AD NO. ________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9418

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 810

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
FOERSTER GROUP
140 INDUSTRY DRIVE
PITTSBURGH, PA 15275

TECHNOLOGY TYPE/PLATFORM:
FEREX FLUXGATE GRADIENT
MAGNETOMETER/SLING

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
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MAY 2007

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
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)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
May 2007	Final	24 through 28 April 2006

4. TITLE AND SUBTITLE
STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE BLIND GRID SCORING RECORD NO. 810 (FOERSTER GROUP, FEREX FLUXGATE GRADIENT MAGNETOMETER/SLING)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER
8-CO-160-UXO-021

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
ATC-9418

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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U.S. Army Environmental Command
ATTN: IMAE-ATT
Aberdeen Proving Ground, MD 21010-5401

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
None

14. ABSTRACT

This scoring record documents the efforts of the Foerster Group to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. This Scoring Record was coordinated by Michael Karwatka 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 Command, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS
Foerster Group, UXO Standardized Technology Demonstration Site, Blind Grid, FEREX Fluxgate Gradient Magnetometer/Sling, MEC

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

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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 Command (USAEC). 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 may 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. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 <u>Scoring Factors</u>

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-mm, 40-mm, 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 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
	M75 Submunition

HEAT = high-explosive antitank.
JPG = Jefferson Proving Ground.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 System Description (provided by demonstrator)

Foerster proposes fluxgate vertical gradient magnetic sensor technology coupled with Differential Global Positioning System (DGPS) positioning methods, specifically the FOERSTER FEREX® 4.032 geophysical sensor and the Leica 1200 DGPS technology.

The proposed FOERSTER FEREX® uses fluxgate vertical gradient magnetic technology to facilitate the detection and discrimination of ferrous metallic objects. Ferromagnetic parts that are located in the earth's magnetic field generate a magnetic interference field in their environment. This interference field can be detected using the Foerster differential magnetometer. Its amplitude and its magnetic polarity are displayed and can be used for object pinpointing.

The eight linear measurements range from 0 to 3 nT to 0 to 1000 nT and one logarithmic range. The unit displays a 0.3 nT resolution and may utilize up to four separate detection probes. The FEREX 4.032 can be used in the data logger versions, together with the FEREX-DATALINE® software for computer assisted cartography and localization.

FEREX-DATALINE® 4.800 software is the analysis software that runs under Windows for interactive graphical evaluation of measurements to calculate objects' coordinates and positioning as well as the size and object depth of suspected ferromagnetic objects. DATALINE enables exact scaled reproduction of recorded and measured data by means of color-coded magnetic field value charts. ISO lines or 3D presentations can be displayed to additionally optimize the presentation of measurements. Data exports are possible with a selectable delimiter as a file for further editing or evaluation in other application programs.

This FEREX detector is easy to handle and operate. The detection probes require neither adjustment nor maintenance and display a high level of search sensitivity. The FEREX is available in three variants: FEREX API with analog indicator, FEREX DLG with data logger standard, and the FEREX DLG with GPS data logger.

Foerster intends to use the FEREX DLG with GPS data logger in a four-sensor configuration for the APG demonstration where applicable. Some reasons for this are that the operator controls and indicators are within the unit housing and are always within the operator's field of view, the battery pack is integrated in the carrying tube, and a permanently integrated loudspeaker within the detector assists with defining the survey parameters and warns the operator of unacceptable DGPS quality. The system is shown in Figure 1.

Figure 1. Demonstrator's system, FEREX fluxgate gradient MAG/sling.

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

DGPS position data are acquired and recorded within the FEREX data logger at a rate of 1 Hz. The FOERSTER FEREX® data are recorded at 20 Hz by the internal data logger. The FEREX requires GGK and PJK NMEA strings for defining positions and PPS (pulse per second) as a timing constant.

Foerster DATALINE software is used to convert the FEREX data to units of nanotesla (nT). The positioning and FEREX signal data are merged within the data logger during acquisition. The DATALINE software has been proven and verified on various UXO removal projects across the world, and it is the standard software tool in multiple military units.

