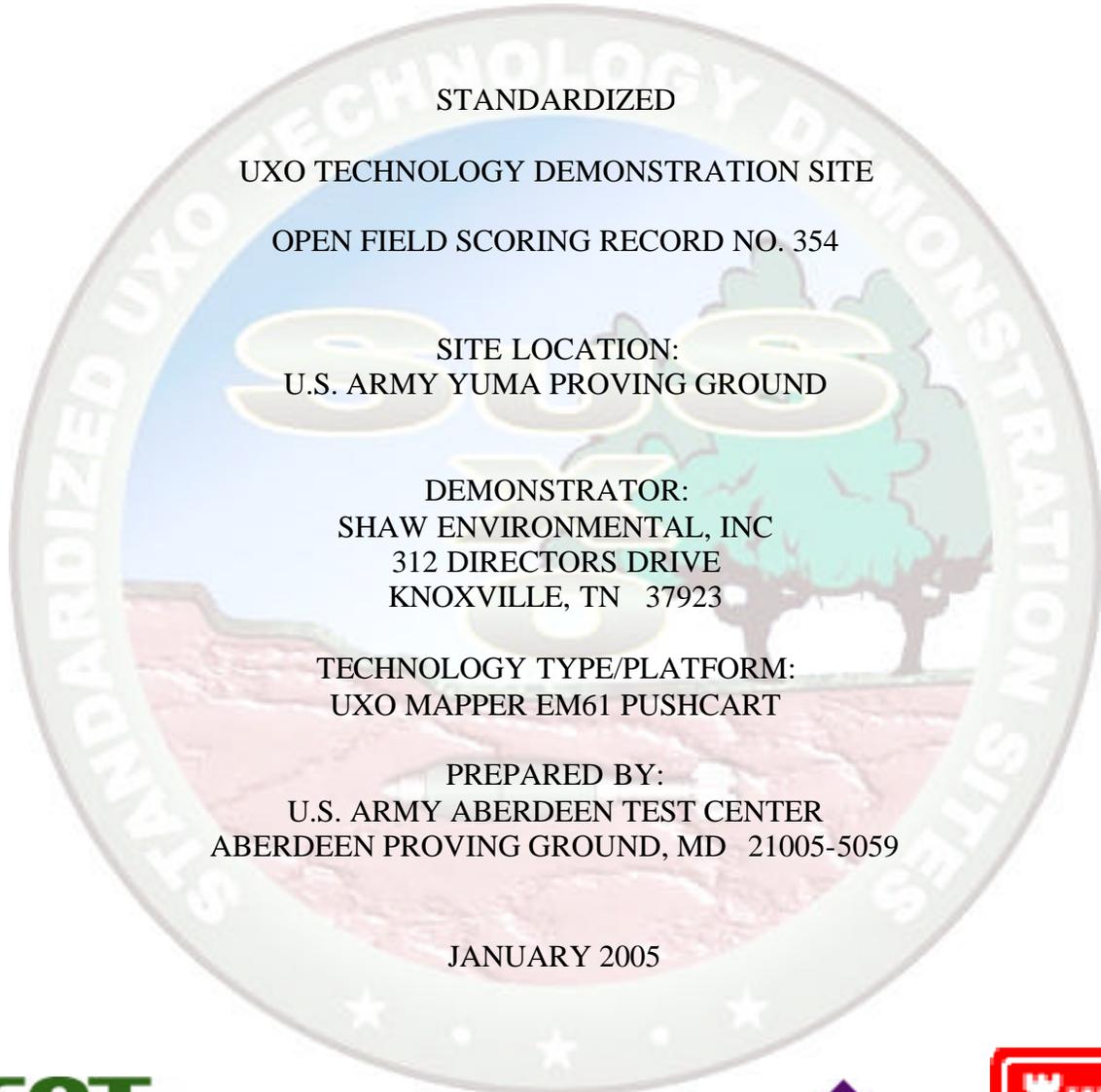




AD NO. \_\_\_\_\_  
DTC PROJECT NO. 8-CO-160-UXO-021  
REPORT NO. ATC-8915



STANDARDIZED  
UXO TECHNOLOGY DEMONSTRATION SITE  
OPEN FIELD SCORING RECORD NO. 354

SITE LOCATION:  
U.S. ARMY YUMA PROVING GROUND

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

TECHNOLOGY TYPE/PLATFORM:  
UXO MAPPER EM61 PUSH CART

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

JANUARY 2005



Prepared for:  
U.S. ARMY ENVIRONMENTAL CENTER  
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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 Open Field. The scoring record was coordinated by Larry Overbay and by the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center.					
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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 open field RESPONSE STAGE, the demonstrator provides the scoring committee with the field 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 and will only include signals that are above 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 same field 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 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 termed the Discrimination Stage Threshold (i.e. that is expected to retain all detected ordnance and reject the maximum amount of clutter).

d. 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. 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 the entire response stage anomaly list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

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

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

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

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

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

### **1.2.2 Scoring Factors**

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

a. Response Stage ROC curves:

- (1) Probability of Detection ( $P_d^{\text{res}}$ ).
- (2) Probability of False Positive ( $P_{\text{fp}}^{\text{res}}$ ).
- (3) Background Alarm Rate ( $\text{BAR}^{\text{res}}$ ) or Probability of Background Alarm ( $P_{\text{BA}}^{\text{res}}$ ).

b. Discrimination Stage ROC curves:

- (1) Probability of Detection ( $P_d^{\text{disc}}$ ).
- (2) Probability of False Positive ( $P_{\text{fp}}^{\text{disc}}$ ).
- (3) Background Alarm Rate ( $\text{BAR}^{\text{disc}}$ ) or Probability of Background Alarm ( $P_{\text{BA}}^{\text{disc}}$ ).

c. Metrics:

- (1) Efficiency (E).
- (2) False Positive Rejection Rate ( $R_{\text{fp}}$ ).
- (3) Background Alarm Rejection Rate ( $R_{\text{BA}}$ ).

d. Other:

- (1) Probability of Detection by Size and Depth.
- (2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).
- (3) Location accuracy.
- (4) Equipment setup, calibration time and corresponding man-hour requirements.
- (5) Survey time and corresponding man-hour requirements.

- (6) Reacquisition/resurvey time and man-hour requirements (if any).
- (7) Downtime due to system malfunctions and maintenance requirements.

### 1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

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

**TABLE 1. INERT ORDNANCE TARGETS**

<b>Standard Type</b>	<b>Nonstandard (NS)</b>
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 high-explosive, antitank (HEAT) Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

JPG = Jefferson Proving Ground

## SECTION 2. DEMONSTRATION

### 2.1 DEMONSTRATOR INFORMATION

#### 2.1.1 Demonstrator 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. For this demonstration an EM61 configuration has been selected. 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 electromagnetic (EM61-MKII) sensor.
- ? 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 (figure 1) consists of four integrated components; 1) geophysical sensors such as an array of magnetometer or electromagnetic (EM) sensors (selected for this demonstration), 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  $\pm 5\text{mm} + 2\text{ppm}$  accuracy which translates to 0.25 inches (3D) at distances of up to 1400 feet.

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 the straightforward interpolation mode (for open areas) or in hybrid switching mode that alternates to "dead reckoning" for the brief periods when the RTS is obstructed in the woods.

