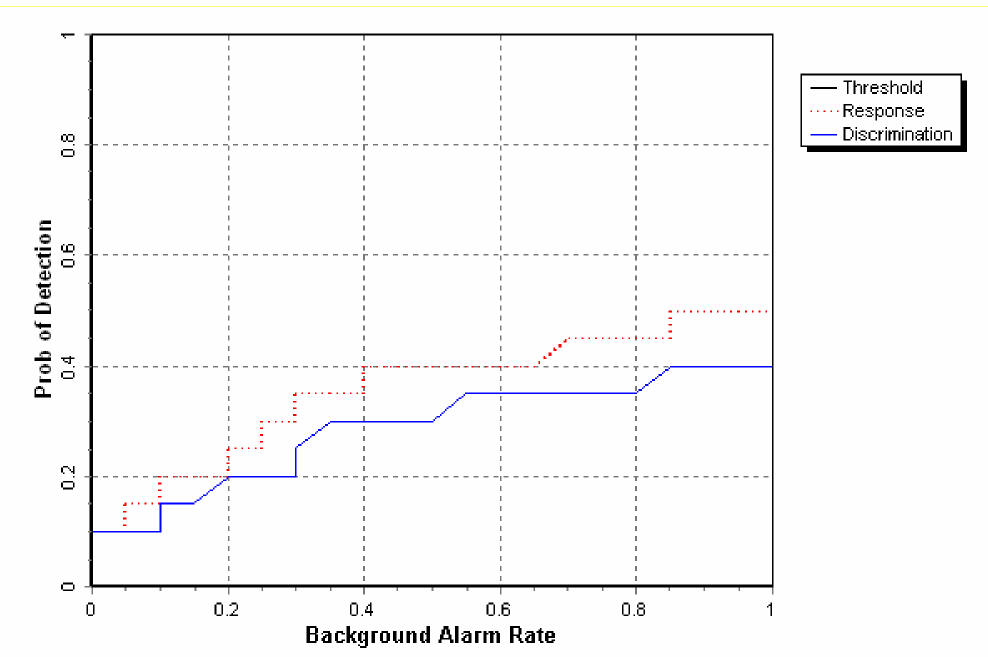

Figure 5. GEM-3 Realtime Disc/hand held mogul probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the Mogul Area test broken out by size, depth and nonstandard ordnance are presented in Table 5 (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

TABLE 5. SUMMARY OF MOGUL RESULTS FOR GEM-3 REALTIME DISC/HAND HELD

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.70	0.75	0.60	0.75	0.65	0.55	0.90	0.50	0.15
P_d Low 90% Conf	0.63	0.68	0.51	0.68	0.55	0.40	0.85	0.43	0.08
P_d Upper 90% Conf	0.72	0.80	0.67	0.81	0.72	0.68	0.94	0.61	0.32
P_{fp}	0.65	-	-	-	-	-	0.75	0.50	0.35
P_{fp} Low 90% Conf	0.62	-	-	-	-	-	0.73	0.46	0.13
P_{fp} Upper 90% Conf	0.68	-	-	-	-	-	0.81	0.56	0.60
BAR	3.00	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.50	0.50	0.50	0.60	0.50	0.30	0.70	0.40	0.10
P_d Low 90% Conf	0.46	0.44	0.44	0.50	0.43	0.19	0.62	0.32	0.02
P_d Upper 90% Conf	0.56	0.58	0.60	0.65	0.60	0.45	0.75	0.50	0.22
P_{fp}	0.40	-	-	-	-	-	0.50	0.25	0.20
P_{fp} Low 90% Conf	0.36	-	-	-	-	-	0.45	0.23	0.06
P_{fp} Upper 90% Conf	0.42	-	-	-	-	-	0.54	0.32	0.49
BAR	1.45	-	-	-	-	-	-	-	-

Response Stage Noise Level: -1,000.00
Recommended Discrimination Stage Threshold: 4.97

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.76	0.39	0.51
With No Loss of P_d	1.00	0.02	0.06

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	69.4
Medium	44.1
Large	25.0
Overall	56.0

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the Blind Grid, only depth errors are calculated, since (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)

	Mean	Standard Deviation
Northing	-0.02	0.15
Easting	0.05	0.12
Depth	0.07	0.18

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor", the second person was designated "data analyst", and the third and following personnel were considered "field support". Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the Calibration Lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	4.83	$458.85
Data Analyst	1	57.00	4.83	275.31
Field Support	3	28.50	4.83	412.97
SubTotal				**$1,147.13**
Calibration				
Supervisor	1	$95.00	2.50	$237.50
Data Analyst	1	57.00	2.50	142.50
Field Support	0	28.50	2.50	0.00
SubTotal				**$380.00**
Site Survey				
Supervisor	1	$95.00	51.08	$4,852.60
Data Analyst	1	57.00	51.08	2,911.56
Field Support	3	28.50	51.08	4,637.34
SubTotal				**$12,131.50**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	0.83	$78.85
Data Analyst	1	57.00	0.83	47.31
Field Support	3	28.50	0.83	70.97
Subtotal				**$197.13**
Total				**$13,855.76**

Notes: Calibration time includes time spent in the Calibration Lanes as well as calibration before each data run.

Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO OPEN FIELD DEMONSTRATION

6.1 SUMMARY OF RESULTS FROM OPEN FIELD DEMONSTRATION

No comparisons to date.

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g. TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to nonordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

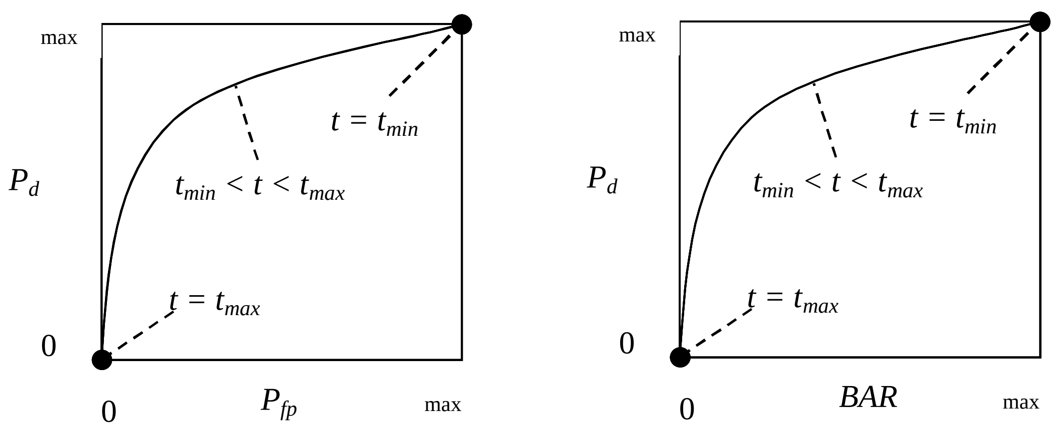

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind Grid	Open Field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

(Page A-8 Blank)

APPENDIX B.   DAILY WEATHER LOGS

Date	Time	Average Temperature, F°	Relative Humidity, %	Total Precipitation, in.
4/18/2005	0700	60.7	35.16	0
4/18/2005	0800	66.0	33.10	0
4/18/2005	0900	69.2	27.27	0
4/18/2005	1000	71.5	29.77	0
4/18/2005	1100	73.2	28.55	0
4/18/2005	1200	74.8	28.11	0
4/18/2005	1300	75.9	27.63	0
4/18/2005	1400	75.6	27.31	0
4/18/2005	1500	76.6	27.27	0
4/18/2005	1600	76.6	26.56	0
4/18/2005	1700	76.2	27.98	0
4/19/2005	0700	52.4	92.60	0
4/19/2005	0800	61.0	75.63	0
4/19/2005	0900	66.6	57.14	0
4/19/2005	1000	71.3	45.06	0
4/19/2005	1100	74.2	41.87	0
4/19/2005	1200	77.7	37.06	0
4/19/2005	1300	81.5	32.03	0
4/19/2005	1400	82.0	31.2	0
4/19/2005	1500	83.6	30.45	0
4/19/2005	1600	83.5	30.46	0
4/19/2005	1700	79.9	32.40	0
4/20/2005	0700	60.3	62.59	0
4/20/2005	0800	59.4	61.01	0
4/20/2005	0900	59.6	56.79	0
4/20/2005	1000	58.0	57.52	0
4/20/2005	1100	58.2	56.40	0
4/20/2005	1200	58.7	51.74	0
4/20/2005	1300	59.5	44.35	0
4/20/2005	1400	59.5	41.73	0
4/20/2005	1500	61.1	36.11	0
4/20/2005	1600	62.8	31.52	0
4/20/2005	1700	63.1	31.77	0
4/21/2005	0700	55.9	93.2	0
4/21/2005	0800	64.7	77.58	0
4/21/2005	0900	71.4	58.34	0
4/21/2005	1000	77.5	45.34	0
4/21/2005	1100	82.2	36.5	0
4/21/2005	1200	83.6	28.94	0
4/21/2005	1300	84.2	27.81	0
4/21/2005	1400	85.5	26.22	0
4/21/2005	1500	84.6	26.56	0
4/21/2005	1600	84.4	27.14	0
4/21/2005	1700	84.8	26.02	0