The FEREX raw data are output via the DATALINE software as an ASCII file that contains the relative X/Y, a selected local (e.g., UTM) and WGS84 coordinates, and the corresponding FEREX signal intensity reading. The quantity of magnetic data to be stored in the memory of the FEREX DLG can be defined in the setup menu of the FEREX by setting a minimum "data point distance." The following has been established as a standard setting for most applications: FEREX data are interpolated between corresponding position segments that are spaced at intervals of 12 to 18 inches along the ground surface; at a normal acquisition speed of 3 feet per second, samples along each acquisition transect are produced at intervals of approximately 3 to 4 inches.

2.1.3 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook (ref 1). These submitted data are not included in this report in order to protect ground truth information.

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

QC: Field personnel, data processors, and data interpreters shall implement the QC program in a consistent fashion. In general, the QC program consists of a series of pre-project tests, and once the project has started, a test regimen is applied for each acquisition session. The test regimen includes functional checks to ensure the position and geophysical sensor instrumentation is functioning properly prior to and at the end of each data acquisition session; processing checks to ensure the data collected are of sufficient quality and quantity to meet the project objectives; and interpretation checks to ensure the processed data are representative of the site conditions. Pre-project tests include functional checks to ensure the position and geophysical sensor instrumentation is operating within their defined parameters. Specific pre-project tests include the following:

a. Cable integrity tests for each FEREX 4.032 system.

b. Manufacturer-suggested functional checks for DGPS positioning systems.

c. Acquisition personnel metal check (ensures no metal on acquisition personnel).

QA: The QA procedures applied during the processing phase of the project are performed each day in the field to ensure the integrity of the data. Data that are not of sufficient quality and quantity to meet the project objectives are documented and recollected. Procedural checks during the processing of the data include the following:

a. Corner stake locations for the survey grid are compared with known survey data and verified.

b. Sample density along transects is verified through statistics.

c. Unreasonable FEREX 4.032 measurement values are documented and compared with the site cultural features map.

Foerster has developed internal software to meet some of the needs during merging, processing, and interpretation of the data. Quality assurance measures applied during the interpretation of the data are the following:

a. Depth and target volume information are calculated by a dipole fit algorithm, based on a method which is proven worldwide and accepted as a qualified tool for applications like these.

b. The target evaluation is performed on the basis of magnetic polarities, selected by the user.

c. A quality indication informs the user of how well the dipole fit method could be performed using his selected polarity configuration.

d. Several aboveground metal features (e.g., fence posts, monitoring wells, etc.) are selected from each acquisition session for reacquisition by field personnel to verify accuracy of the interpreted position coordinates.

e. Comparison of the position and FEREX 4.032 data to the site features map (e.g., aboveground cultural features are documented (should be variance in track path)).

Interpreted data characteristics are compared with the known responses acquired during the initial test program.

2.1.5 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 of APG. 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 consists 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 equipment calibration.
Blind 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.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (24 through 28 April 2006)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total numbers 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	1.00
Blind grid	3.42

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately 1 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 represent 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, 2006	Average Temperature, ^{o}F	Total Daily Precipitation, in.
24 April	64.20	0.02
28 April	63.79	0.00

3.3.2 Field Conditions

The Foerster group demonstration was conducted during sunny and muddy conditions.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: calibration, mogul, 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 breakdown. A four-person crew took 2 hours and 5 minutes to perform the initial setup and mobilization. There was 10 minutes of daily equipment preparation and no end of the day equipment breakdown.

3.4.2 Calibration

Foerster spent a total of 60 minutes in the calibration lanes, of which 25 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 nonchargeable 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 35 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data were being properly recorded/collected. Foerster spent an additional 40 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. Forty-five minutes was needed to resolve equipment failures that occurred while surveying the blind grid. A GPS data cable failed and had to be replaced.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Foerster spent a total time of 3 hours and 25 minutes in the blind grid area, 1 hour and 15 minutes of which was spent collecting data.

3.4.5 Demobilization

The Foerster survey crew conducted a full demonstration of the site. Therefore, demobilization did not occur until 28 April 2006. On that day, it took the crew 15 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Foerster submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data were also provided on 23 August 2006.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

Foerster surveyed in a linear manner, in a north to south direction. Foerster used approximately 2-meter line spacing. Foerster separated ropes 4 meters apart, walked through the middle of the rope, turned, executed another pass, and then walked through the middle of the next rope.

