AD NO. ______________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC 8865

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 312

SITE LOCATION:
U.S. ARMY YUMA PROVING GROUND

DEMONSTRATOR:
SHAW ENVIRONMENTAL, INC
312 DIRECTORS DRIVE
KNOXVILLE, TN 37923

TECHNOLOGY TYPE/PLATFORM:
UXO MAPPER G856 MAGNOMETER

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

MARCH 2005

Prepared for:
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14. ABSTRACT
This scoring record documents the efforts of Shaw Environmental, Inc. to detect and discriminate inert unexploded ordnance (UXO) utilizing the YPG Standardized UXO Technology Demonstration Site Blind Grid. The scoring record was coordinated by Larry Overbay and the by the Standardized UXO Technology Demonstration 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.

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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. 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-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

JPG = Jefferson Proving Ground.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Mr. John E. Foly
(978) 458-9807

Address: Shaw Environmental, Inc.
312 Directors Drive
Knoxville, TN 37923

2.1.2 System Description (provided by demonstrator)

Shaw's geophysical mapping technology is an engineered combination of off-the-shelf geophysical sensors, innovative navigation technologies, a flexible/configurable deployment system, and customized data acquisition software. The geophysical sensor selected for this demonstration is an array of magnetometers. The Shaw UXO Mapper has both hardware and software components:

Leica TSP1100 Robotic Total Station (RTS) for in-the-tree and open-area navigation
Crossbow 3-axis gyro system.
Shaw's composite material cart-deployment system
Off-the-shelf magnetic (G858) sensors
Software for data acquisition system for sensor, navigation and gyro data collection
Software to achieve robust navigation and sensor time-base synchronization
Software to implement realtime telemetry and data merging

Hardware: System hardware (fig. 1) consists of four integrated components; 1) geophysical sensors such as an array of magnetometer (selected for this demonstration) or EM sensors, 2) Shaw's composite-material cart survey system, 3) the Leica TPS1100 dual laser RTS, and 4) the Crossbow solid state gyro. Shaw's UXO Mapper was engineered as a mapping device that can be customized to adapt to a wide range of conditions seen on UXO sites. Customizations available for survey optimization include; the number, spacing, and height of the sensors; the number of wheels (2 or 4) and wheel diameter; the forward sensor distances (relative to the wheel base), and handle configuration (to push, pull or tow the system) allowing the flexibility to customize the configuration of the equipment to respond to local site conditions and maximize data quality.

For navigation, the Shaw UXO Mapper uses RTS technology. The Leica TSP1100 RTS is a motorized robotic total station that uses automatic target recognition to track the location of the prism and has a highly accurate distance/azimuth measurement system to produce $\pm$5 mm +2 ppm accuracy which translates to 0.25 inches (3D) at distances of up to 1400 feet.

Figure 1. Demonstrator's system, UXO MAPPER G856 MAG.

Software: The Shaw UXO Mapper has three software components. First, customized RTS firmware is used to track the roving prism. Developed specifically for Shaw's UXO mapping applications, this firmware allows for rapid collection of data to 4 hertz and outputs solutions to the base station and rover units. The firmware enables the user to optimize prism-tracking parameters for rapid recovery of lock if obstructed by trees during a survey. Second, Shaw's data control software determines precise time synchronization between the RTS and sensor time bases, ensuring accurate collection of all data. Third, Shaw's software for data merging accommodates various sensor navigation geometries used during data collection and provides a robust framework to spatially configure sensors relative to each other and with respect to the prism location. Additionally, this software allows RTS and sensor data to be merged in either a straightforward interpolation mode (for open areas) or in hybrid switching mode that alternates to "dead reckoning" for the brief periods when the RTS if obstructed in the woods.

Shaw Cart System: This composite and fiberglass cart system deploys magnetometers, gradiometers, or electromagnetic (EM) sensors (fig. 1). The device has been modified to replace the standard configuration of the EM61 cart system. This adaptation is critical to collection of high fidelity data, as the operator has enhanced control of the sensor in terms of sensor orientation.

2.1.3 Data Processing Description (provided by demonstrator)

Shaw's standard data processing includes data leveling, statistical data assessment, grid generation, and customized data filtering to accentuate target signatures. Shaw uses software from the sensor manufacturers, in-house software, and Geosoft's Oasis Montaj and UX-Detect Software and MATLAB to complete all tasks. Collected field data are downloaded from the data acquisition system as American Standard Code for Information Interchange (ASCII) XYZ files. Custom Shaw software is used to download the data and for initial review, generation of summary statistics, and conversion data formats, gridding and analysis. All activities will be documented on the Data Processing Log. The initial steps taken in the data processing flow include:

Initial Review of Collected Data: Validate that data fall within prescribed recording ranges, establish number of points collected, data density, and time-on/time-off.

Statistical Analysis: Review XYZ statistics describing survey coordinates and sensor values, etc.

Data Leveling: Based on the initial review and statistics, and calibration data as well as diurnal variations magnetometer data are adjusted.

Data Cataloging: All data are stored in Oracle database for subsequent review and analysis.

Data Gridding: XYZ data are interpolated using Geosoft onto 0.25-foot grid and reviewed by a geophysicist.

Data Filtering: After assessment, data filters are applied to enhance target signatures by reducing the effects of high frequency and/or low frequency noise sources.