Date	Time	Average Temperature, F°	Relative Humidity, %	Total Precipitation, in.
4/22/2005	0700	50.6	92.3	0
4/22/2005	0800	52.3	86.7	0
4/22/2005	0900	53.0	85.8	0
4/22/2005	1000	53.2	82.9	0
4/22/2005	1100	52.7	84.00	0
4/22/2005	1200	51.6	84.2	0
4/22/2005	1300	52.5	84.5	0
4/22/2005	1400	52.1	83.9	0
4/22/2005	1500	52.2	77.81	0
4/22/2005	1600	52.6	77.49	0
4/22/2005	1700	52.4	79.38	0
4/25/2005	0700	44.4	64.32	0
4/25/2005	0800	46.8	62.75	0
4/25/2005	0900	48.2	63.92	0
4/25/2005	1000	51.9	49.84	0
4/25/2005	1100	53.7	44.96	0
4/25/2005	1200	55.7	41.60	0
4/25/2005	1300	57.8	35.8	0
4/25/2005	1400	58.5	33.25	0
4/25/2005	1500	59.9	30.95	0
4/25/2005	1600	60.0	30.38	0
4/25/2005	1700	60.5	29.96	0
4/26/2005	0700	50.1	81.6	0
4/26/2005	0800	54.9	67.28	0
4/26/2005	0900	58.9	54.94	0
4/26/2005	1000	62.5	49.24	0
4/26/2005	1100	65.1	47.47	0
4/26/2005	1200	69.2	39.99	0
4/26/2005	1300	71.5	30.33	0
4/26/2005	1400	71.6	28.84	0
4/26/2005	1500	71	29.24	0
4/26/2005	1600	70.4	29.28	0
4/26/2005	1700	69.1	31.78	0
4/27/2005	0700	58.2	97.9	0
4/27/2005	0800	60	92.6	0
4/27/2005	0900	62.3	81	0
4/27/2005	1000	64.7	67.51	0
4/27/2005	1100	66.4	56.64	0
4/27/2005	1200	67.2	55.07	0
4/27/2005	1300	67.6	50.23	0
4/27/2005	1400	68.8	42.96	0
4/27/2005	1500	69	41.4	0
4/27/2005	1600	69.8	35.34	0
4/27/2005	1700	69.7	30.16	0

APPENDIX C. SOIL MOISTURE

Date: 4/18/2005 Time: 0800 AM, 1600 PM			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	5.5	5.4
	6 to 12	36.8	36.7
	12 to 24	50.1	50.1
	24 to 36	44.0	44.0
	36 to 48	39.0	38.7
Blind Grid/Moguls	0 to 6	3.2	3.1
	6 to 12	23.6	23.5
	12 to 24	37.2	37.0
	24 to 36	34.4	34.4
	36 to 48	38.5	38.4

Date: 4/19/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	5.3	5.3
	6 to 12	36.6	36.6
	12 to 24	50.1	50.0
	24 to 36	44.0	43.8
	36 to 48	38.6	38.5
Blind Grid/Moguls	0 to 6	3.0	3.0
	6 to 12	23.2	23.3
	12 to 24	36.9	36.8
	24 to 36	34.2	34.2
	36 to 48	38.5	38.3

Date: 4/20/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	5.2	5.1
	6 to 12	36.7	36.5
	12 to 24	50.1	50.2
	24 to 36	43.5	43.7
	36 to 48	38.4	38.3
Blind Grid/Moguls	0 to 6	2.9	2.8
	6 to 12	23.2	23.1
	12 to 24	36.6	36.4
	24 to 36	34.0	34.1
	36 to 48	38.3	38.2

Date: 4/21/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	5.1	5.0
	6 to 12	36.4	36.8
	12 to 24	50.2	50.1
	24 to 36	43.8	43.5
	36 to 48	38.0	38.2
Blind Grid/Moguls	0 to 6	2.7	2.7
	6 to 12	23.1	23.0
	12 to 24	36.3	36.2
	24 to 36	33.8	33.7
	36 to 48	38.0	38.1

Date: 4/22/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	4.8	4.8
	6 to 12	36.6	36.6
	12 to 24	49.8	49.7
	24 to 36	43.3	43.2
	36 to 48	38.0	38.1
Blind Grid/Moguls	0 to 6	2.5	2.6
	6 to 12	22.7	22.8
	12 to 24	36.1	36.3
	24 to 36	33.5	33.1
	36 to 48	38.0	38.0

Date: 4/25/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	4.6	4.7
	6 to 12	36.5	36.4
	12 to 24	49.8	49.7
	24 to 36	42.9	43.0
	36 to 48	38.2	38.1
Blind Grid/Moguls	0 to 6	2.5	2.4
	6 to 12	22.5	22.7
	12 to 24	36.0	36.2
	24 to 36	33.0	33.3
	36 to 48	37.7	37.7