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 probability of background alarm. 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.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

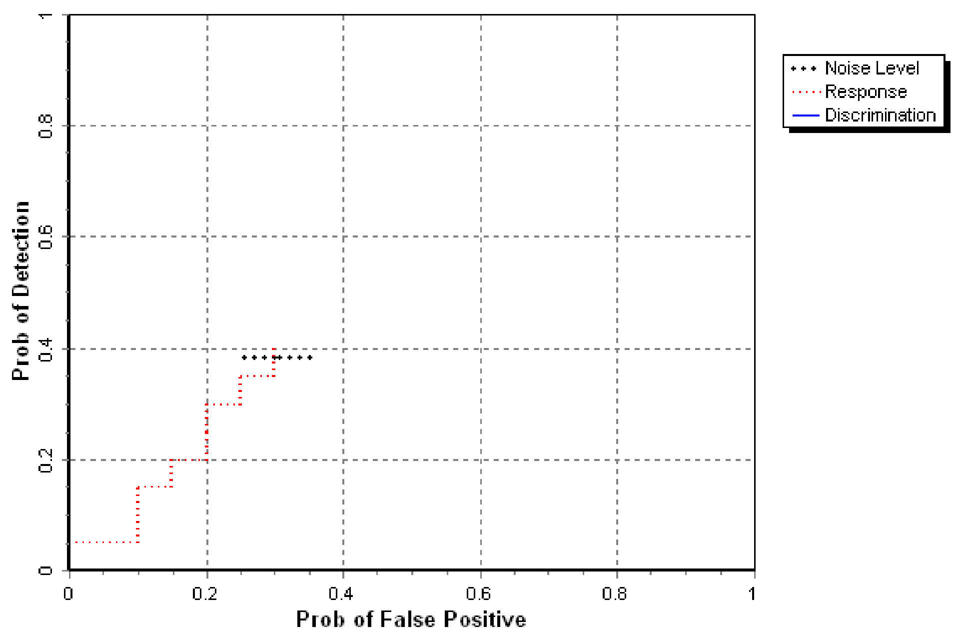

Figure 2. FEREX fluxgate gradient MAG/sling blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

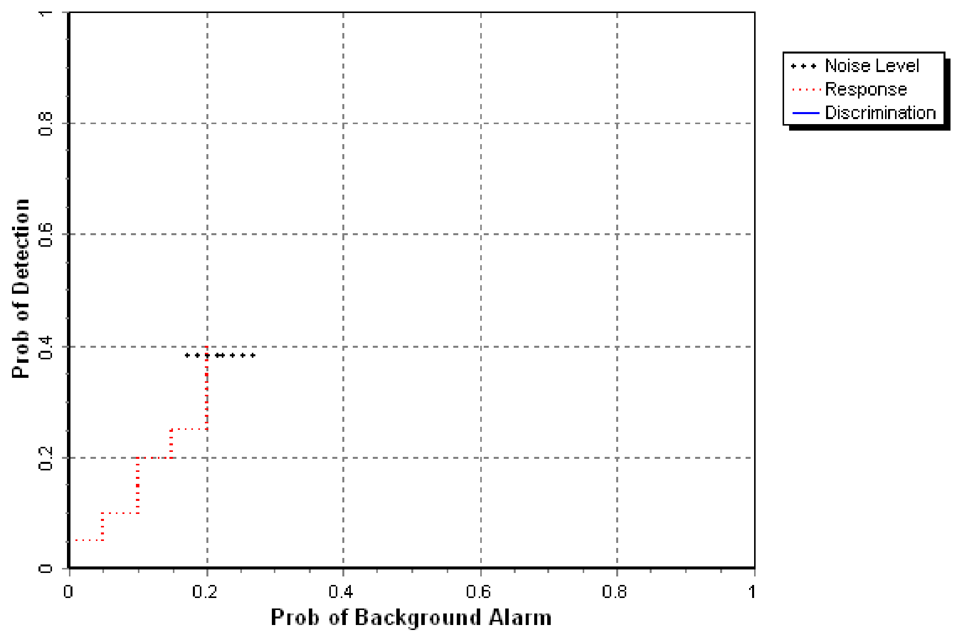

Figure 3. FEREX fluxgate gradient MAG/sling blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

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 probability of background alarm. 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.