Shaw Cart System: This composite and fiberglass cart system deploys magnetometers, gradiometers, or 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.



Figure 1. Demonstrator's system, EM61 pushcart.

### **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, EM data are adjusted for DC level.

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

Data Gridding: XYZ data are interpolated using Geosoft onto 0.5-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.

EM Analysis: The EM data are analyzed in two ways. First, the location of the target is defined by defining point of maximum response in the data. Next, the transient decay curve shapes, based on the four time gates in the EM data for each target, are modeled to define target type based on templates defined from known responses of various UXO and non-UXO control targets.

Shaw's target detection and analysis methods for the EM 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 predefined 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.

Quality assurance measures the Quality Control activities described above.

To ensure complete and continuous area coverage, the EM61 data will be collected at an approximate line spacing of 2-feet. Deviations from this line spacing is 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:

- a. A 50-foot-long straight-line transect will be established with the positions of the endpoints and midpoint logged via RTS.
- b. Wherever possible, the traverse line will be oriented North to South. Each survey system (sensor and navigation unit) used to collect data will be operated over the transaction each day following these steps:
  - (1) An operator will log “background” data along the traverse, first heading north from the southern endpoint, and then returning south from the northern endpoint.
  - (2) A metallic pin-flag shall be placed over the midpoint.
  - (3) The operator will log data along the same path, first traveling north, and then returning south.
  - (4) 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.
- c. 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 MicroSoft Word documents at [www.uxotestsites.org](http://www.uxotestsites.org). The counterpart to this report is Scoring Record #199.

## **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 meters). 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 the 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<sup>-5</sup> SI.

For more details concerning the soil properties at the YPG test site, go to [www.uxotestsites.org](http://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**

<b>Area</b>	<b>Description</b>
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.
Open Field	A 4-hectare (10-acre) site containing open areas, dips, ruts and obstructions, including vegetation.

### SECTION 3. FIELD DATA

#### **3.1 DATE OF FIELD ACTIVITIES (12 through 15 and 27 January 2004)**

#### **3.2 AREAS TESTED/NUMBER OF HOURS**

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

**TABLE 3. AREAS TESTED AND NUMBER OF HOURS**

<b>Area</b>	<b>Number of Hours</b>
Calibration Lanes	2.58
Open Field	29.57

#### **3.3 TEST CONDITIONS**

##### **3.3.1 Weather Conditions**

A YPG weather station located approximately 1-mile west of the test site was used to record average temperature and precipitation on an hourly basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 through 1700 hours while the 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/PRECIPIATION DATA SUMMARY**

<b>Date, 2004</b>	<b>Average Temperature, °C</b>	<b>Total Daily Precipitation, in.</b>
12 January	18.2	0.00
13 January	29.8	0.00
14 January	21.1	0.00
15 January	19.2	0.00
27 January	13.6	0.00

##### **3.3.2 Field Conditions**

Shaw surveyed the Open Field area with the EM61 UXO MAPPER pushcart 12 through 15 and 27 January 2004 with field conditions remaining dry.

##### **3.3.3 Soil Moisture**

Five soil probes were placed at various locations of the site to capture soil moisture data: dry, desert extreme, open areas, the calibration lanes, and the blind grid/moguls. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil layers (0 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. The three-person crew took 1-hour and 25 minutes to perform the initial setup and mobilization. There was 6 hours and 14 minutes of daily equipment preparation and end of day equipment break down lasted 40 minutes.

### **3.4.2 Calibration**

Shaw spent a total time of 2 hours and 35 minutes in the calibration lanes, 20 minutes of which were 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 lunch/breaks. 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 included. Breaks and lunches are included in this section and billed to the Site Survey area.

**3.4.3.1 Equipment/data checks, maintenance.** Equipment/data checks and maintenance activities accounted for 4 hours and 3 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure data were being properly recorded/collected. In addition, the Shaw team spent 2 hours and 20 minutes throughout test operations on breaks and lunches.

**3.4.3.2 Equipment failure or repair.** Two minor equipment failures occurred while surveying in the Open Field area. The GPS was down for a few minutes but restored, and the connector cable to the gyroscope was replaced. The total time for the failures was 36 minutes.

**3.4.3.3 Weather.** No delays occurred due to weather.

### **3.4.4 Data Collection**

Shaw spent a total time of 29 hours and 34 minutes in the Open Field area, 15 hours and 41 minutes of which were spent collecting data.

### **3.4.5 Demobilization**

Shaw went on to survey the entire YPG Site. Therefore, actual demobilization did not occur until 27 January 2004. On that day, 1-hour and 5 minutes were spent demobilizing all of the equipment.

### **3.5 PROCESSING TIME**

Shaw submitted the raw data from demonstration activities on a date required by the test director. The scoring submission data were also provided within the required 30-day timeframe.

### **3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD**

Shaw started surveying the Open Field area in the northeast portion and generally in the east/west direction. One lane was surveyed and then the demonstrator returned to the beginning of the next lane, until completion. Lanes were laid out in approximately 50 meter intervals, where appropriate.

### **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 ( $P_d^{\text{res}}$ ) and the discrimination stage ( $P_d^{\text{disc}}$ ) versus their respective  $P_{\text{fp}}$ . Figure 3 shows both probabilities plotted against their respective BAR. Both figures use a horizontal line to illustrate the performance of the demonstrator at the demonstrator's recommended discrimination stage threshold level, which defines the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

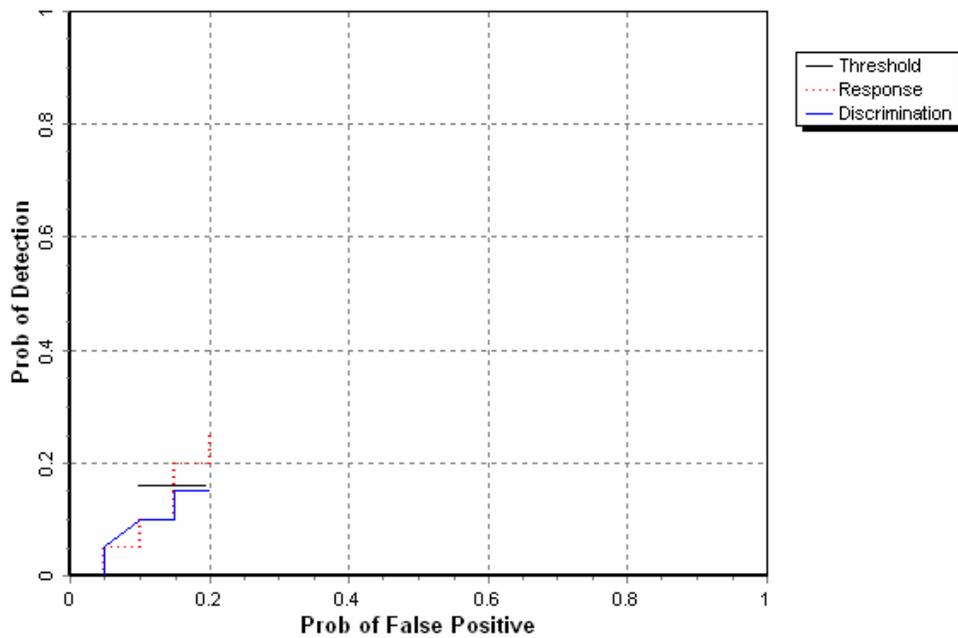


Figure 2. EM61 UXO MAPPER pushcart open field  $P_d^{\text{res}}$  and  $P_d^{\text{disc}}$  versus their respective over all ordnance categories combined.