Date: 4/26/2005 **Time: 0800 AM, 1600 PM**			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	NA	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	4.6	4.6
	6 to 12	36.2	36.1
	12 to 24	49.5	49.6
	24 to 36	42.8	42.9
	36 to 48	38.0	37.9
Blind Grid/Moguls	0 to 6	2.3	2.2
	6 to 12	22.6	22.5
	12 to 24	36.0	36.1
	24 to 36	33.2	33.1
	36 to 48	37.5	37.4

APPENDIX D. DAILY ACTIVITY LOGS

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
4/18/2005	5	MOGULS	1000	1415	255	1	INITIAL SETUP		GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	5	MOGULS	1100	1135	35	1	INITIAL SETUP		GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1135	1200	25	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1200	1320	80	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1320	1605	165	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1605	1620	15	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1620	1750	90	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
4/19/2005	3	MOGULS	1750	1800	10	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	800	900	60	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	900	1130	150	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1130	1135	5	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1135	1310	95	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1310	1400	50	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1400	1615	135	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1615	1645	30	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1645	1745	60	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/20/2005	2	MOGULS	1745	1800	15	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	745	815	30	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	SUNNY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
04/21/2005	5	MOGULS	815	1100	165	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1100	1130	30	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1130	1200	30	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1200	1230	30	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1230	1415	105	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1415	1445	30	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1445	1650	125	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1650	1700	10	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1700	1750	50	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/21/2005	5	MOGULS	1750	1800	10	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY	MUDDY
04/22/2005	5	MOGULS	800	830	30	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	CLOUDY	MUDDY
04/22/2005	5	MOGULS	830	1130	180	4	COLLECTING DATA		GPS	NA	LINEAR	CLOUDY	MUDDY
04/22/2005	5	MOGULS	1130	1135	5	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
04/22/2005	5	MOGULS	1135	1230	55	5	BREAK/LUNCH		GPS	NA	LINEAR	CLOUDY	MUDDY
04/22/2005	5	MOGULS	1230	1400	90	4	COLLECTING DATA		GPS	NA	LINEAR	CLOUDY	MUDDY
04/22/2005	5	MOGULS	1400	1635	155	4	COLLECTING DATA		GPS	NA	LINEAR	CLOUDY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
04/22/2005	5	MOGULS	1635	1650	15	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	CLOUDY	MUDDY
04/25/2005	5	MOGULS	745	830	45	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	830	1000	90	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1000	1030	30	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1030	1130	60	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1130	1215	45	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1215	1500	165	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1500	1520	20	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1520	1735	135	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/25/2005	5	MOGULS	1735	1750	15	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	MOGULS	740	750	10	3	DAILY START, STOP	SET UP	GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	MOGULS	750	1100	190	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	MOGULS	1100	1115	15	3	DAILY START, STOP	GET FLAGS	GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	MOGULS	1115	1205	50	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	MOGULS	1205	1310	65	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	2	BLIND GRID	1310	1515	125	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	BLIND GRID	1515	1530	15	5	BREAK/LUNCH		GPS	NA	LINEAR	SUNNY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Op Stat Code	Operational Status	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
04/26/2005	5	BLIND GRID	1530	1735	125	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	5	BLIND GRID	1735	1750	15	3	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	2	CAL. LANES	1245	1455	130	4	COLLECTING DATA		GPS	NA	LINEAR	SUNNY	MUDDY
04/26/2005	2	CAL. LANES	1455	1515	20	7	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
04/27/2005	5	CAL. LANES	740	830	50	10	DEMOBILIZE	DEMOBILIZE	GPS	NA	LINEAR	SUNNY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

APPENDIX F. ABBREVIATIONS

ADC = analog-to-digital converter
AEC = U.S. Army Environmental Center
APG = Aberdeen Proving Ground
ASCII = American Standard Code for Information Interchange.
ATC = U.S. Army Aberdeen Test Center
DFT = discrete Fourier transform
DGPS = Differential Global Positioning System
EM = electromagnetic
ERDC = U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP = Environmental Security Technology Certification Program
EQT = Army Environmental Quality Technology Program
GPS = Global Positioning System
HEAT = high-explosive, antitank
JPG = Jefferson Proving Ground
POC = point of contact
ppm = parts per million
QA = quality assurance
QC = quality control
ROC = receiver-operating characteristic
Rx = receiver coil
SERDP = Strategic Environmental Research and Development Program
Tx = transmitting coils
UXO = unexploded ordnance
YPG = U.S. Army Yuma Proving Ground

Secondary distribution is controlled by Commander, U.S. Army Environmental Center, ATTN: SFIM-AEC-ATT.