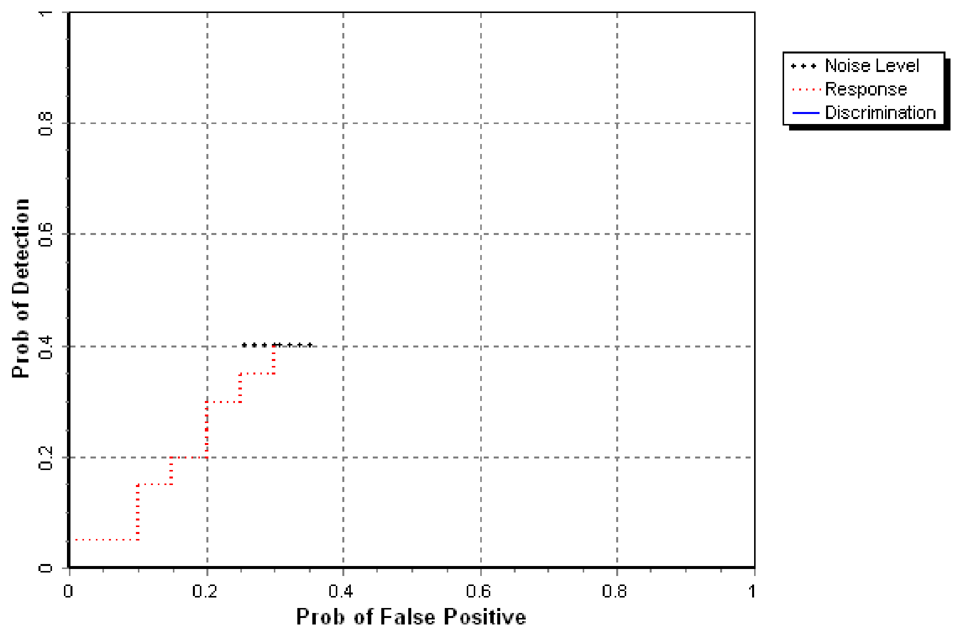

Figure 4. FEREX fluxgate gradient MAG/sling blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

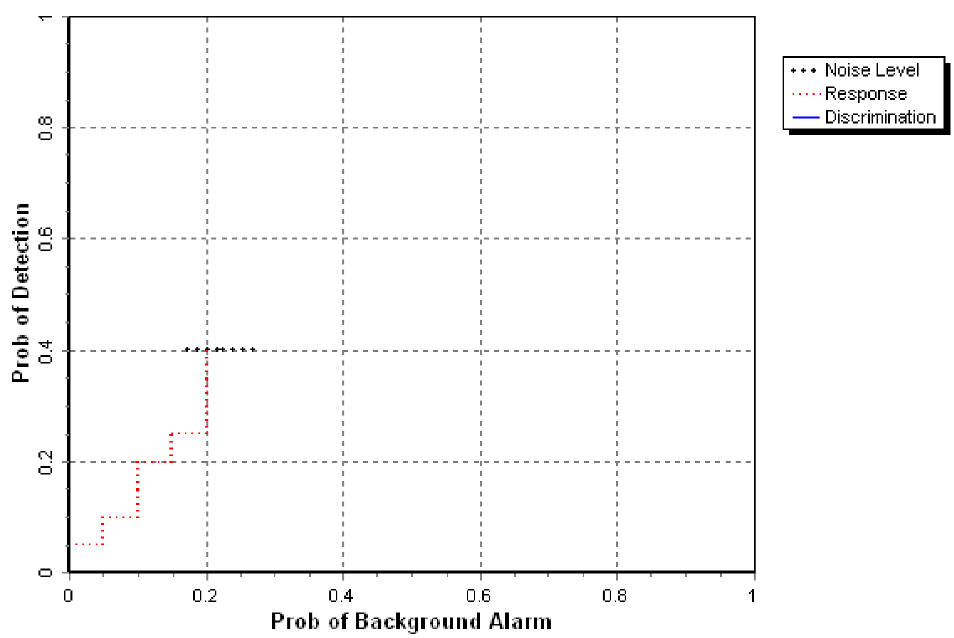

Figure 5. FEREX fluxgate gradient MAG/sling blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the blind grid test, broken out by size, depth, and nonstandard ordnance, are presented in Tables 5a and 5b (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 ordnances emplaced. Depth is measured from the geometric center of anomalies.