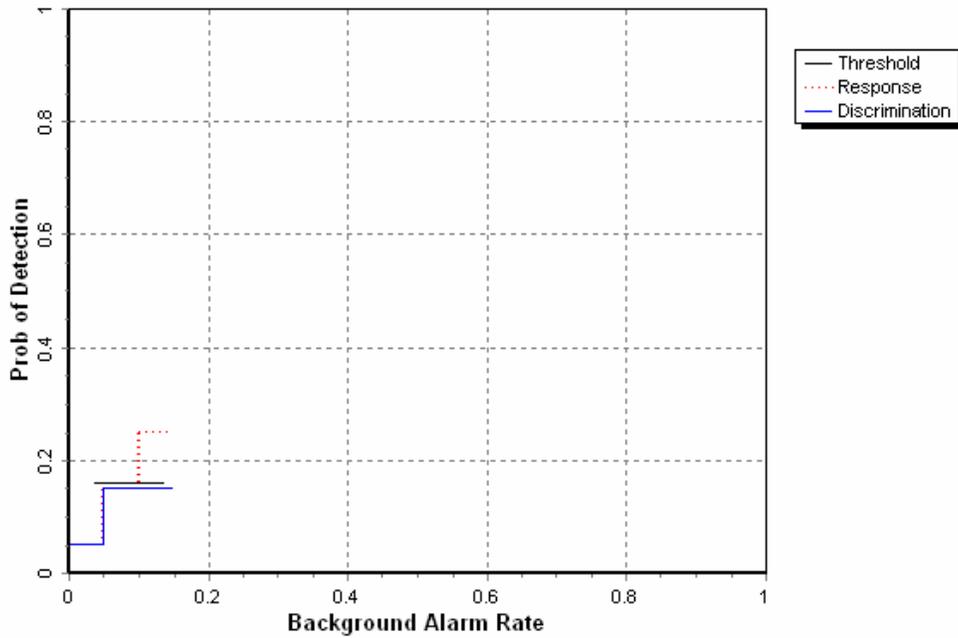


Figure 3. EM61 UXO MAPPER pushcart open field  $P_d^{\text{res}}$  and  $P_d^{\text{disc}}$  versus their respective BAR over all ordnance categories combined.

#### 4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 4 shows the probability of detection for the response stage ( $P_d^{\text{res}}$ ) and the discrimination stage ( $P_d^{\text{disc}}$ ) versus their respective  $P_{\text{fp}}$  when only targets larger than 20 mm are scored. Figure 5 shows both probabilities plotted against their respective BAR. Both figures use a horizontal line to illustrate the performance of the demonstrator at the demonstrator's recommended discrimination stage threshold level, which defines the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

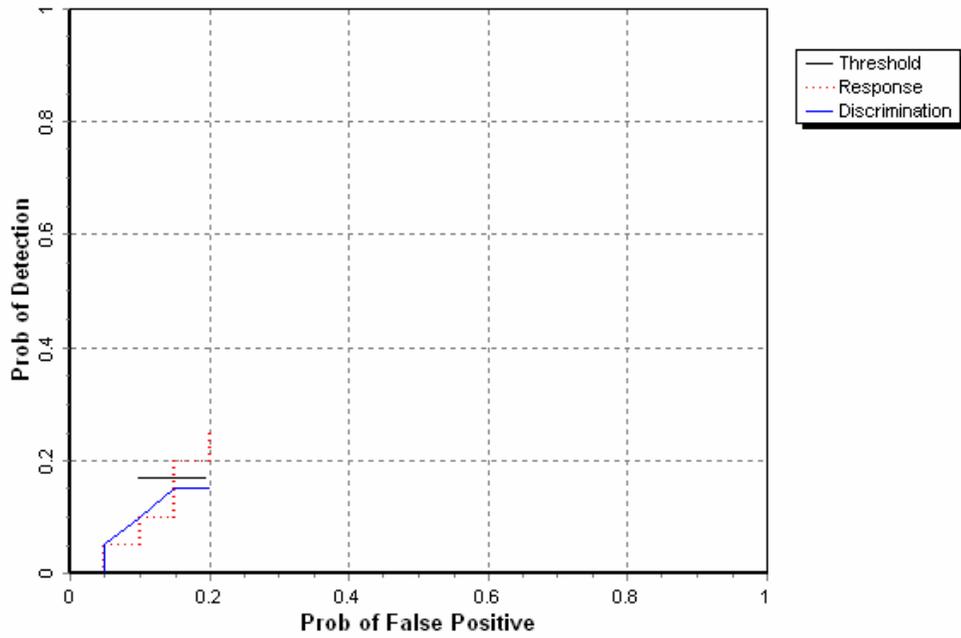


Figure 4. EM61 UXO MAPPER pushcart open field  $P_d^{\text{res}}$  and  $P_d^{\text{disc}}$  versus their respective  $P_{\text{fp}}$  for all ordnance larger than 20 mm.

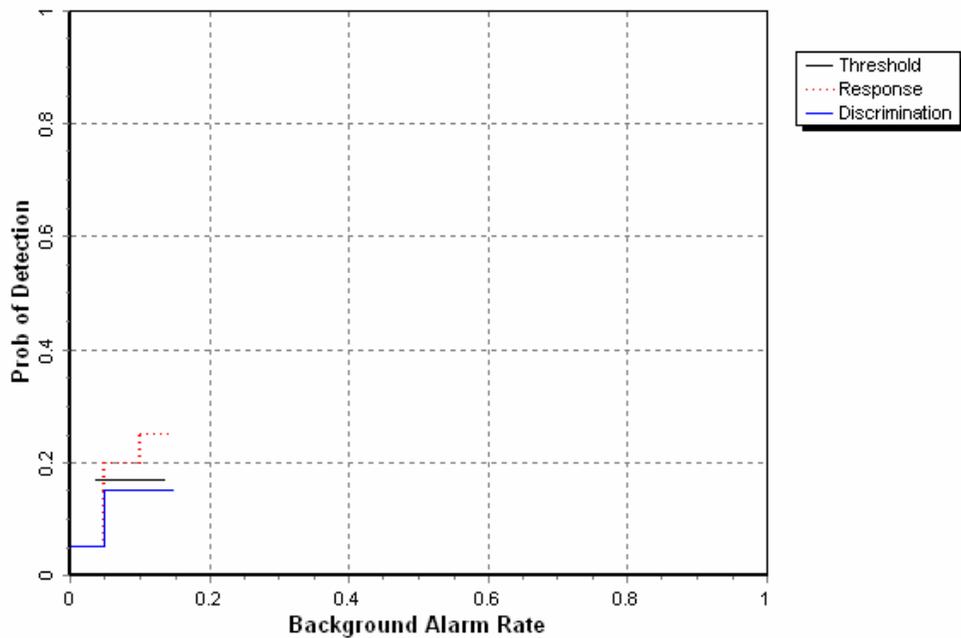


Figure 5. EM61 UXO MAPPER pushcart open field  $P_d^{\text{res}}$  and  $P_d^{\text{disc}}$  versus their respective  $\text{BAR}^{\text{res}}$  for all ordnance larger than 20 mm.