Target Detection: Shaw's automated "region growing" techniques are used initially detect targets. Next, a geophysicist visually detects targets and reviews auto-detections.

Target Analysis: Magnetic and EM data are analyzed with separate methods to define target parameters. All target data (raw data, processed data, and analysis parameters) are stored within the Oracle database and analyzed in MATLAB via a linked database connection.

Magnetic Analysis: Each target is modeled with an induced dipole model where a least squares fit is made to the data. This produces estimates of target location, depth, azimuth, dip, magnetic moment and effective diameter. Dipole "misfit" surfaces are analyzed to produce measure is fit quality and to identify elongate and/or compound targets. Shaw's target detection and analysis methods for magnetic data form the basis of our target discrimination process.

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)

Quality Control for geophysical mapping is ensured through utilization of qualified staff, adherence to standard procedures, and full documentation. The following procedures and logs are used to maximize standardization, repeatability, and control of mapping activities:

Calibration - Geophysical instruments used for geophysical mapping will be field-tested daily to ensure that they are operating properly. The site geophysicist will establish standard verification procedures and will be provided in the submitted Work Plans. The function of each geophysical instrument will be checked according to the manufacturer's specifications upon daily checkout by the survey teams. The site geophysicist is responsible for the assessment of instrument functionality and will review and sign each Equipment Verification Log prior to deployment in the field.

Data Processing Log - All data from the field are run through a standard data-processing procedure. This procedure is the same for all data and is tracked with the Data Processing Log. This log documents all coordinate transformations, visual data-quality checks, statistical data-quality checks, survey-coverage statistics, interpolation parameters, etc.

Crew Deployment Log - This log defines the location of each geophysical survey crew on a daily basis. The log tracks crewmembers, equipment, and expected area to be surveyed. Attached to this daily log are maps of the areas to be surveyed containing the coordinates of benchmarks in the areas as well as the coordinate of each quadrant corner.

Field Activity Log - This log is filled out by each crew chief and details all activities of the survey. This is a daily log and contains observations about crew performance, sensor performance, site conditions, and weather changes.

Equipment Verification Log - This log documents the daily calibration of each field instrument. Daily calibration procedures are executed for each geophysical and navigational instrument. The sensor system is brought to a calibration area before each survey day starts and the background magnetic field and the magnetic field signal from a reference target is measured and recorded.

Data Control Log - Kept in the office trailer, this log tracks all data flowing in from the field and out of the office. Data include all geophysical field data, sensor verification data (via Equipment Verification Logs), all field notes from Field Activity Logs, and all RTS quadrant coordinate data.

Data Analysis Log - All data reduction, processing and analysis steps are documented through this form. Each log is checked by the project geophysicist for completeness and adherence to pre-defined procedures.

Target Reanalysis - All targets analyzed as part of the project will be subject to review by the project geophysicist. Additionally, a minimum of 10-percent of all targets will be reanalyzed by a separate geophysicist to ensure data quality.

Overview of QA:

Quality assurance measures the QC activities described above.

To insure complete and continuous area coverage, the magnetometer system will collect data in 6-foot swaths. Since the magnetometer sensors are 1.5 feet apart, the effective line spacing will be 1.5 feet. Deviations from this line spacing are anticipated where obstructions such as trees exist. Maps of the traverses will be plotted and obstructions verified

Additionally, standardization procedures implemented on a site-specific basis to maximize efficiency and to adjust to logistical and schedule requirements. The procedure below shall be utilized at the site to define the spatial accuracy of the data as well as the repeatability of the sensor readings:

1. A 50-foot-long straight-line transect will be established with the positions of the endpoints and midpoint logged via RTS.

2. Wherever possible the traverse line will be oriented North-South. Each survey system (sensor and navigation unit) used to collect data will be operated over the transect each day following these steps:

- An operator will log "background" data along the traverse, first heading north from the southern endpoint, and then returning south from the northern endpoint.
- A metallic pin-flag shall be placed over the midpoint.
- The operator will log data along the same path, first traveling north, then returning south.
- The operator will log data along the same path, first traveling north at a slow pace, then returning south at a significantly more rapid pace.

3. All data lines will be downloaded and provided to the site geophysicist for review. These data will be examined to determine the repeatability of the pin-flag anomaly amplitude and the repeatability of the positional location of the amplitude peak.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the PDF files at www.uxotestsites.org.

2.2 YPG SITE INFORMATION

2.2.1 Location

YPG is located adjacent to the Colorado River in the Sonoran Desert. The UXO Standardized Test Site is located south of Pole Line Road and east of the Countermine Testing and Training Range. The Open Field range, Calibration Grid, Blind Grid, Mogul area, and Desert Extreme area comprise the 350 by 500-meter general test site area. The open field site is the largest of the test sites and measures approximately 200 by 350 meters. To the east of the open field range are the calibration and blind test grids that measure 30 by 40 meters and 40 by 40 meters, respectively. South of the Open Field is the 135- by 80-meter Mogul area consisting of a sequence of man-made depressions. The Desert Extreme area is located southeast of the open field site and has dimensions of 50 by 100 meters. The Desert Extreme area, covered with desert-type vegetation, is used to test the performance of different sensor platforms in a more severe desert conditions/environment.

