AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9002

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

MOGULS SCORING RECORD NO. 451

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

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

TECHNOLOGY TYPE/PLATFORM:
GEM-3/HAND HELD

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

AUGUST 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

REPORT DOCUMENTATION PAGE							Form Approved OMB No. 0704-0188

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

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
9 through 13 December 2002

4. TITLE AND SUBTITLE
STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE MOGULS SCORING RECORD NO. 451 (GEOPHEX LTD.)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

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

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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

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
ATC-9002

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

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. The scoring record was 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 Program, Moguls, GEM-3/Hand Held

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

(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 unexploded ordnance (UXO) 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 Scoring Methodology

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

605 Mercury Street
Raleigh, NC 27603

2.1.2 System Description (provided by demonstrator)

GEM-3 Electromagnetic Induction (EMI) sensors are multi-frequency (up to 10 frequencies logarithmically spaced in the 30 Hz to 47930 Hz range) sensors consisting of three concentric coils and digital electronics. The outer coil is the primary transmitter, the inner coil the receiver, and the annular coil is a secondary (bucking) transmitter that creates a primary field cavity around the transmitter. The electronics includes a digitally controlled switching H-bridge transmitter current-source, a 24 bit analog to digital (A/D), and a Digital Signal Processor (DSP) with random access memory (RAM) and flash memory and serial data ports (RS-232). A user interface consists of a palm pack computer with Geophex software; commercial digital Global Positioning System (DGPS) is fully integrated.

The system is a continuous wave frequency domain system in which data are recorded while the transmitter is on; the transmitter waveform consists of a continuous mix of superposed sine waves at the specified frequencies. The measured raw time-series data are voltages (pre-amplified) measured by the receiver coil and by a small reference coil located in the transmitter primary/bucking coil annular space (proportional to primary field and phase referenced to primary field), and sampled by the A/D. Data are pre-processed in units of 30-Hz intervals (base periods) and averaged over a selectable number of base periods, typically two for cart-survey operation (net output rate of 15 Hz).

The cart-mounted configuration, with a 96-cm diameter coil disk mounted on either a manually pushed composite material wheeled cart or an all terrain vehicle (ATV) towed wooden wheeled cart, is used in environments where a large sensor on a wheeled cart is practical and wide-area coverage required, such as flat, open terrain (fig.1). The ATV towed system is augmented with a navigation system that provides the driver with steering indicators in order to maintain preplanned survey lines, but it requires greater room for turning than the hand pushed cart. The actual sensors are identical and can be interchanged. A DGPS system is integrated with the GEM console, and the antenna mounted directly above the sensor, provides geo-referenced data, which are recorded in the GEM console flash memory and/or the system (laptop PC) computer. Data are post-processed for target detection/classification.

Figure 1. GEM-3/hand held demonstrator's system.

2.1.3 <u>Data Processing Description (provided by demonstrator)</u>

The front-end data processing is performed in real-time by the system DSP. This processing consists of performing a partial Digital Fourier Transform (DFT) on the receiver and reference time series provided by the A/D at 96 kHz. The DFT frequency samples correspond to the logarithmically spaced transmitted frequencies characterizing the hybrid current waveform. Complex division of the receiver and reference DFT outputs are performed, and system transfer function (calibration) corrections are applied, to generate inphase and quadrature measurements at each frequency. These data are recorded in the console flash memory and/or output to the system computer.

Further processing, performed during post-processing, consists of color-contour map generation using commercial software such as Geosoft©. Target detection utilizes either a composite measurement such as the sum of the quadratures over all frequencies, or a weighted average apparent conductivity over all frequencies. Anomalies identified from the maps may be further scrutinized in profile format. For target discrimination, a spectral matching algorithm compares the measurement with a library of known possible target spectra; this algorithm allows for a linear combination of the intrinsic longitudinal and transverse target response. The quality of the best fit (i.e. rms or mean absolute error) is compared with a threshold for clutter declaration and used as a confidence measure.

The survey method in the calibration and blind grids will be applied by occupying the potential target location points, preceded with a nearby background reading or (optionally) utilizing a continuous filtered background reading, and operator initiated data sampling/storing for two seconds. Target locations will be identified in the data files via line numbers. The raw data will be post-processed as described above.

In the open area, the cart will be towed with an ATV at walking speed along half-meter spaced lines; these lines will be maintained using the onboard navigation system based on DGPS. The console and downloading software, as well as the system computer logging the data, perform geo-referencing of the GEM data automatically. The GEM and Global Positioning System (GPS) data will be post-processed to provide geo-referenced dig lists as described above. The cart will be manually pushed, as needed, where maneuvering the ATV is difficult and in small patches that extend outside the main area.