### 4.3 PERFORMANCE SUMMARIES

Results for the Open field test broken out by size, depth and nonstandard ordnance are presented in Table 5 (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced. 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  $P_{fp}$  was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

**TABLE 5. SUMMARY OF OPEN FIELD RESULTS FOR THE EM61 UXO MAPPER**

Metric				By Size			By Depth, m		
	Overall	Standard	Non-Standard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
<b>RESPONSE STAGE</b>									
$P_d$	0.25	0.25	0.25	0.20	0.20	0.40	0.25	0.25	0.00
$P_d$ Low 90% Conf	0.21	0.19	0.20	0.15	0.18	0.32	0.22	0.20	0.00
$P_d$ Upper 90% Conf	0.26	0.26	0.28	0.22	0.27	0.46	0.28	0.29	0.16
$P_{fp}$	0.20	-	-	-	-	-	0.20	0.25	0.00
$P_{fp}$ Low 90% Conf	0.19	-	-	-	-	-	0.17	0.24	0.00
$P_{fp}$ Upper 90% Conf	0.22						0.20	0.30	0.21
$P_{ba}$	0.15	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
$P_d$	0.15	0.15	0.15	0.15	0.15	0.20	0.20	0.15	0.05
$P_d$ Low 90% Conf	0.14	0.13	0.12	0.11	0.13	0.17	0.15	0.12	0.01
$P_d$ Upper 90% Conf	0.18	0.19	0.19	0.16	0.22	0.29	0.21	0.19	0.12
$P_{fp}$	0.15	-	-	-	-	-	0.15	0.20	0.00
$P_{fp}$ Low 90% Conf	0.13	-	-	-	-	-	0.11	0.18	0.00
$P_{fp}$ Upper 90% Conf	0.16						0.14	0.24	0.21
$P_{ba}$	0.10	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.80

Recommended Discrimination Stage Threshold: 6.95

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

#### 4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

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

**TABLE 6. EFFICIENCY AND REJECTION RATES FOR THE EM61 UXO MAPPER**

	<b>Efficiency (E)</b>	<b>False Positive Rejection Rate</b>	<b>Background Alarm Rejection Rate</b>
At Operating Point	0.69	0.28	0.48
With No Loss of $P_d$	1.00	0.00	1.00

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 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**

<b>Size</b>	<b>% Correct</b>
Small	0.00
Medium	0.00
Large	0.00
Overall	0.00

Note: The demonstrator did not attempt to identify ordnance type.

#### 4.5 LOCATION ACCURACY

The mean and standard deviations of location accuracy are presented in Table 8 for each of the three dimensions of location. Location accuracy was calculated for those ordnance items correctly identified in the discrimination stage. Note that depth is measured from the closest point of the ordnance to the surface.

**TABLE 8. MEAN LOCATION ACCURACY AND  
STANDARD DEVIATION FOR THE EM61 UXO MAPPER**

	<b>Mean, m</b>	<b>Standard Deviation, m</b>
Northing	-0.10	0.23
Easting	0.02	0.24
Depth	-0.30	0.26

## 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
<b>INITIAL SETUP</b>				
Supervisor	1	\$95.00	2.42	\$229.90
Data Analyst	1	57.00	2.42	137.94
Field Support	1	28.50	2.42	68.97
Subtotal				<b>\$436.81</b>
<b>CALIBRATION</b>				
Supervisor	1	\$95.00	2.58	\$245.10
Data Analyst	1	57.00	2.58	147.06
Field Support	1	28.50	2.58	73.53
Subtotal				<b>\$465.69</b>
<b>SITE SURVEY</b>				
Supervisor	1	\$95.00	29.57	\$2,809.15
Data Analyst	1	57.00	29.57	1,685.49
Field Support	1	28.50	29.57	827.96
Subtotal				<b>\$5,322.60</b>

See notes at end of table.

**TABLE 9 (CONT'D)**

	<b>No. People</b>	<b>Hourly Wage</b>	<b>Hours</b>	<b>Cost</b>
<b>DEMOBILIZATION</b>				
Supervisor	1	\$95.00	1.08	\$102.60
Data Analyst	1	57.00	1.08	61.56
Field Support	1	28.50	1.08	30.78
Subtotal				<b>\$194.94</b>
<b>Total</b>				<b>\$7,020.04</b>

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

### 6.1 SUMMARY OF RESULTS FROM BLIND GRID DEMONSTRATION

Table 10 shows the results from Blind Grid survey conducted prior to surveying the Open Field during the same site visit in January of 2004. For more details on the Blind Grid survey results reference section 2.1.6.

**TABLE 10. SUMMARY OF BLIND GRID RESULTS FOR THE EM61 UXO MAPPER**

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
<b>RESPONSE STAGE</b>									
$P_d$	0.70	0.75	0.70	0.70	0.70	0.85	0.80	0.70	0.15
$P_d$ Low 90% Conf	0.64	0.63	0.55	0.56	0.54	0.66	0.72	0.56	0.01
$P_{fp}$	0.85	-	-	-	-	-	0.85	0.95	0.00
$P_{fp}$ Low 90% Conf	0.82	-	-	-	-	-	0.77	0.87	-
$P_{ba}$	0.05	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
$P_d$	0.55	0.50	0.60	0.45	0.60	0.65	0.60	0.60	0.15
$P_d$ Low 90% Conf	0.46	0.41	0.45	0.35	0.45	0.44	0.47	0.43	0.01
$P_{fp}$	0.60	-	-	-	-	-	0.60	0.70	0.00
$P_{fp}$ Low 90% Conf	0.55	-	-	-	-	-	0.52	0.54	-
$P_{ba}$	0.00	-	-	-	-	-	-	-	-

### 6.2 COMPARISON OF ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 6 shows  $P_d^{res}$  versus the respective  $P_{fp}$  over all ordnance categories. Figure 7 shows  $P_d^{disc}$  versus their respective  $P_{fp}$  over all ordnance categories. Figure 7 uses horizontal lines to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

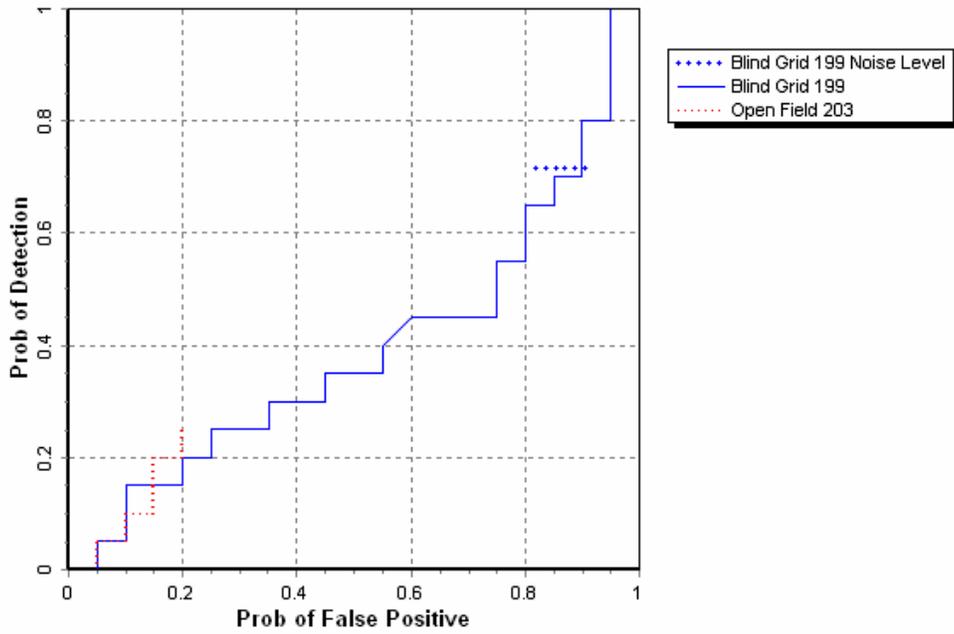


Figure 6. EM61 UXO MAPPER pushcart  $P_d^{res}$  stages versus the respective  $P_{fp}$  over all ordnance categories combined.