2.2.2 Soil Type

Soil samples were collected at the YPG UXO Standardized Test Site by ERDC to characterize the shallow subsurface (< 3 m). Both surface grab samples and continuous soil borings were acquired. The soils were subjected to several laboratory analyses, including sieve/hydrometer, water content, magnetic susceptibility, dielectric permittivity, X-ray diffraction, and visual description.

There are two soil complexes present within the site, Riverbend-Carrizo and Cristobal-Gunsight. The Riverbend-Carrizo complex is comprised of mixed stream alluvium, whereas the Cristobal-Gunsight complex is derived from fan alluvium. The Cristobal-Gunsight complex covers the majority of the site. Most of the soil samples were classified as either a sandy loam or loamy sand, with most samples containing gravel-size particles. All samples had a measured water content less than 7 percent, except for two that contained 11-percent moisture. The majority of soil samples had water content between 1 to 2 percent. Samples containing more than 3 percent were generally deeper than 1 meter.

An X-ray diffraction analysis on four soil samples indicated a basic mineralogy of quartz, calcite, mica, feldspar, magnetite, and some clay. The presence of magnetite imparted a moderate magnetic susceptibility, with volume susceptibilities generally greater than 100 by 10-5 SI.

For more details concerning the soil properties at the YPG 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 YPG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains the 15 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 0.16-hectare (0.39-acre) site. The center of each grid cell contains ordnance, clutter, or nothing.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (20, 22, and 26 January 2004)

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	0.16
Blind Grid	2.32

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

A YPG 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, 2004	Average Temperature, °C	Total Daily Precipitation, in.
20 January	15.74	0.00
22 January	14.55	0.00
26 January	13.7	0.00

3.3.2 Field Conditions

The field conditions remained dry throughout the demonstration.

3.3.3 Soil Moisture

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

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. A three-person crew took 3 hours and 15 minutes to perform the initial setup and mobilization. There was 8 minutes of daily equipment preparation and end of the day equipment break down lasted 10 minutes.

3.4.2 Calibration

Shaw spent a total of 10 minutes in the calibration lanes, all of which was spent collecting data.

3.4.3 Downtime Occasions

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

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for 1-hour and 35 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. Shaw spent an additional 10 minutes for breaks and lunches.

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

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Shaw spent a total time of 2 hours and 19 minutes in the Blind Grid area, 16 minutes of which was spent collecting data.

3.4.5 Demobilization

The Shaw survey crew went on to conducted a full demonstration of the site. Therefore, demobilization did not occur until 26 January 2004. On that day, it took the crew 45 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Shaw 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 PERSONNEL

Project Geophysicist:	Martin Miele
Site Geophysicist:	Raul Fonda
Staff Geophysicist:	Jeremy Flemmer

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

The Calibration Lanes was surveyed in four direction: NS, SN, EW, and WE. Then, repeated in the SN orientation to check for repeatability. The Blind Grid was surveyed in the exact same method.

3.8 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.

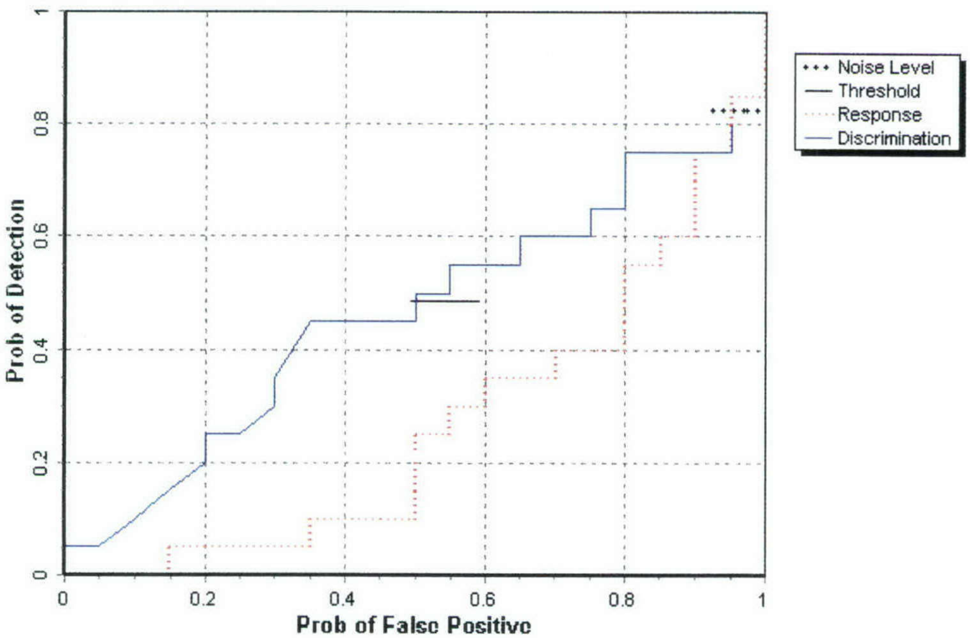

Figure 2. UXO MAPPER pushcart blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