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 probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Tables 5a and 5b have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the summary presented in Table 5a exhibits results based on the subset of the ground truth that is solely the ferrous anomalies. Table 5b exhibits results based on the full ground truth. All other tables presented in this section are based on scoring against the ferrous-only ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

TABLE 5a. SUMMARY OF BLIND GRID RESULTS (FERROUS ONLY)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	≥ 1
RESPONSE STAGE									
P_d	0.40	0.40	0.35	0.50	0.25	0.40	0.50	0.30	0.40
P_d Low 90% Conf	0.31	0.31	0.21	0.37	0.17	0.19	0.36	0.18	0.23
P_d Upper 90% Conf	0.47	0.52	0.47	0.63	0.40	0.65	0.64	0.41	0.60
P_{fp}	0.30	-	-	-	-	-	0.35	0.25	0.50
P_{fp} Low 90% Conf	0.24	-	-	-	-	-	0.24	0.18	0.20
P_d Upper 90% Conf	0.37	-	-	-	-	-	0.44	0.36	0.80
P_{ba}	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_d Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{ba}	NA	-	-	-	-	-	-	-	-

Response Stage Noise Level: 3.00
Recommended Discrimination Stage Threshold: 0.50

TABLE 5b. SUMMARY OF BLIND GRID RESULTS (FULL GROUND TRUTH)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	≥ 1
RESPONSE STAGE									
P_d	0.40	0.40	0.40	0.50	0.25	0.40	0.50	0.30	0.45
P_d Low 90% Conf	0.32	0.30	0.29	0.38	0.17	0.19	0.37	0.19	0.26
P_d Upper 90% Conf	0.47	0.49	0.52	0.60	0.40	0.65	0.61	0.41	0.62
P_{fp}	0.30	-	-	-	-	-	0.35	0.25	0.50
P_{fp} Low 90% Conf	0.24	-	-	-	-	-	0.24	0.18	0.20
P_d Upper 90% Conf	0.37	-	-	-	-	-	0.44	0.36	0.80
P_{ba}	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_d Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{ba}	NA	-	-	-	-	-	-	-	-

Response Stage Noise Level: 3.00
Recommended Discrimination Stage Threshold 0.50

Note: The recommended discrimination stage threshold values are provided by the demonstrator.
No discrimination algorithm was applied. Therefore, the response and discrimination stage results are exactly the same.

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	N/A	N/A	N/A
With no loss of P_d	N/A	N/A	N/A

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 types 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	0.0
Medium	0.0
Large	0.0
Overall	0.0

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
Depth	0.32	0.91

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	2.08	$197.60
Data analyst	1	57.00	2.08	118.56
Field support	2	28.50	2.08	118.56
Subtotal				**$434.72**
Calibration				
Supervisor	1	$95.00	1.00	$95.00
Data analyst	1	57.00	1.00	57.00
Field support	2	28.50	1.00	57.00
Subtotal				**$209.00**
Site Survey				
Supervisor	1	$95.00	3.42	$324.90
Data analyst	1	57.00	3.42	194.94
Field support	2	28.50	3.42	194.94
Subtotal				**$714.78**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	0.25	$23.75
Data analyst	1	57.00	0.25	14.25
Field support	2	28.50	0.25	14.25
Subtotal				$52.25
Total				**$1410.75**

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 BLIND GRID 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 non-ordnance 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.

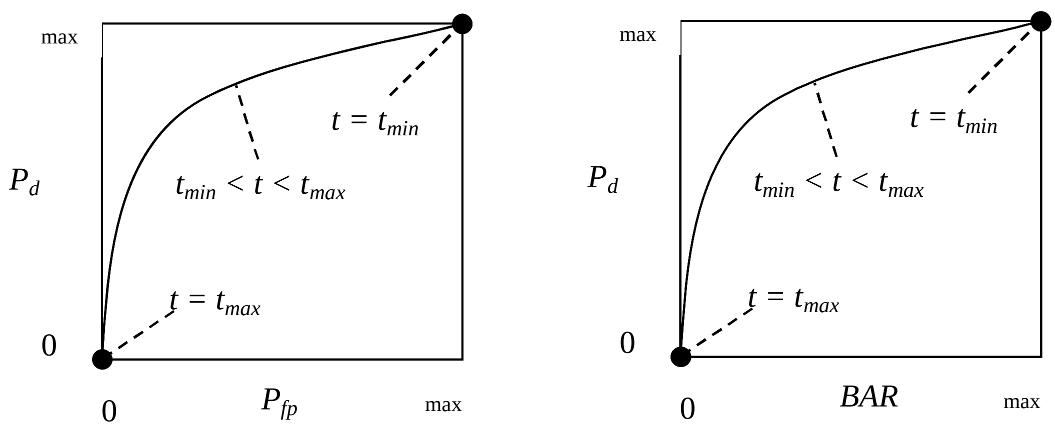

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[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 non-ordnance 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 t_{min}) 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