2.1.4 Data Submission Format

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 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

QC will be performed by testing the systems with a test target (ferrite) each day, and verifying proper and consistent system measurements. QA will include a review of recorded data at the end of each day.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org.

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.
Open Field	A 4-hectare (10-acre) site containing open areas, dips, ruts and obstructions that challenge platform systems or hand held detectors. The challenges include a gravel road, wet areas and trees. The vegetation height varies from 15 to 25 cm.
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 (9 through 13 December 2002)

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	3.52
Mogul	30.53

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, 2002	Average Temperature, ^{o}F	Total Daily Precipitation, in.
December 9	25.67	0.00
December 10	27.49	0.00
December 11	35.50	1.50
December 12	41.55	0.03
December 13	34.40	0.67

3.3.2 Field Conditions

Geophex surveyed the Mogul area on 9 through 13 December 2002. On 11 December no data was taken due to inclement weather (rain). The area surveyed was very wet throughout the time spent. Snow was also on he ground throughout the survey.

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 <u>Setup/Mobilization</u>

These activities included initial mobilization and daily equipment preparation and break down. An eight-person crew took 3 hours and 20 minutes to perform the initial setup and mobilization. There was 2 hours and 11 minutes of daily equipment preparation and end of the day equipment break down lasted 1-hour and 30 minutes.

3.4.2 <u>Calibration</u>

Geophex spent a total of 3 hours and 31 minutes in the calibration grid on 28 April 2003, 2 hours and 41 minutes of which was spent collecting data.

3.4.3 <u>Downtime Occasions</u>

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 <u>Equipment/data checks, maintenance</u>. Equipment data checks and maintenance activities accounted for 2 hours and 44 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 1-hour and 56 minutes for breaks and lunches.

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

3.4.3.3 <u>Weather</u>. No weather delays occurred during the survey.

3.4.4 <u>Data Collection</u>

Geophex spent a total time of 30 hours and 32 minutes in the Mogul area, 22 hours and 11 minutes of which was spent collecting data.

3.4.5 Demobilization

The Geophex survey crew went on to conducted a full demonstration of the site. Therefore, demobilization did not occur until 13 December 2002. On that day, it took the crew 2 hours 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 also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

Geophex began identifying targets in the northwest 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 snow, 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.