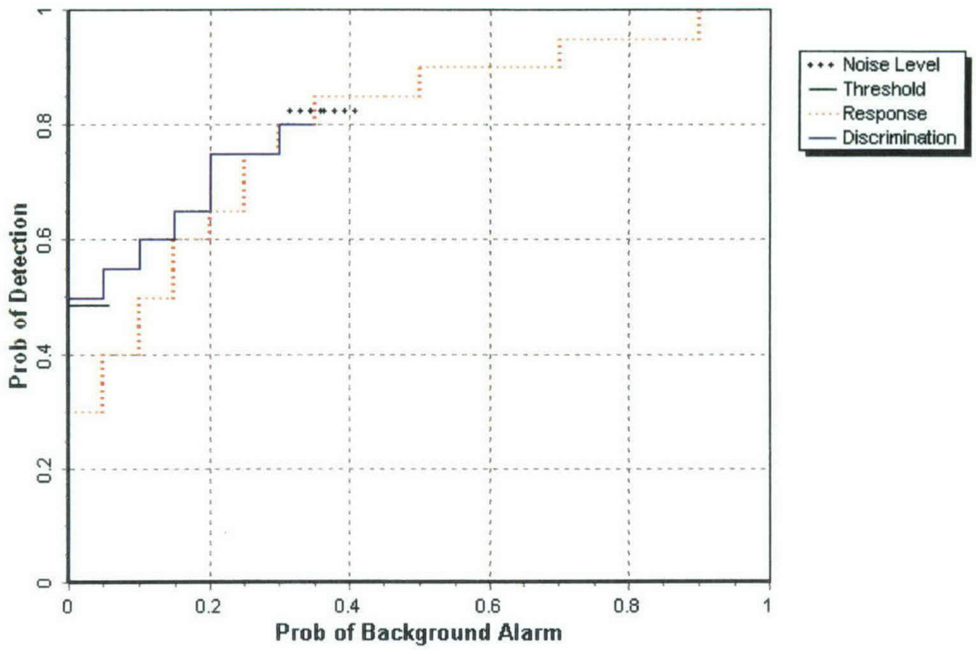

Figure 3. UXO MAPPER pushcart blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

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.

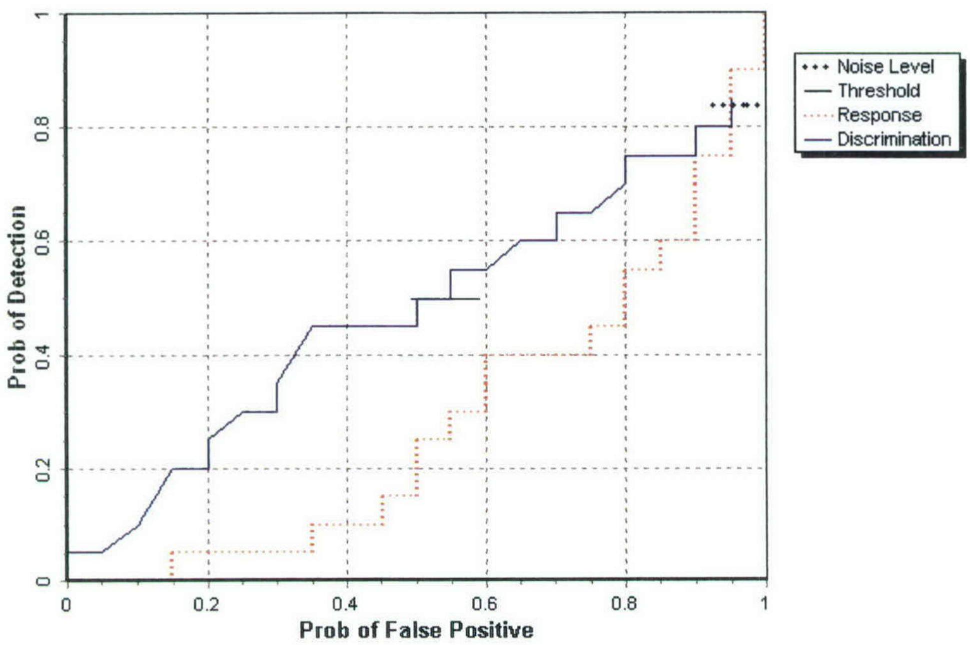

Figure 4. UXO MAPPER pushcart blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