Date, 2006	Time, Eastern Standard Time (EST)	Average Temperature, °F	Total Precipitation, in.
24 April	0700	54.6	0.00
24 April	0800	57.2	0.00
24 April	0900	60.3	0.00
24 April	1000	62.6	0.00
24 April	1100	63.8	0.00
24 April	1200	66.1	0.00
24 April	1300	66.8	0.00
24 April	1400	68.3	0.00
24 April	1500	68.6	0.00
24 April	1600	69.2	0.00
24 April	1700	68.7	0.00
25 April	0700	49.4	0.00
25 April	0800	56.0	0.00
25 April	0900	61.3	0.00
25 April	1000	65.4	0.00
25 April	1100	67.3	0.00
25 April	1200	68.7	0.00
25 April	1300	70.4	0.00
25 April	1400	71.6	0.00
25 April	1500	72.5	0.00
25 April	1600	73.0	0.00
25 April	1700	71.4	0.00
26 April	0700	43.2	0.00
26 April	0800	45.5	0.00
26 April	0900	47.8	0.00
26 April	1000	50.6	0.00
26 April	1100	52.0	0.00
26 April	1200	53.7	0.00
26 April	1300	55.2	0.00
26 April	1400	56.5	0.00
26 April	1500	57.3	0.00
26 April	1600	58.5	0.00
26 April	1700	58.4	0.00
27 April	0700	41.5	0.01
27 April	0800	53.1	0.00
27 April	0900	60.2	0.00
27 April	1000	64.1	0.00
27 April	1100	66.7	0.00
27 April	1200	68.1	0.00
27 April	1300	69.2	0.00

Date, 2006	Time, Eastern Standard Time (EST)	Average Temperature, ^{o}F	Total Precipitation, in.
27 April	1400	70.4	0.00
27 April	1500	71.0	0.00
27 April	1600	69.7	0.00
27 April	1700	69.4	0.00
28 April	0700	50.6	0.00
28 April	0800	52.6	0.00
28 April	0900	54.8	0.00
28 April	1000	57.1	0.00
28 April	1100	58.7	0.00
28 April	1200	60.2	0.00
28 April	1300	61.9	0.00
28 April	1400	63.3	0.00
28 April	1500	64.0	0.00
28 April	1600	64.5	0.00
28 April	1700	64.5	0.00

APPENDIX C. SOIL MOISTURE

Date: 24 April 2006			
Times: 1100 (AM), 1500 (PM)			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Calibration Lanes	0 to 6	5.3	NA
	6 to 12	22.8	NA
	12 to 24	23.8	NA
	24 to 36	25.2	NA
	36 to 48	23.7	NA
Blind Grid/Moguls	0 to 6	6.8	6.7
	6 to 12	17.8	17.6
	12 to 24	19.9	19.8
	24 to 36	22.3	22.4
	36 to 48	21.6	21.5

Date: 25 April 2006			
Times: 0900 (AM), 1600 (PM)			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	36.2	36.1
	6 to 12	54.2	54.5
	12 to 24	39.4	39.3
	24 to 36	42.6	42.8
	36 to 48	51.7	51.9
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	6.9	6.7
	6 to 12	15.8	15.6
	12 to 24	14.2	14.6
	24 to 36	17.9	17.7
	36 to 48	19.8	19.6
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 26 April 2006			
Times: 0800 (AM), 1500 (PM)			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	36.0	35.7
	6 to 12	55.3	54.9
	12 to 24	38.7	38.9
	24 to 36	42.7	42.3
	36 to 48	51.5	51.6
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	6.4	6.3
	6 to 12	15.9	15.7
	12 to 24	14.4	14.5
	24 to 36	17.6	17.5
	36 to 48	19.9	19.7
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 27 April 2006			
Times: 0800 (AM), 1500 (PM)			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	35.4	35.2
	6 to 12	54.7	54.6
	12 to 24	38.8	38.7
	24 to 36	42.5	42.5
	36 to 48	51.7	51.5
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	6.1	6.1
	6 to 12	15.5	15.4
	12 to 24	14.7	14.5
	24 to 36	17.7	17.6
	36 to 48	19.8	19.9
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 28 April 2006			
Times: 1000 (AM)			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet Area	0 to 6	35.1	NA
	6 to 12	54.4	NA
	12 to 24	38.7	NA
	24 to 36	42.6	NA
	36 to 48	51.8	NA
Wooded Area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open Area	0 to 6	6.0	NA
	6 to 12	15.4	NA
	12 to 24	14.5	NA
	24 to 36	17.9	NA
	36 to 48	19.6	NA
Calibration Lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind Grid/Moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