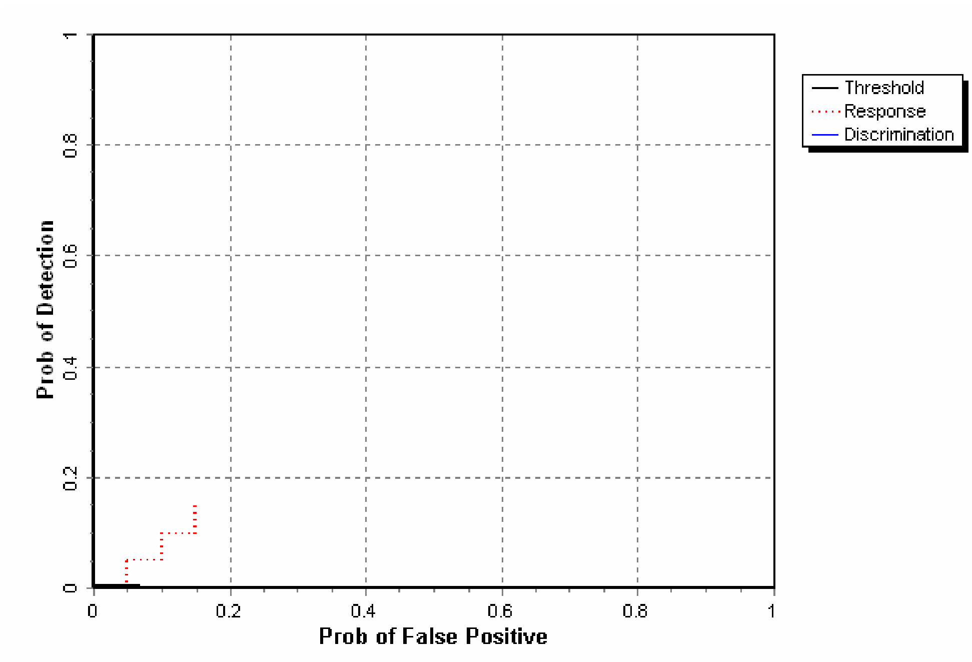

Figure 2. GEM-3 mogul probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

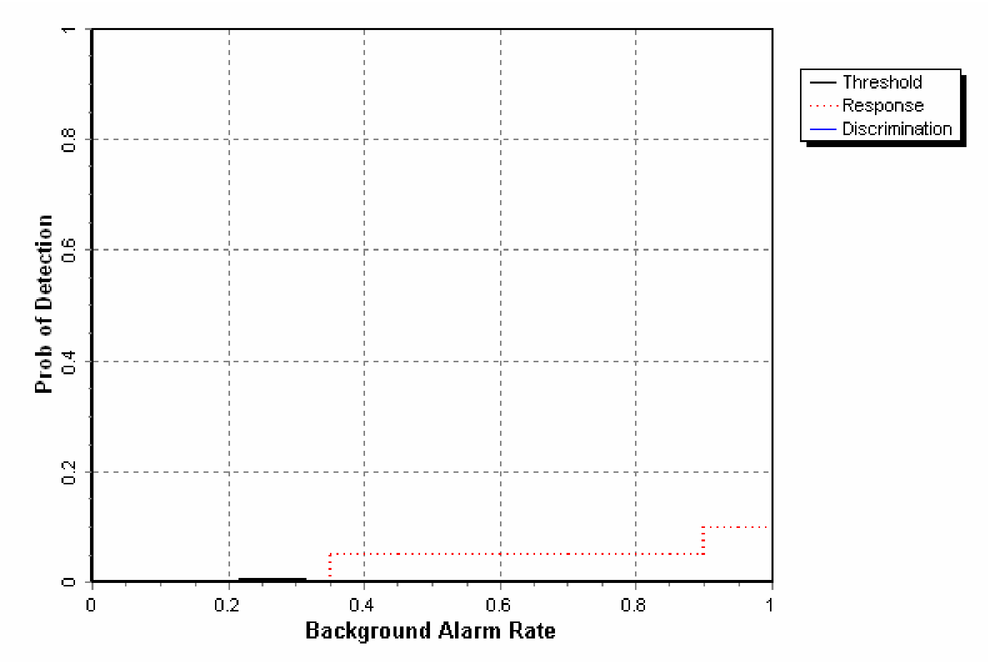

Figure 3. GEM-3 mogul probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

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.