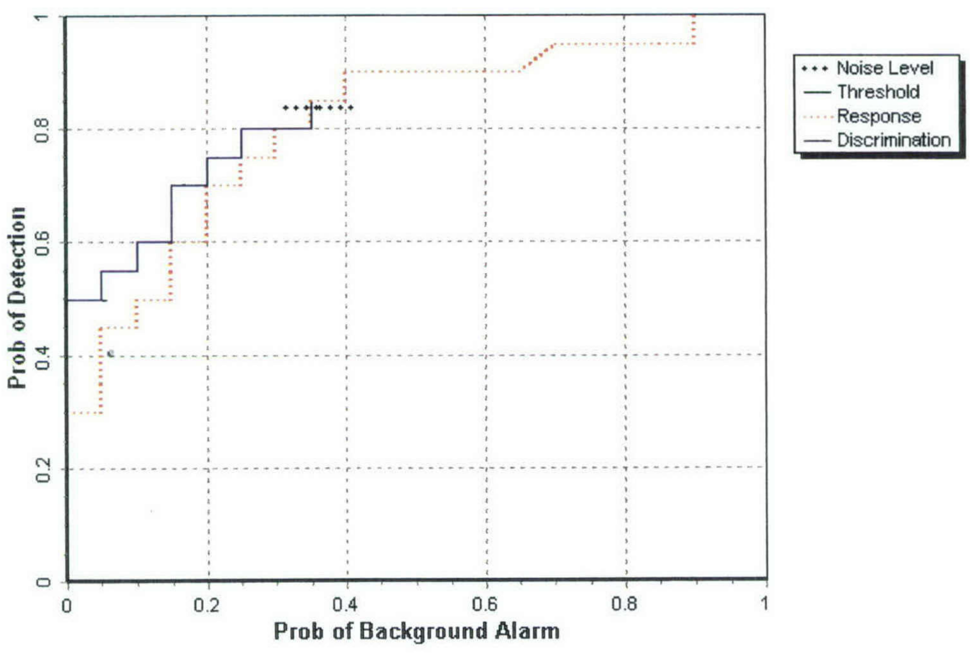

Figure 5. UXO MAPPER pushcart blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

.3 PERFORMANCE SUMMARIES

Results for the Blind Grid test, broken out by size, depth and nonstandard ordnance, are resented in Table 5a and 5b (for cost results, see section 5). Results by size and depth include both :andard and nonstandard ordnance. The results by size show how well the demonstrator did at etecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results re relative to the number of ordnances emplaced. Depth is measured from the geometeric center of nomolies.

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

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

TABLE 5a. SUMMARY OF BLIND GRID RESULTS FOR (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	0.85	0.90	0.80	0.80	0.85	1.00	0.80	1.00	0.70
P_d Low 90% Conf	0.79	0.83	0.64	0.65	0.73	0.85	0.69	0.90	0.40
P_d Upper 90% Conf	0.91	0.97	0.88	0.88	0.95	1.00	0.89	1.00	0.92
P_{fp}	0.95	-	-	-	-	-	1.00	0.95	N/A
P_{fp} Low 90% Conf	0.94	-	-	-	-	-	0.94	0.87	-
P_d Upper 90% Conf	0.99	-	-	-	-	-	0.99	1.00	-
P_{ba}	0.35	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.55	0.55	0.45	0.60	0.65	0.60	0.60	0.15
P_d Low 90% Conf	0.47	0.44	0.42	0.33	0.45	0.44	0.49	0.43	0.01
P_d Upper 90% Conf	0.64	0.66	0.69	0.60	0.75	0.81	0.72	0.74	0.45
P_{fp}	0.55	-	-	-	-	-	0.55	0.55	N/A
P_{fp} Low 90% Conf	0.48	-	-	-	-	-	0.47	0.40	-
P_d Upper 90% Conf	0.61	-	-	-	-	-	0.62	0.67	-
P_{ba}	0.00	-	-	-	-	-	-	-	-

esponse Stage Noise Level: 9.95.
ecommended Discrimination Stage Threshold: 6.95.

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	0.80	0.90	0.70	0.75	0.85	1.00	0.75	0.95	0.70
P_d Low 90% Conf	0.75	0.80	0.59	0.61	0.73	0.85	0.66	0.85	0.40
P_d Upper 90% Conf	0.88	0.94	0.83	0.82	0.95	1.00	0.85	1.00	0.92
P_{fp}	0.95	-	-	-	-	-	1.00	0.95	N/A
P_{fp} Low 90% Conf	0.94	-	-	-	-	-	0.94	0.87	-
P_d Upper 90% Conf	0.99	-	-	-	-	-	0.99	1.00	-
P_{ba}	0.35	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.50	0.45	0.50	0.35	0.60	0.65	0.50	0.55	0.15
P_d Low 90% Conf	0.41	0.36	0.38	0.25	0.45	0.44	0.40	0.39	0.01
P_d Upper 90% Conf	0.57	0.57	0.65	0.47	0.75	0.81	0.62	0.69	0.45
P_{fp}	0.55	-	-	-	-	-	0.55	0.55	N/A
P_{fp} Low 90% Conf	0.48	-	-	-	-	-	0.47	0.40	-
P_d Upper 90% Conf	0.61	-	-	-	-	-	0.62	0.67	-
P_{ba}	0.00	-	-	-	-	-	-	-	-

Response Stage Noise Level: 9.95.
Recommended Discrimination Stage Threshold 6.95.

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	0.64	0.44	0.97
With No Loss of P_d	1.00	0.02	0.10

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 8). 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	0.00
Medium	0.00
Large	0.00
Overall	0.00

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	0.27

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	3.25	$308.75
Data Analyst	1	57.00	3.25	185.25
Field Support	1	28.50	3.25	92.63
SubTotal				**$586.63**
Calibration				
Supervisor	1	$95.00	0.16	$15.20
Data Analyst	1	57.00	0.16	9.12
Field Support	1	28.50	0.16	4.56
SubTotal				**$28.88**
Site Survey				
Supervisor	1	$95.00	2.32	$220.40
Data Analyst	1	57.00	2.32	132.24
Field Support	1	28.50	2.32	66.12
SubTotal				**$418.76**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	0.75	$71.25
Data Analyst	1	57.00	0.75	42.75
Field Support	1	28.50	0.75	21.38
Subtotal				**$135.38**
Total				**$1169.65**

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 DATE

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.