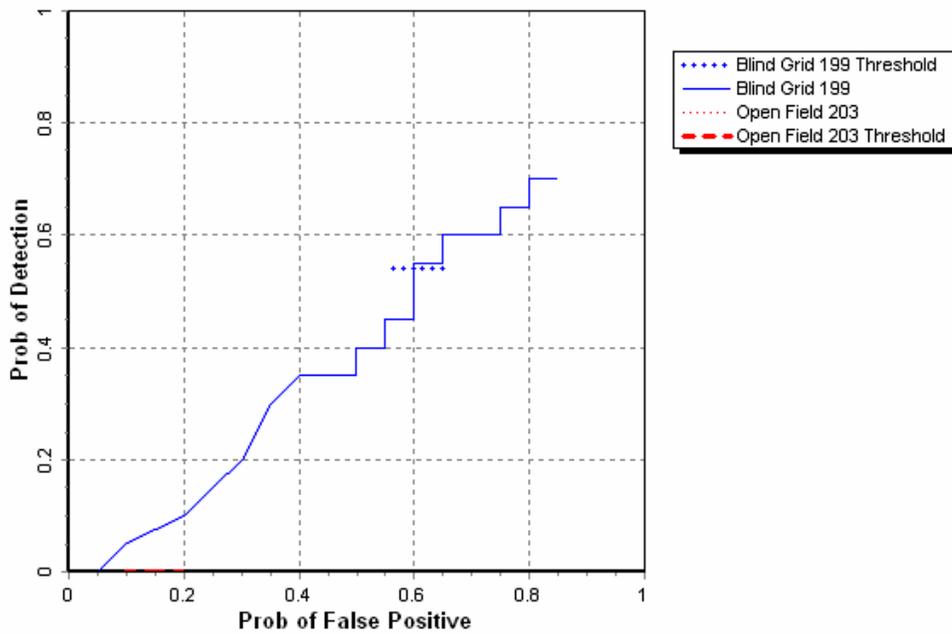


Figure 7. EM61 UXO MAPPER pushcart  $P_d^{disc}$  versus the respective  $P_{fp}$  over all ordnance categories combined.

### 6.3 COMPARISON OF ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8 shows the  $P_d^{\text{res}}$  versus the respective probability of  $P_{\text{fp}}$  over ordnance larger than 20 mm. Figure 9 shows  $P_d^{\text{disc}}$  versus the respective  $P_{\text{fp}}$  over ordnance larger than 20 mm. Figure 9 uses horizontal lines to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

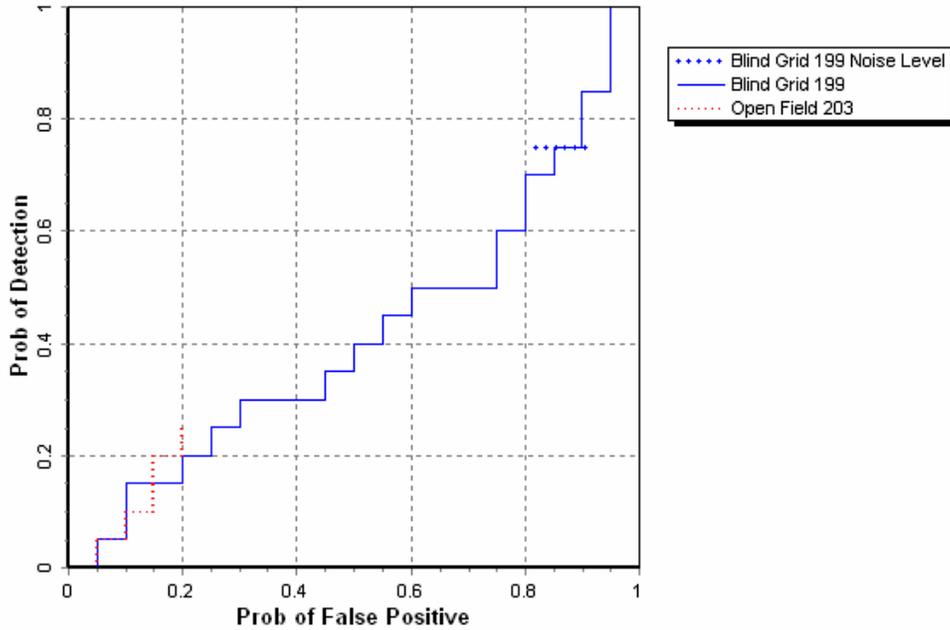


Figure 8. EM61 UXO MAPPER pushcart  $P_d^{\text{res}}$  versus the respective  $P_{\text{fp}}$  for ordnance larger than 20 mm.

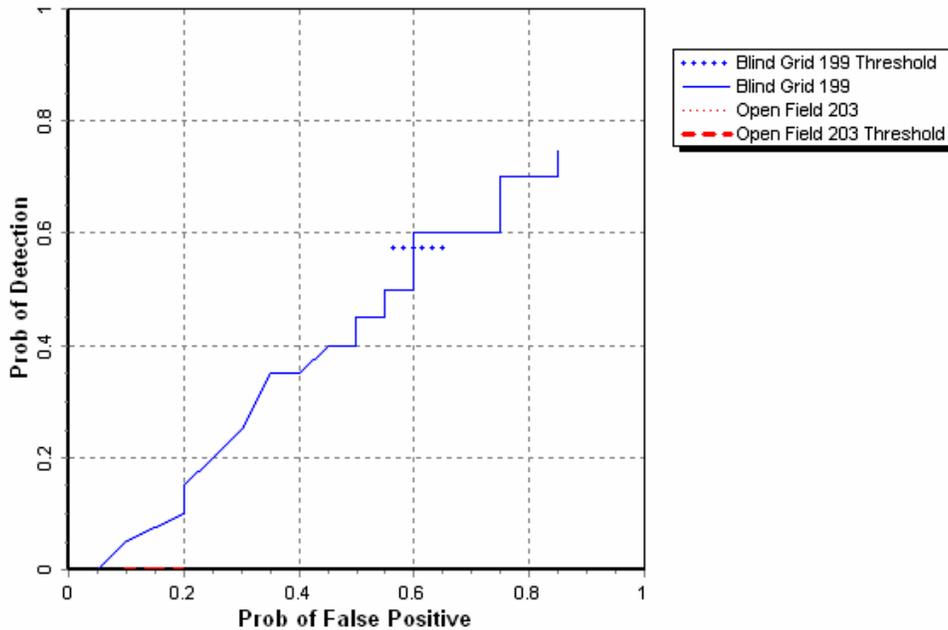


Figure 9. EM61 UXO MAPPER pushcart  $P_d^{disc}$  versus the respective  $P_{fp}$  for ordnance larger than 20 mm.