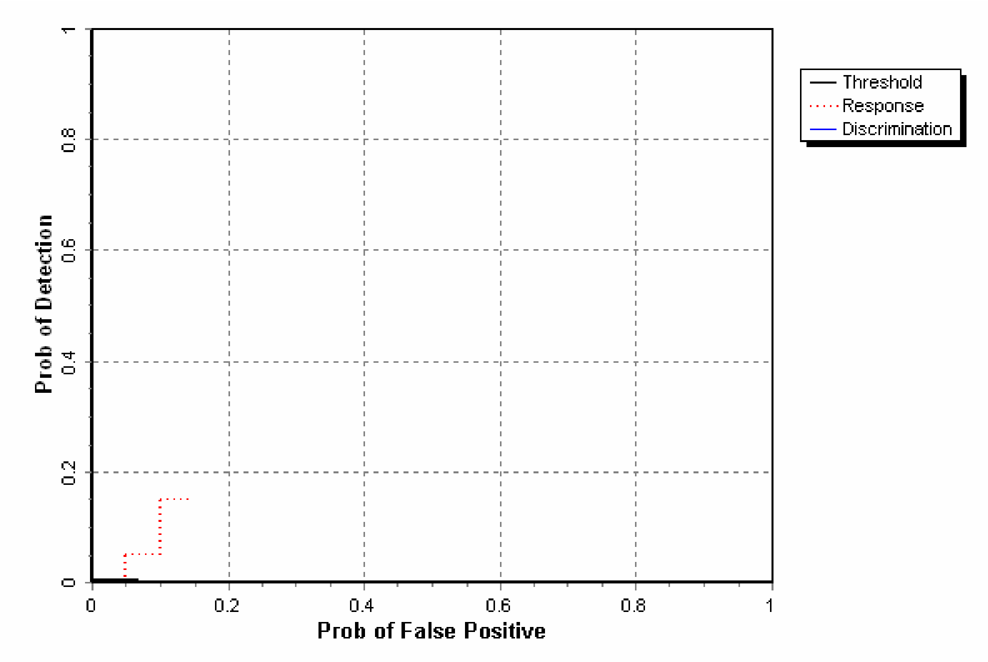

Figure 4. GEM-3 mogul probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

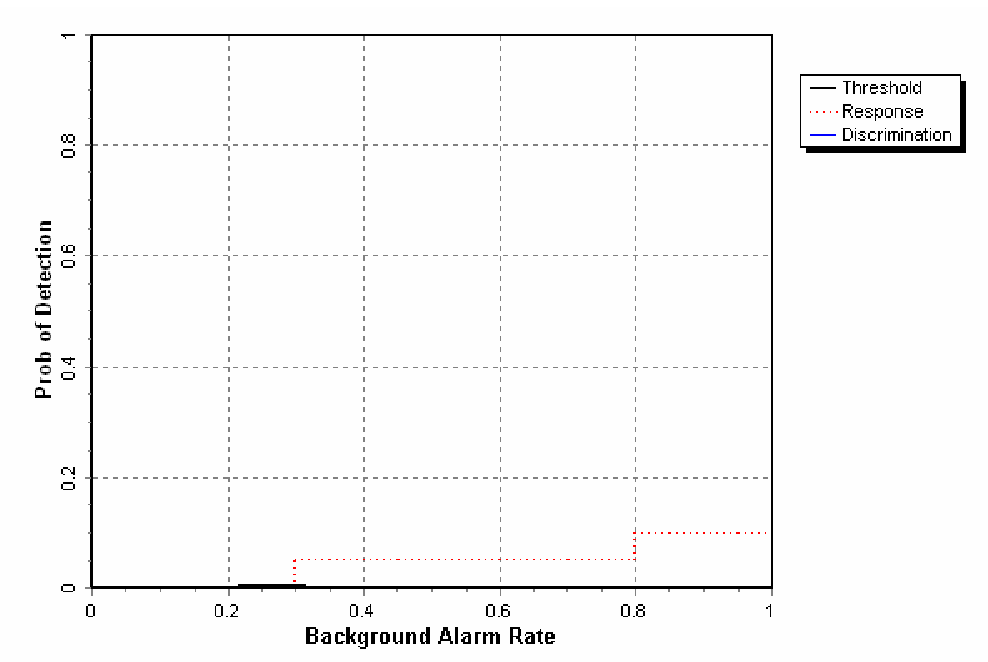

Figure 5. GEM-3 mogul probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

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

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.15	0.15	0.10	0.10	0.15	0.10	0.15	0.15	0.15
P_d Low 90% Conf	0.10	0.09	0.08	0.06	0.11	0.04	0.09	0.08	0.05
P_d Upper 90% Conf	0.17	0.19	0.19	0.16	0.24	0.24	0.19	0.20	0.27
P_{fp}	0.15	-	-	-	-	-	0.15	0.10	0.20
P_{fp} Low 90% Conf	0.11	-	-	-	-	-	0.13	0.08	0.06
P_{fp} Upper 90% Conf	0.16	-	-	-	-	-	0.19	0.14	0.49
BAR	1.65	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05
P_d Low 90% Conf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P_{fp} Upper 90% Conf	0.02	0.04	0.03	0.03	0.03	0.14	0.02	0.04	0.16
P_{fp}	0.00	-	-	-	-	-	0.05	0.00	0.00
P_{fp} Low 90% Conf	0.01	-	-	-	-	-	0.01	0.00	0.00
P_{fp} Upper 90% Conf	0.03	-	-	-	-	-	0.04	0.03	0.23
BAR	0.25	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00
Recommended Discrimination Stage Threshold: 5.00

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	0.04	0.87	0.84
With No Loss of P_d	1.00	0.02	0.02

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	N/A
Medium	N/A
Large	N/A
Overall	N/A

Note: The demonstrator did not attempt to provide type classification.

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	0.20	0.00
Easting	0.38	0.00
Depth	-1.22	0.00

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	2	$95.00	3.33	$632.70
Data Analyst	1	57.00	3.33	189.81
Field Support	5	28.50	3.33	474.53
SubTotal				**$1,297.04**
Calibration				
Supervisor	2	$95.00	3.52	$668.80
Data Analyst	1	57.00	3.52	200.64
Field Support	5	28.50	3.52	501.60
SubTotal				**$1,371.04**
Site Survey				
Supervisor	2	$95.00	30.53	$5,800.70
Data Analyst	1	57.00	30.53	1,740.21
Field Support	5	28.50	30.53	4,350.53
SubTotal				**$11,891.44**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	2	$95.00	2.0	$380.00
Data Analyst	1	57.00	2.0	114.00
Field Support	5	28.50	2.0	285.00
Subtotal				**$779.00**
Total				**$15,338.52**

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

No comparison was made due to demonstrator not surveying the Open Field with this particular system.