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.

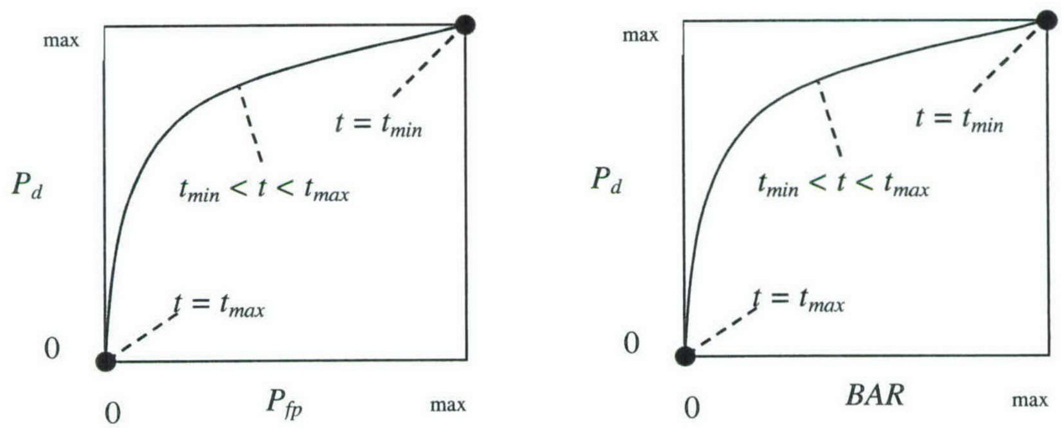

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[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

Time, HHMM	Temp. deg. C	R/H, %	Precip., in.
20 January 2004			
01:00	12.2	40	0.00
02:00	9.4	43	0.00
03:00	10.1	47	0.00
04:00	8.6	51	0.00
05:00	8.9	51	0.00
06:00	8.5	55	0.00
07:00	9.0	55	0.00
08:00	8.0	57	0.00
09:00	9.8	51	0.00
10:00	12.8	45	0.00
11:00	15.3	39	0.04
12:00	18.0	33	0.00
13:00	19.4	31	0.00
14:00	19.8	29	0.00
15:00	20.2	29	0.00
16:00	20.6	29	0.00
17:00	20.2	29	0.00
18:00	18.7	33	0.00
19:00	17.0	35	0.00
20:00	15.7	37	0.00
21:00	14.7	40	0.00
22:00	14.2	40	0.02
23:00	15.6	42	0.04
24:00	14.5	47	0.00

TABLE B-1 (CONT'D)

Time, HHMM	Temp. deg. C	R/H, %	Precip., in.
21 January 2004			
01:00	13.1	52	0.00
02:00	13.5	54	0.00
03:00	13.1	59	0.00
04:00	12.1	59	0.00
05:00	11.9	61	0.00
06:00	11.0	64	0.00
07:00	11.3	60	0.00
08:00	11.1	61	0.00
09:00	11.8	59	0.00
10:00	14.9	49	0.00
11:00	13.6	63	0.04
12:00	15.5	56	0.00
13:00	16.3	48	0.00
14:00	17.7	42	0.00
15:00	17.7	40	0.00
16:00	15.1	60	0.00
17:00	13.5	70	0.00
18:00	13.8	67	0.00
19:00	13.9	68	0.00
20:00	11.8	81	0.00
21:00	12.2	79	0.00
22:00	11.5	88	0.02
23:00	11.2	93	0.04
24:00	10.8	96	0.00

TABLE B-1 (CONT'D)

Time, HHMM	Temp. deg. C	R/H, %	Precip., in.
22 January 2004			
01:00	10.8	95	0.00
02:00	10.8	95	0.00
03:00	10.9	95	0.00
04:00	11.0	94	0.00
05:00	10.7	95	0.00
06:00	11.3	89	0.00
07:00	11.2	92	0.00
08:00	11.0	92	0.00
09:00	11.3	92	0.00
10:00	12.9	86	0.00
11:00	14.7	73	0.00
12:00	15.9	58	0.00
13:00	15.2	60	0.00
14:00	16.4	50	0.00
15:00	16.4	51	0.00
16:00	17.6	47	0.00
17:00	17.5	43	0.00
18:00	16.5	37	0.00
19:00	15.7	40	0.00
20:00	13.7	75	0.00
21:00	12.7	85	0.00
22:00	12.7	82	0.00
23:00	11.7	90	0.00
24:00	11.7	88	0.00

TABLE B-1 (CONT'D)

Time, HHMM	Temp. deg. C	R/H, %	Precip., in.
23 January 2004			
01:00	11.4	91	0.00
02:00	11.3	92	0.00
03:00	10.7	94	0.00
04:00	10.1	96	0.00
05:00	9.9	96	0.00
06:00	9.6	97	0.00
07:00	9.0	97	0.00
08:00	8.4	97	0.00
09:00	9.0	98	0.00
10:00	11.7	88	0.00
11:00	13.4	81	0.00
12:00	15.1	69	0.00
13:00	16.8	57	0.00
14:00	17.8	53	0.00
15:00	18.9	45	0.00
16:00	18.9	44	0.00
17:00	17.9	44	0.00
18:00	17.4	54	0.00
19:00	16.2	54	0.00
20:00	15.8	53	0.00
21:00	15.1	58	0.00
22:00	14.1	61	0.00
23:00	13.0	65	0.00
24:00	11.6	74	0.00