APPENDIX D. DAILY ACTIVITY LOGS

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions
24 April	4	CALIBRATION LANES	0845	1050	125	INITIAL SETUP	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	CALIBRATION LANES	1050	1115	25	COLLECTING DATA	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	CALIBRATION LANES	1115	1125	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY MUDDY
24 April	4	CALIBRATION LANES	1125	1150	25	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1150	1200	10	DAILY START, STOP	SET UP GRID	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1200	1235	35	COLLECTING DATA	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1235	1315	40	BREAK/LUNCH	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1315	1400	45	DOWNTIME DUE TO EQUIPMENT FAILURE	SWAPPED GPS DATA CABLE	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1400	1415	15	COLLECTING DATA	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1415	1425	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1425	1440	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1440	1505	25	COLLECTING DATA	-	GPS	LINEAR	CLOUDY MUDDY
24 April	4	BLIND TEST GRID	1505	1515	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY MUDDY
24 April	4	OPEN FIELD	1515	1605	50	DAILY START, STOP	SET UP GRID	GPS	LINEAR	CLOUDY MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions
24 April	4	OPEN FIELD	1605	1625	20	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	CLOUDY MUDDY
25 April	4	OPEN FIELD	0745	0955	130	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	0955	1110	75	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1110	1130	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1130	1140	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1140	1215	35	BREAK/LUNCH	-	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1215	1410	115	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1410	1445	35	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1445	1625	100	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1625	1640	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
25 April	4	OPEN FIELD	1640	1700	20	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	0750	0945	115	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	0945	1005	20	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1005	1015	10	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1015	1105	50	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1105	1115	10	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1115	1210	55	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions
26 April	4	OPEN FIELD	1210	1230	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1230	1320	50	BREAK/LUNCH	-	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1320	1525	125	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1525	1545	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1545	1630	45	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1630	1640	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
26 April	4	OPEN FIELD	1640	1700	20	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	0750	0845	55	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	0845	1030	105	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1030	1115	45	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1115	1140	25	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1140	1200	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1200	1245	45	BREAK/LUNCH	-	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1245	1305	20	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1305	1440	95	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1440	1450	10	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1450	1540	50	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions
27 April	4	OPEN FIELD	1540	1605	25	DOWNTIME DUE TO EQUIPMENT FAILURE	GPS ANTENNA CABLE CAME UNATTACHED	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1605	1615	10	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1615	1630	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
27 April	4	OPEN FIELD	1630	1710	40	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	0750	0820	30	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	0820	0910	50	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	0910	0930	20	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	0930	0955	25	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	0955	1000	5	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	1000	1010	10	COLLECTING DATA	-	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	1010	1025	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY MUDDY
28 April	4	OPEN FIELD	1025	1040	15	DEMOBILIZATION	DEMOBILIZATION	GPS	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

3D = three-dimensional
APG = Aberdeen Proving Ground
ASCII = American Standard Code for Information Interchange
ATC = U.S. Army Aberdeen Test Center
BAR = background alarm rate
DGPS = Differential Global Positioning System
EQT = Army Environmental Quality Technology Program
ERDC = U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP = Environmental Security Technology Certification Program
GPS = Global Positioning System
ISO = International Standards Organization
JPG = Jefferson Proving Ground
NA = not applicable
P_d = probability of detection
P_d^{disc} = probability of detection, discrimination stage
P_d^{res} = probability of detection, response stage
P_{fp} = probability of false positive
P_{fp}^{disc} = probability of false positive, discrimination stage
P_{fp}^{res} = probability of false positive, response stage
POC = point of contact
PPS = pulse per second
QA = quality assurance
QC = quality control
ROC = receiver-operating characteristic
SERDP = Strategic Environmental Research and Development Program
USAEC = U.S. Army Environmental Command
UXO = unexploded ordnance
YPG = U.S. Army Yuma Proving Ground

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