(Page 22 Blank)

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.

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.

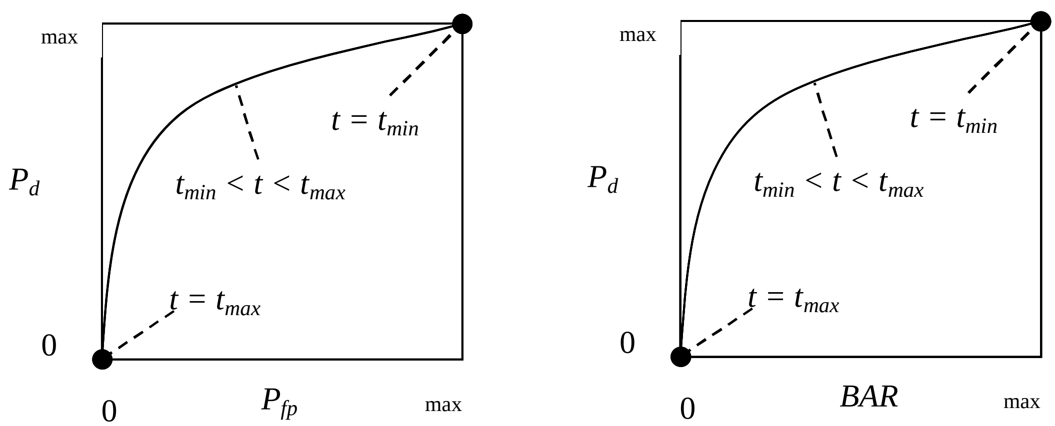

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

---

[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.

APPENDIX B. DAILY WEATHER LOGS

TABLE B-1. WEATHER LOG

Date & Time	Average Temp (°F)	Relative Humidity (%)	Total Precip (in)
12/09/2002 00:00:00	34.7	43.47	0
12/09/2002 01:00:00	32.9	47.78	0
12/09/2002 02:00:00	31.4	50.31	0
12/09/2002 03:00:00	29.7	47.13	0
12/09/2002 04:00:00	27.7	51.65	0
12/09/2002 05:00:00	25.9	55.19	0
12/09/2002 06:00:00	24	58.12	0
12/09/2002 07:00:00	22.3	60.42	0
12/09/2002 08:00:00	21.7	57.95	0
12/09/2002 09:00:00	23.2	51.08	0
12/09/2002 10:00:00	24.2	49.65	0
12/09/2002 11:00:00	25.5	46.96	0
12/09/2002 12:00:00	27	41.87	0
12/09/2002 13:00:00	28.5	37.95	0
12/09/2002 14:00:00	28.2	39.26	0
12/09/2002 15:00:00	29.1	38.87	0
12/09/2002 16:00:00	27.3	45.35	0
12/09/2002 17:00:00	25.4	52.13	0
12/09/2002 18:00:00	23.3	55.91	0
12/09/2002 19:00:00	20.6	62.49	0
12/09/2002 20:00:00	19	66.94	0
12/09/2002 21:00:00	19	69.72	0
12/09/2002 22:00:00	15.7	78.97	0
12/09/2002 23:00:00	15.4	83.1	0
12/09/2002 23:59:00	15.3	83	

TABLE B-1. (CONT'D)

Date & Time	Average Temp (°F)	Relative Humidity (%)	Total Precip (in)
12/10/2002 00:00:00	15.3	83.3	0
12/10/2002 01:00:00	14.2	86.4	0
12/10/2002 02:00:00	13.7	89.9	0
12/10/2002 03:00:00	13.9	90.5	0
12/10/2002 04:00:00	15.3	89.4	0
12/10/2002 05:00:00	15.9	89.4	0
12/10/2002 06:00:00	16.3	90.4	0
12/10/2002 07:00:00	17.4	89.5	0
12/10/2002 08:00:00	17.3	90.3	0
12/10/2002 09:00:00	21.2	82.4	0
12/10/2002 10:00:00	25	74.22	0
12/10/2002 11:00:00	27.5	68.8	0
12/10/2002 12:00:00	29.4	65.76	0
12/10/2002 13:00:00	31.5	60.64	0
12/10/2002 14:00:00	32.9	58.84	0
12/10/2002 15:00:00	33.7	55.23	0
12/10/2002 16:00:00	33.8	56.42	0
12/10/2002 17:00:00	32.7	60.18	0
12/10/2002 18:00:00	31.1	63.6	0
12/10/2002 19:00:00	29.7	65.75	0
12/10/2002 20:00:00	29.5	63.87	0
12/10/2002 21:00:00	29.1	63.2	0
12/10/2002 22:00:00	26.5	69.08	0
12/10/2002 23:00:00	26.4	69.92	0
12/10/2002 23:59:00	29.1	65	