## 6.4 STATISTICAL COMPARISONS

Statistical Chi-square significance tests were used to compare results between the Blind Grid and Open Field scenarios. The intent of the comparison is to determine if the feature introduced in each scenario has a degrading effect on the performance of the sensor system. However, any modifications in the UXO sensor system during the test, like changes in the processing or changes in the selection of the operating threshold, will also contribute to performance differences.

The Chi-square test for comparison between ratios was used at a significance level of 0.05 to compare Blind Grid to Open Field with regard to  $P_d^{res}$ ,  $P_d^{disc}$ ,  $P_{fp}^{res}$  and  $P_{fp}^{disc}$ , Efficiency and Rejection Rate. These results are presented in Table 11. A detailed explanation and example of the Chi-square application is located in Appendix A.

**TABLE 11. CHI-SQUARE RESULTS - BLIND GRID VERSUS OPEN FIELD**

<b>Metric</b>	<b>Small</b>	<b>Medium</b>	<b>Large</b>	<b>Overall</b>
$P_d^{res}$	Significant	Significant	Significant	Significant
$P_d^{disc}$	Not Significant	Not Significant	Not Significant	Not Significant
$P_{fp}^{res}$	Not Significant	Not Significant	Not Significant	Not Significant
$P_{fp}^{disc}$	-	-	-	Significant
Efficiency	-			Significant
Rejection rate	-	-	-	Significant

## 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  $R_{\text{halo}}$  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.

$R_{\text{halo}}$ : 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. 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 projected length of the ordnance onto the ground plane 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-inch 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-lb 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 selects the 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 ( $P_d^{\text{res}}$ ):  $P_d^{\text{res}} = (\text{No. of response-stage detections})/(\text{No. of emplaced ordnance in the test site})$ .

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

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

Response Stage Background Alarm: 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  $R_{\text{halo}}$  of any emplaced ordnance or emplaced clutter item.

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

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

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

## 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 ( $P_d^{\text{disc}}$ ):  $P_d^{\text{disc}} = (\text{No. of discrimination-stage detections})/(\text{No. of emplaced ordnance in the test site})$ .

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

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

Discrimination Stage Background Alarm: 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  $R_{\text{halo}}$  of any emplaced ordnance or emplaced clutter item.

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

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

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 CHARACTERISTIC (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.<sup>1</sup> 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.

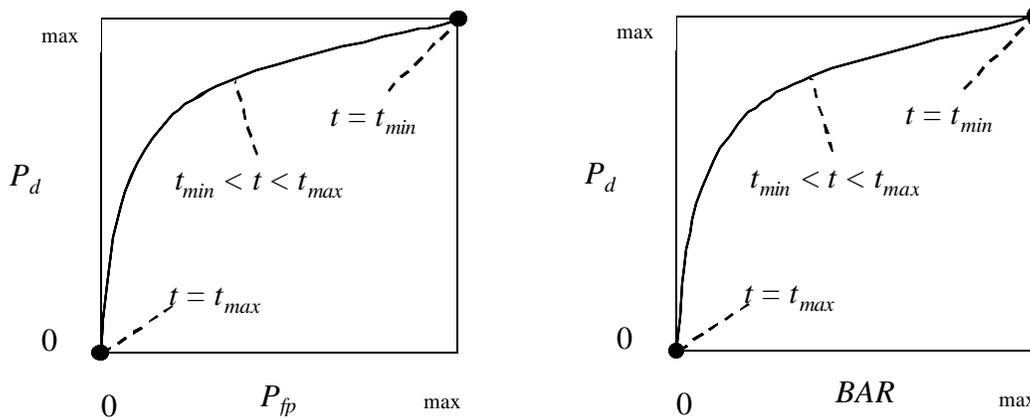


Figure A-1. ROC curves for open-field testing. Each curve applies to both the response and discrimination stages.

<sup>1</sup>Strictly speaking, ROC curves plot the  $P_d$  versus  $P_{ba}$  over a predetermined 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):  $E = P_d^{\text{disc}}(t^{\text{disc}})/P_d^{\text{res}}(t_{\text{min}}^{\text{res}})$ : 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  $t_{\text{min}}$ ) 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,  $t^{\text{disc}}$ .

False Positive Rejection Rate ( $R_{\text{fp}}$ ):  $R_{\text{fp}} = 1 - [P_{\text{fp}}^{\text{disc}}(t^{\text{disc}})/P_{\text{fp}}^{\text{res}}(t_{\text{min}}^{\text{res}})]$ : 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  $t_{\text{min}}$ ). 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 ( $R_{\text{ba}}$ ):

Blind Grid:  $R_{\text{ba}} = 1 - [P_{\text{ba}}^{\text{disc}}(t^{\text{disc}})/P_{\text{ba}}^{\text{res}}(t_{\text{min}}^{\text{res}})]$

Open Field:  $R_{\text{ba}} = 1 - [\text{BAR}^{\text{disc}}(t^{\text{disc}})/\text{BAR}^{\text{res}}(t_{\text{min}}^{\text{res}})]$

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 4, pages 144 through 151).

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
$P_d^{\text{res}}$	100/100 = 1.0	8/10 = .80	20/33 = .61
$P_d^{\text{disc}}$	80/100 = 0.80	6/10 = .60	8/33 = .24

$P_d^{\text{res}}$ : 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.

$P_d^{\text{disc}}$ : 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.

$P_d^{\text{res}}$ : 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.

$P_d^{\text{disc}}$ : 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**

<b>Time, HHMM</b>	<b>Temp., deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>12 January 2004</b>			
01:00	12.6	34	0.00
02:00	11.9	35	0.00
03:00	11.1	38	0.00
04:00	10.8	39	0.00
05:00	10.0	41	0.00
06:00	9.3	42	0.00
07:00	8.5	44	0.00
08:00	7.4	46	0.00
09:00	11.3	38	0.00
10:00	14.9	31	0.00
11:00	17.7	27	0.00
12:00	20.5	24	0.00
13:00	22.3	22	0.00
14:00	23.3	20	0.00
15:00	24.1	19	0.00
16:00	25.0	19	0.00
17:00	25.0	19	0.00
18:00	22.9	21	0.00
19:00	19.9	24	0.00
20:00	18.2	26	0.00
21:00	17.3	27	0.00
22:00	14.8	29	0.00
23:00	13.0	31	0.00
24:00	13.0	34	0.00