TABLE B-1 (CONT'D)

Time, HHMM	Temp. deg. C	R/H, %	Precip., in.
26 January 2004			
01:00	9.8	57	0.00
02:00	10.5	43	0.00
03:00	10.4	34	0.00
04:00	9.9	28	0.00
05:00	9.3	26	0.00
06:00	7.9	29	0.00
07:00	6.6	31	0.00
08:00	6.3	33	0.00
09:00	8.0	32	0.00
10:00	11.3	19	0.00
11:00	13.9	15	0.00
12:00	16.1	12	0.00
13:00	17.0	10	0.00
14:00	17.7	10	0.00
15:00	17.8	10	0.00
16:00	18.1	11	0.00
17:00	17.9	11	0.00
18:00	17.0	12	0.00
19:00	15.0	16	0.00
20:00	12.6	26	0.00
21:00	11.1	33	0.00
22:00	9.3	40	0.00
23:00	8.1	46	0.00
24:00	7.9	48	0.00

APPENDIX C. SOIL MOISTURE

SOIL MOISTURE LOGS (20 through 23, and 26 January 2004)

Date: January 20, 2004
Times: (0715), (1300)

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.7	1.8
	6 to 12	2.3	2.3
	12 to 24	3.7	3.7
	24 to 36	3.6	3.6
	36 to 48	4.0	4.0
Mogul Area	0 to 6	1.7	1.7
	6 to 12	2.0	2.0
	12 to 24	3.5	3.5
	24 to 36	3.9	3.9
	36 to 48	3.9	3.9
Desert Extreme Area	0 to 6	1.8	1.8
	6 to 12	2.1	2.1
	12 to 24	3.3	3.3
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 21, 2004
Times: (0715), (1300)

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.7	1.7
	6 to 12	2.3	2.3
	12 to 24	3.7	3.7
	24 to 36	3.6	3.6
	36 to 48	3.9	4.0
Mogul Area	0 to 6	1.7	1.7
	6 to 12	2.0	2.1
	12 to 24	3.5	3.5
	24 to 36	3.9	3.9
	36 to 48	3.9	3.9
Desert Extreme Area	0 to 6	1.6	1.6
	6 to 12	2.1	2.1
	12 to 24	3.3	3.3
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 22, 2004
Times: (0715), (1300)

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.9	1.8
	6 to 12	2.5	2.5
	12 to 24	3.7	3.6
	24 to 36	3.6	3.6
	36 to 48	3.9	3.9
Mogul Area	0 to 6	1.6	1.6
	6 to 12	2.5	2.5
	12 to 24	3.5	3.5
	24 to 36	3.9	3.9
	36 to 48	3.9	3.9
Desert Extreme Area	0 to 6	1.6	1.6
	6 to 12	2.4	2.4
	12 to 24	3.3	3.3
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 23, 2004
Times: (0715), (1400)

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.8	1.8
	6 to 12	2.5	2.5
	12 to 24	3.7	3.7
	24 to 36	3.6	3.6
	36 to 48	4.0	3.9
Mogul Area	0 to 6	1.6	1.6
	6 to 12	2.5	2.5
	12 to 24	3.5	3.5
	24 to 36	3.9	3.9
	36 to 48	3.9	3.9
Desert Extreme Area	0 to 6	1.6	1.6
	6 to 12	2.4	2.4
	12 to 24	3.3	3.3
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 26, 2004
Times: (0800), (1330)

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.6	1.6
	6 to 12	2.4	2.4
	12 to 24	3.7	3.7
	24 to 36	3.6	3.6
	36 to 48	3.9	3.9
Mogul Area	0 to 6	1.6	1.6
	6 to 12	2.3	2.3
	12 to 24	3.5	3.5
	24 to 36	3.9	3.9
	36 to 48	3.9	3.9
Desert Extreme Area	0 to 6	1.6	1.6
	6 to 12	2.3	2.3
	12 to 24	3.3	3.3
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

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	
01/20/2004	3	CALIBRATION LANES	0655	1010	195	INITIAL SETUP	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/20/2004	3	CALIBRATION LANES	1010	1020	10	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/20/2004	3	BLIND TEST GRID	1020	1022	2	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/20/2004	3	BLIND TEST GRID	1022	1035	13	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/20/2004	3	BLIND TEST GRID	1035	1045	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL
01/20/2004	3	BLIND TEST GRID	1045	1210	85	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	WARM
01/20/2004	3	BLIND TEST GRID	1210	1220	10	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1220	1300	40	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1300	1405	65	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1405	1510	65	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	WARM

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	
01/20/2004	3	OPEN FIELD	1510	1520	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1520	1620	60	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1620	1625	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1625	1655	30	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/20/2004	3	OPEN FIELD	1655	1710	15	SETUP/DAILY START/STOP/ CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	WARM
01/21/2004	3	OPEN FIELD	0650	1005	195	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COLD
01/21/2004	3	OPEN FIELD	1005	1040	35	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1040	1045	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	RAIN
01/21/2004	3	OPEN FIELD	1045	1100	15	BREAK/LUNCH	BREAK	NA	NA	NA	CLOUDY	RAIN
01/21/2004	3	OPEN FIELD	1100	1145	45	BREAK/LUNCH	LUNCH	NA	NA	NA	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1145	1210	25	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	CLOUDY	COOL