TABLE B-1. (CONT'D)

Date & Time	Average Temp (°F)	Relative Humidity (%)	Total Precip (in)
12/11/2002 00:00:00	29.1	65.05	0
12/11/2002 01:00:00	30.8	59.11	0
12/11/2002 02:00:00	32	54.22	0
12/11/2002 03:00:00	33.5	48.72	0
12/11/2002 04:00:00	33.9	52.79	0
12/11/2002 05:00:00	32.7	68.79	0
12/11/2002 06:00:00	32.8	74.61	0.01
12/11/2002 07:00:00	33.8	72.96	0
12/11/2002 08:00:00	34.8	69.61	0.01
12/11/2002 09:00:00	34	83.1	0.03
12/11/2002 10:00:00	34.1	90.1	0
12/11/2002 11:00:00	34.8	96	0.09
12/11/2002 12:00:00	35.9	96.3	0.11
12/11/2002 13:00:00	37.2	96.6	0.28
12/11/2002 14:00:00	36.5	98.7	0.5
12/11/2002 15:00:00	35.8	99.3	0.29
12/11/2002 16:00:00	36.6	97.3	0.06
12/11/2002 17:00:00	37	97	0.01
12/11/2002 18:00:00	37.1	97.3	0.02
12/11/2002 19:00:00	37.4	97.1	0.01
12/11/2002 20:00:00	37.1	97.5	0.01
12/11/2002 21:00:00	36.5	97.8	0.02
12/11/2002 22:00:00	36.5	98.1	0.01
12/11/2002 23:00:00	36.8	97.2	0
12/11/2002 23:59:00	36.9	97	

TABLE B-1. (CONT'D)

Date & Time	Average Temp (°F)	Relative Humidity (%)	Total Precip (in)
12/12/2002 00:00:00	36.9	97	0.01
12/12/2002 01:00:00	36.8	98.3	0.01
12/12/2002 02:00:00	37	96.8	0
12/12/2002 03:00:00	37.2	95.7	0
12/12/2002 04:00:00	37	96.3	0.01
12/12/2002 05:00:00	37.1	96.1	0
12/12/2002 06:00:00	36.7	95.7	0
12/12/2002 07:00:00	37.3	93.1	0
12/12/2002 08:00:00	37.3	91	0
12/12/2002 09:00:00	38.8	87.3	0
12/12/2002 10:00:00	39.9	84.2	0.01
12/12/2002 11:00:00	41.3	80.1	0
12/12/2002 12:00:00	43.2	75.02	0
12/12/2002 13:00:00	44.7	70.47	0
12/12/2002 14:00:00	44.8	70.4	0
12/12/2002 15:00:00	43.8	73.21	0
12/12/2002 16:00:00	43.3	74.3	0
12/12/2002 17:00:00	42.6	75.85	0
12/12/2002 18:00:00	42	77.43	0
12/12/2002 19:00:00	41.6	78.53	0
12/12/2002 20:00:00	40.9	80.4	0
12/12/2002 21:00:00	38.8	85.7	0
12/12/2002 22:00:00	35.4	93.2	0
12/12/2002 23:00:00	34.9	93.9	0
12/12/2002 23:59:00	33	99	

TABLE B-1. (CONT'D)