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>13 January 2004</b>			
01:00	12.1	37	0.00
02:00	13.5	37	0.00
03:00	11.0	41	0.00
04:00	11.1	44	0.00
05:00	11.9	41	0.00
06:00	9.4	44	0.00
07:00	9.5	47	0.00
08:00	8.0	51	0.00
09:00	10.3	45	0.00
10:00	14.3	37	0.00
11:00	17.9	31	0.00
12:00	21.0	26	0.00
13:00	22.7	23	0.00
14:00	23.5	22	0.00
15:00	24.3	21	0.00
16:00	24.2	21	0.00
17:00	23.9	21	0.00
18:00	23.3	23	0.00
19:00	21.3	25	0.00
20:00	19.2	28	0.00
21:00	18.4	29	0.00
22:00	16.7	32	0.00
23:00	18.3	29	0.00
24:00	17.6	30	0.00

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>14 January 2004</b>			
01:00	16.2	33	0.00
02:00	15.6	34	0.00
03:00	16.1	33	0.00
04:00	16.1	32	0.00
05:00	16.1	32	0.00
06:00	15.5	32	0.00
07:00	15.9	31	0.00
08:00	15.8	31	0.00
09:00	15.8	31	0.00
10:00	16.2	31	0.00
11:00	20.9	23	0.00
12:00	22.9	19	0.00
13:00	24.5	17	0.00
14:00	25.5	15	0.00
15:00	25.9	14	0.00
16:00	25.0	15	0.00
17:00	23.8	16	0.00
18:00	22.0	18	0.00
19:00	20.2	20	0.00
20:00	18.9	21	0.00
21:00	17.8	23	0.00
22:00	14.6	27	0.00
23:00	14.5	27	0.00
24:00	16.9	39	0.00

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>15 January 2004</b>			
01:00	16.5	47	0.00
02:00	15.4	52	0.00
03:00	15.6	53	0.00
04:00	15.8	53	0.00
05:00	15.0	56	0.00
06:00	14.8	57	0.00
07:00	14.2	58	0.00
08:00	14.0	59	0.00
09:00	15.3	55	0.00
10:00	18.1	45	0.00
11:00	19.5	40	0.00
12:00	20.3	39	0.00
13:00	21.2	37	0.00
14:00	21.7	35	0.00
15:00	22.1	33	0.00
16:00	22.1	33	0.00
17:00	22.4	30	0.00
18:00	21.1	32	0.00
19:00	19.1	35	0.00
20:00	17.8	44	0.00
21:00	16.5	45	0.00
22:00	15.2	49	0.00
23:00	14.2	49	0.00
24:00	15.0	46	0.00

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>16 January 2004</b>			
01:00	12.3	51	0.00
02:00	11.9	53	0.00
03:00	11.1	56	0.00
04:00	12.0	54	0.00
05:00	11.5	55	0.00
06:00	12.5	52	0.00
07:00	10.2	57	0.00
08:00	9.3	59	0.00
09:00	11.4	52	0.00
10:00	15.7	35	0.00
11:00	17.3	32	0.00
12:00	19.6	26	0.00
13:00	21.7	22	0.00
14:00	22.4	20	0.00
15:00	23.1	18	0.00
16:00	22.8	16	0.00
17:00	22.5	17	0.00
18:00	21.2	18	0.00
19:00	18.6	21	0.00
20:00	16.7	23	0.00
21:00	14.6	26	0.00
22:00	14.1	28	0.00
23:00	13.0	30	0.00
24:00	12.7	30	0.00

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>23 January 2004</b>			
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)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>26 January 2004</b>			
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

**TABLE B-1 (CONT'D)**

<b>Time, HHMM</b>	<b>Temp. deg. C</b>	<b>R/H, %</b>	<b>15 min. Precip., in.</b>
<b>27 January 2004</b>			
01:00	7.2	44	0.00
02:00	7.1	44	0.00
03:00	6.8	45	0.00
04:00	6.8	44	0.00
05:00	5.8	52	0.00
06:00	5.3	52	0.00
07:00	5.1	51	0.00
08:00	5.0	49	0.00
09:00	9.0	37	0.00
10:00	12.8	20	0.00
11:00	14.0	17	0.00
12:00	15.4	16	0.00
13:00	16.5	15	0.00
14:00	17.3	15	0.00
15:00	18.0	15	0.00
16:00	18.5	15	0.00
17:00	18.3	16	0.00
18:00	17.6	18	0.00
19:00	15.5	23	0.00
20:00	14.0	28	0.00
21:00	12.4	34	0.00
22:00	11.3	41	0.00
23:00	10.8	39	0.00
24:00	9.5	42	0.00

## APPENDIX C. SOIL MOISTURE

SOIL MOISTURE LOGS (13 through 16, and 27 January 2004)

Date: January 13, 2004

Times: (0720), (1300)

<b>Probe Location:</b>	<b>Layer, in.</b>	<b>AM Reading, %</b>	<b>PM Reading, %</b>
Calibration Area	0 to 6	1.8	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	3.9
Mogul Area	0 to 6	1.7	1.6
	6 to 12	2.0	2.0
	12 to 24	3.6	3.6
	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	2.0	2.2
	12 to 24	3.4	3.4
	24 to 36	3.9	3.9
	36 to 48	4.1	4.0

Date: January 15, 2004  
 Times: (0830), (1330)

<b>Probe Location:</b>	<b>Layer, in.</b>	<b>AM Reading, %</b>	<b>PM Reading, %</b>
Calibration Area	0 to 6	1.7	1.6
	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	3.9
Mogul Area	0 to 6	1.6	1.6
	6 to 12	2.0	2.0
	12 to 24	3.6	3.6
	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	2.2	2.2
	12 to 24	3.4	3.4
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 16, 2004  
Times: (0715), (1400)

<b>Probe Location:</b>	<b>Layer, in.</b>	<b>AM Reading, %</b>	<b>PM Reading, %</b>
Calibration Area	0 to 6	1.8	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	3.9	4.0
Mogul Area	0 to 6	1.6	1.6
	6 to 12	2.0	2.0
	12 to 24	3.6	3.6
	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	2.2	2.2
	12 to 24	3.4	3.4
	24 to 36	3.9	3.9
	36 to 48	4.0	4.0

Date: January 27, 2004  
Times: (0715), (1300)

<b>Probe Location:</b>	<b>Layer, in.</b>	<b>AM Reading, %</b>	<b>PM Reading, %</b>
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	2.2	2.2
	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

D-1

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	
EM61												
01/12/2004	3	CALIBRATION LANES	1430	1655	145	SETUP/DAILY START/STOP/CALIBRATION	INITIAL SETUP/MOBILIZATION	NA	NA	NA	SUNNY	DRY
01/12/2004	3	CALIBRATION LANES	1655	1710	15	SETUP/DAILY START/STOP/CALIBRATION	END OF DAILY OPERATIONS/EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	DRY
01/13/2004	3	CALIBRATION LANES	0715	0915	120	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	CALIBRATION LANES	0915	0935	20	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	BLIND TEST GRID	0935	1000	25	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	BLIND TEST GRID	1000	1027	27	EQUIPMENT FAILURE	LOST GPS	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	BLIND TEST GRID	1027	1035	8	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	BLIND TEST GRID	1035	1042	7	BREAK/LUNCH	BREAK	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1042	1145	63	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1145	1150	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1150	1220	30	BREAK/LUNCH	LUNCH	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1220	1250	30	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	CLOUDY	COOL