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	
01/21/2004	3	OPEN FIELD	1210	1240	30	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/21/2004	3	OPEN FIELD	1240	1300	20	SETUP/DAILY START/STOP/ CALIBRATION	SET UP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/21/2004	3	OPEN FIELD	1300	1315	15	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/21/2004	3	OPEN FIELD	1315	1320	49	EQUIPMENT FAILURE	LOST RIGHT WHEEL	NA	NA	NA	SUNNY	COOL
01/21/2004	3	OPEN FIELD	1320	1350	30	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/21/2004	3	OPEN FIELD	1350	1405	15	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1405	1505	60	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1505	1515	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1515	1535	20	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/21/2004	3	OPEN FIELD	1535	1545	10	SETUP/DAILY START/STOP/ CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	CLOUDY	COOL

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	
01/22/2004	3	OPEN FIELD	0655	0750	55	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	LINEAR	CLOUDY	COLD
01/22/2004	3	OPEN FIELD	0750	0900	70	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COLD
01/22/2004	3	OPEN FIELD	0900	0907	7	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COLD
01/22/2004	3	OPEN FIELD	0907	1022	75	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	OPEN FIELD	1022	1050	28	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	OPEN FIELD	1050	1135	45	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	MOGUL	1135	1140	5	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	MOGUL	1140	1155	15	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	MOGUL	1155	1207	12	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	MOGUL	1207	1310	63	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	MOGUL	1310	1340	30	BREAK/LUNCH	LUNCH	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	MOGUL	1340	1445	65	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	CLOUDY	COOL

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	
01/22/2004	3	MOGUL	1445	1507	22	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/22/2204	3	MOGUL	1507	1540	33	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/22/2004	3	MOGUL	1540	1548	8	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COOL
01/22/2004	3	OPEN FIELD	1548	1625	37	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	OPEN FIELD	1625	1642	17	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	OPEN FIELD	1642	1650	8	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/22/2004	3	OPEN FIELD	1650	1701	11	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	BLIND TEST GRID	1701	1707	6	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/22/2204	3	BLIND TEST GRID	1707	1710	3	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/22/2004	3	BLIND TEST GRID	1710	1720	10	SETUP/DAILY START/STOP/ CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	CLOUDY	COOL
01/23/2004	3	YUMA EXTERME	0650	0840	110	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COLD
01/23/2004	3	YUMA EXTERME	0840	0932	52	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL

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	
01/23/2004	3	YUMA EXTERME	0932	1215	163	BREAK/LUNCH	BREAK	NA	NA	NA	SUNNY	COOL
01/23/2004	2	YUMA EXTERME	1215	1325	70	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/23/2004	2	YUMA EXTERME	1325	1410	45	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	WARM
01/23/2004	2	YUMA EXTERME	1410	1415	5	BREAK/LUNCH	BREAK	NA	NA	NA	SUNNY	WARM
01/23/2004	2	YUMA EXTERME	1415	1420	5	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	WARM
01/23/2004	3	YUMA EXTERME	1420	1429	9	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/23/2004	3	YUMA EXTERME	1429	1450	21	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	WARM
01/23/2204	3	YUMA EXTERME	1450	1520	30	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/23/2004	3	YUMA EXTERME	1520	1550	30	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/23/2004	3	YUMA EXTERME	1550	1655	65	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/23/2004	3	YUMA EXTERME	1655	1740	45	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	CLOUDY	COOL
01/23/2004	3	OPEN FIELD	1740	1805	25	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL

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	
01/23/2004	3	OPEN FIELD	1805	1810	5	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	NA	CLOUDY	COOL
01/23/2004	3	OPEN FIELD	1810	1815	5	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/23/2004	3	OPEN FIELD	1815	1820	5	COLLECT DATA	COLLECT DATA BIDIRECTIONAL EAST TO WEST	GPS	NA	NA	CLOUDY	COOL
01/23/2004	3	OPEN FIELD	1820	1840	20	SETUP/DAILY START/STOP/ CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	CLOUDY	COOL
01/26/2004	2	YUMA EXTERME	0750	0845	55	SETUP/DAILY START/STOP/ CALIBRATION	SETUP/MOBILIZATI ON	NA	NA	NA	SUNNY	COLD
01/26/2004	2	YUMA EXTERME	0845	0855	10	COLLECT DATA	COLLECT DATA BIDIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COLD
01/26/2204	2	YUMA EXTERME	0855	0930	35	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COLD
01/26/2004	2	YUMA EXTERME	0930	1015	45	DEMOBILIZATION	DEMOBILIZATION END OF TEST	NA	NA	NA	SUNNY	COOL

(Page D-8 Blank)

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.

5. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, pages 144 through 151.

APPENDIX F. ABBREVIATIONS

AEC = U.S. Army Environmental Center
APG = Aberdeen Proving Ground
ASCII = American Standard Code for Information Interchange.
ATC = U.S. Army Aberdeen Test Center
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
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

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