Date & Time	Average Temp (°F)	Relative Humidity (%)	Total Precip (in)
12/13/2002 00:00:00	33	98.7	0
12/13/2002 01:00:00	31.2	99.6	0
12/13/2002 02:00:00	30.7	100	0
12/13/2002 03:00:00	30	100	0
12/13/2002 04:00:00	29	100	0
12/13/2002 05:00:00	28.5	100	0
12/13/2002 06:00:00	28.8	100	0
12/13/2002 07:00:00	28.6	100	0
12/13/2002 08:00:00	30.5	100	0
12/13/2002 09:00:00	31.3	100	0
12/13/2002 10:00:00	33.1	100	0
12/13/2002 11:00:00	35.2	99.6	0
12/13/2002 12:00:00	35.7	97.7	0
12/13/2002 13:00:00	36.3	96.5	0
12/13/2002 14:00:00	36.8	95.5	0.01
12/13/2002 15:00:00	36.7	98.1	0.1
12/13/2002 16:00:00	36.9	99.5	0.09
12/13/2002 17:00:00	37.3	100	0.09
12/13/2002 18:00:00	38.1	100	0.04
12/13/2002 19:00:00	39.9	100	0.11
12/13/2002 20:00:00	40.4	99.6	0.11
12/13/2002 21:00:00	41.7	98.9	0.06
12/13/2002 22:00:00	43	98.7	0.04
12/13/2002 23:00:00	44.1	98.8	0.01

APPENDIX C. SOIL MOISTURE

Demonstrator: GEOPHEX

Date: 12/09/2002
Times: No AM readings, 1400 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No Readings Taken	84.9
	6 to 12		67.3
	12 to 24		75.5
	24 to 36		63.1
	36 to 48		52.0
Wooded Area	0 to 6	No Readings taken	22.5
	6 to 12		24.2
	12 to 24		28.1
	24 to 36		4.2
	36 to 48		26.0
Open Area	0 to 6	No Readings taken	17.9
	6 to 12		1.9
	12 to 24		10.5
	24 to 36		22.4
	36 to 48		22.0

Date: 12/10/2002
Times: 0937 hours, 1423 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	67.6	76.1
	6 to 12	68.5	68.5
	12 to 24	75.4	75.8
	24 to 36	63.1	63.7
	36 to 48	52.1	51.8
Wooded Area	0 to 6	21.0	20.5
	6 to 12	21.1	20.5
	12 to 24	27.4	27.1
	24 to 36	4.2	4.2
	36 to 48	25.8	25.5
Open Area	0 to 6	14.5	15.9
	6 to 12	1.6	2.8
	12 to 24	8.6	10.2
	24 to 36	19.0	18.9
	36 to 48	18.4	19.4

Date: 12/12/2002
Times: 0846 hours, 1423 hours

Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	66.8	72.7
	6 to 12	83.6	87.3
	12 to 24	62.1	63.8
	24 to 36	55.6	60.2
	36 to 48	61.9	61.3

Date: 12/13/2002
Times: 0815 hours, No PM readings

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	73.3	No Readings Taken
	6 to 12	89.0	
	12 to 24	61.6	
	24 to 36	58.3	
	36 to 48	57.5	

APPENDIX D. DAILY ACTIVITY LOG

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions
12/09/2002	8	MOGUL AREA	900	1220	320	INITIAL MOBILIZATION	REMOVE EQUIPMENT FROM VEHICLES	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/09/2002	8	MOGUL AREA	1220	1406	186	COLLECTING DATA		PIN FLAGS	PIN FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/09/2002	8	MOGUL AREA	1406	1410	4	DOWNTIME MAINTENANCE CHECK	CHANGE BATTERY, DATA CHECK	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/09/2002	8	MOGUL AREA	1410	1700	290	COLLECTING DATA	COLLECTION DATA	PIN FLAGS	PIN FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/09/2002	8	MOGUL AREA	1700	1730	30	DAILY START/STOP	END OF DAILY OPERATIONS	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	745	920	175	DAILY START/STOP	PREPARE FOR DAILY OPERATIONS	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	920	1010	90	COLLECTING DATA		PIN FLAGS	PIN FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1010	1015	5	DOWNTIME MAINTENANCE CHECK	CHANGE BATTERY	OTHER	NA	N/A	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1015	1200	185	COLLECTING DATA		PIN FLAGS	PIN FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1200	1250	50	NO ACTIVITY-LUNCH		OTHER	N/A	N/A	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1250	1334	84	DOWNTIME MAINTENANCE CHECK	CHANGE BATTERY	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1334	1630	296	COLLECTING DATA	COLLECTING DATA WHILE ITEMIFYING ITEMS	PIN FLAGS	PIN FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/10/2002	8	MOGUL AREA	1630	1715	85	DAILY START/STOP	END OF DAILY OPERATIONS - EQUIPMENT BREAK DOWN	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED