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	
01/13/2004	3	OPEN FIELD	1250	1405	75	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1405	1415	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1415	1425	10	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1425	1443	18	EQUIPMENT FAILURE	LOST GPS	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1443	1500	17	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1500	1508	8	DOWNTIME DUE TO EQUIP MAIN/CHECK	LOST GPS	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1508	1545	37	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1545	1600	15	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1600	1622	22	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1622	1627	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1627	1630	3	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	CLOUDY	COOL
01/13/2004	3	OPEN FIELD	1630	1640	10	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	CLOUDY	COOL
01/14/2004	3	OPEN FIELD	0700	0810	70	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL

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	
01/14/2004	3	OPEN FIELD	0810	0820	10	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/14/2004	3	OPEN FIELD	0820	0830	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL
01/14/2004	3	OPEN FIELD	0830	0900	30	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/14/2004	3	OPEN FIELD	0900	0905	5	EQUIPMENT FAILURE	CHANGE CONNECTOR CABLE TO GYROSCOPE	NA	NA	NA	SUNNY	COOL
01/14/2004	3	OPEN FIELD	0905	0945	40	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	NA	SUNNY	COOL
01/14/2004	3	OPEN FIELD	0945	1000	15	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL
01/14/2004	3	OPEN FIELD	1000	1015	15	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/14/2004	3	OPEN FIELD	1015	1023	8	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL
01/14/2004	3	OPEN FIELD	1023	1218	115	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/14/2004	3	OPEN FIELD	1218	1225	7	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1225	1310	45	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WINDY
01/14/2004	3	OPENFIELD	1310	1340	30	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	WINDY

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	
01/14/2004	3	OPEN FIELD	1340	1350	10	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1350	1412	22	SETUP/DAILY START/ STOP/CALIBRATION	SET UP/MOBILIZATION	NA	NA	NA	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1412	1450	38	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1450	1500	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1500	1550	50	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GP	NA	LINEAR	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1550	1605	15	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1605	1635	30	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WINDY
01/14/2004	3	OPEN FIELD	1635	1655	20	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	WINDY
01/15/2004	3	OPEN FIELD	0700	0850	110	SETUP/DAILY START/ STOP/CALIBRATION	SET UP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/15/2004	3	OPEN FIELD	0850	0940	50	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/15/2004	3	OPEN FIELD	0940	0950	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL

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	
01/15/2004	3	OPEN FIELD	0950	1100	70	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1100	1113	13	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1113	1143	30	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1143	1155	12	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1155	1215	20	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1215	1245	30	DOWNTIME DUE TO EQUIP MAIN/CHECK	COLLECT DATA	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1245	1255	10	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1255	1320	25	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1320	1330	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1330	1530	120	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1530	1535	5	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	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	
01/15/2004	3	OPEN FIELD	1535	1610	35	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1610	1614	4	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1614	1700	46	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/15/2004	3	OPEN FIELD	1700	1710	10	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	WARM
01/16/2004	3	MOGUL	0655	0746	51	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/16/2004	3	MOGUL	0746	0909	83	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/16/2004	3	MOGUL	0909	0936	27	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/16/2004	3	MOGUL	0936	1000	24	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/16/2004	3	YUMA EXTREME	1000	1100	60	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/ MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1100	1120	20	BREAK/LUNCH	LUNCH	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	
01/16/2004	3	YUMA EXTREME	1120	1145	25	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	WARM
01/16/2004	3	MOGUL	1145	1151	6	COLLECT DATA	COLLECT DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	WARM
01/16/2004	3	MOGUL	1151	1205	14	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1205	1306	61	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1306	1318	12	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1318	1325	7	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1325	1330	5	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/16/2004	3	YUMA EXTERME	1330	1350	20	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1350	1650	180	EQUIPMENT FAILURE	ELECTRONIC FAILURE EM61 BOX	NA	NA	NA	SUNNY	WARM
01/16/2004	3	YUMA EXTREME	1650	1700	10	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	WARM

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 EXTREME	0932	1015	43	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	WARM
01/23/2004	3	YUMA EXTREME	1015	1120	65	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	WARM
01/23/2004	3	YUMA EXTREME	1120	1215	55	EQUIPMENT FAILURE	COMMUNICATIONS FAILURE	NA	NA	NA	SUNNY	WARM
01/23/2004	1	YUMA EXTREME	1215	1410	115	EQUIPMENT FAILURE	SYSTEM AUTO SHUT OFF	NA	NA	NA	SUNNY	WARM
01/23/2004	1	YUMA EXTREME	1410	1420	10	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	WARM
01/26/2004	3	YUMA EXTREME	1015	1135	80	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1135	1320	105	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1320	1330	10	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1330	1400	30	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1400	1420	20	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	COOL

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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	
01/26/2004	3	YUMA EXTREME	1420	1510	50	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1510	1600	50	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1600	1620	20	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1620	1712	52	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1712	1720	8	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHANGE BATTERY	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTRMEM	1720	1730	10	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1730	1740	10	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COOL
01/26/2004	3	YUMA EXTREME	1740	1750	10	SETUP/DAILY START/ STOP/CALIBRATION	END OF DAILY OPERATIONS/ EQUIPMENT BREAKDOWN	NA	NA	NA	SUNNY	COOL
01/27/2004	3	YUMA EXTREME	0645	0725	40	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COLD
01/27/2004	3	YUMA EXTREME	0725	0831	66	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL

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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	
01/27/2004	3	YUMA EXTREME	0831	0856	25	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COOL
01/27/2004	3	YUMA EXTREME	0856	0910	14	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/27/2004	3	YUMA EXTREME	0910	0920	10	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL NORTH TO SOUTH	GPS	NA	LINEAR	SUNNY	COOL
01/27/2004	3	OPEN FIELD	0920	0940	20	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/27/2004	3	OPEN FIELD	0940	1015	35	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/27/2004	3	OPENFIELD	1015	1020	5	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/27/2004	3	OPEN FIELD	1020	1052	32	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COLD
01/27/2004	3	OPEN FIELD	1052	1100	8	SETUP/DAILY START/STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/27/2004	3	OPEN FIELD	1100	1120	20	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	COOL
01/27/2004	3	OPEN FIELD	1120	1145	25	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	COOL

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	
01/27/2004	3	OPEN FIELD	1145	1247	62	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	COOL
01/27/2004	3	OPEN FIELD	1247	1340	53	SETUP/DAILY START/ STOP/CALIBRATION	SETUP/MOBILIZATION	NA	NA	NA	SUNNY	COOL
01/27/2004	3	OPEN FIELD	1340	1400	20	COLLECT DATA	COLLECTED DATA BI-DIRECTIONAL EAST TO WEST	GPS	NA	LINEAR	SUNNY	WARM
01/27/2004	3	OPEN FIELD	1400	1430	30	DOWNTIME DUE TO EQUIP MAIN/CHECK	CHECK DATA	NA	NA	NA	SUNNY	WARM
01/27/2004	3	OPEN FIELD	1430	1535	65	DEMOBILIZATION	DEMOBILIZATION END OF TEST TURN-IN DATA	NA	NA	NA	SUNNY	WARM

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.
5. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, ages 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
ATSS	=	Aberdeen Test and Support Services
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
HEAT	=	high-explosive, antitank
JPG	=	Jefferson Proving Ground
LLC	=	Limited Liability Company
METDC	=	Military Environmental Technology Demonstration Center
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