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	Operational Status	Operational Status Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions
12/12/2002	6	MOGUL AREA	746	817	71	DAILY START/STOP	START OF DAILY OPERATIONS/ EQUIPMENT SET UP	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	817	1104	287	COLLECTING DATA	IDENTIFING ITEMS WHILE COLLECTING DATA/HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1104	1122	18	NO ACTIVITY-SEE COMMENT	CHANGED BATTERIES IN CONSOLE	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1122	1220	98	COLLECTING DATA	IDENTIFING ITEMS WHILE COLLECTING DATA/HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1220	1312	92	NO ACTIVITY-LUNCH		OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1312	1352	40	COLLECTING DATA	IDENTIFING ITEMS WHILE COLLECTING DATA/HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1352	1406	54	NO ACTIVITY-LUNCH	BREAK	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1406	1430	24	DOWNTIME MAINTENANCE CHECK	CHANGING BATTERIES	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1430	1522	92	COLLECTING DATA	IDENTIFING ITEMS LOCATED WHILE COLLECTING DATA/HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED

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	Operational Status	Operational Status Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions
12/12/2002	6	MOGUL AREA	1522	1600	78	DOWNTIME MAINTENANCE CHECK	CHANGED BATTERIES IN CONSOLE	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/12/2002	6	MOGUL AREA	1600	1615	15	DAILY START/STOP	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	700	715	15	DAILY START/STOP	START OF DAILY OPERATIONS / EQUIPMENT SET UP	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	715	830	115	COLLECTING DATA	IDENTIFING ITEMS WHILE COLLECTING DATA/HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	830	841	11	DOWNTIME MAINTENANCE CHECK	CHANGING BATTERIES IN CONSOLE	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	841	1001	160	COLLECTING DATA	HIGH MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	730	910	180	COLLECTING DATA	IDENTIFYING ITEMS WHILE COLLECTING DATA/LOW MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	910	938	28	DOWNTIME MAINTENANCE CHECK	CHANGED BATTERIES IN CONSOLE	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	938	1130	192	COLLECTING DATA	LOW MOGUL	PIN FLAGS	FLAGS	LINEAR	SNOW/FREEZING RAIN/LIMITED
12/13/2002	6	MOGUL AREA	1130	1330	200	DEMOBILIZATION	END OF OPERATIONS/ EQUIPMENT BREAKDOWN	OTHER	NA	NA	SNOW/FREEZING RAIN/LIMITED

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	Operational Status	Operational Status Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
4/29/2003	2	CALIBRATION LANE	1510	1530	20	SET-UP/DAILY START/STOP CALIBRATION	SET UP/ MOBILIZATION	GPS	NA	LINEAR	CLOUDY	MUDDY
4/29/2003	2	CALIBRATION LANE	1530	1815	165	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
4/29/2003	2	CALIBRATION LANE	1815	1841	26	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
4/29/2003	2	BLIND TEST GRID	1841	1915	34	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
4/29/2003	2	BLIND TEST GRID	1915	1920	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	DOWNLOAD DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
4/29/2003	2	BLIND TEST GRID	1920	1930	10	SET-UP/DAILY START/STOP CALIBRATION	END OF DAILY OPERATIONS EQUIPMENT BREAKDOWN	GPS	NA	LINEAR	CLOUDY	MUDDY
4/30/2003	2	BLIND TEST GRID	1015	1030	15	SET-UP/DAILY START/STOP CALIBRATION	SET UP/ MOBILIZATION	GPS	NA	LINEAR	CLOUDY	MUDDY
4/30/2003	2	BLIND TEST GRID	1030	1225	115	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
4/30/2003	2	BLIND TEST GRID	1225	1305	40	DOWNTIME DUE TO EQUIP MAIN/CHECK	DOWNLOAD DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
5/7/2003	2	OPEN FIELD	1408	1515	67	DEMOBILIZATION	DEMOBILIZATION	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

A/D	=	analog to digital
AEC	=	U.S. Army Environmental Center
APG	=	Aberdeen Proving Ground
ASCII	=	American Standard Code for Information Interchange.
ATC	=	U.S. Army Aberdeen Test Center
ATV	=	all terrain vehicle
DFT	=	Digital Fourier Transform
DGPS	=	digital Global Positioning System
DSP	=	Digital Signal Processor
EM	=	electromagnetic
EMI	=	electromagnetic interference
EMIS	=	Electromagnetic Induction Spectroscopy
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
JPG	=	Jefferson Proving Ground
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
RAM	=	random access memory
ROC	=	receiver-operating characteristic
RTK	=	real time kinematic
RTS	=	Robotic Total Station
SERDP	=	Strategic Environmental Research and Development Program
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground

(Page F-2 Blank)