



AD NO. \_\_\_\_\_  
DTC PROJECT NO. 8-CO-160-UXO-021  
REPORT NO. ATC-9512



STANDARDIZED  
UXO TECHNOLOGY DEMONSTRATION SITE  
MINE GRID SCORING RECORD NO. 838

SITE LOCATION:  
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:  
NAEVA GEOPHYSICS INC.  
P.O. BOX 7325  
CHARLOTTSVILLE, VA 22906

TECHNOLOGY TYPE/PLATFORM:  
EM/PUSHCART

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

OCTOBER 2007



Prepared for:  
U.S. ARMY ENVIRONMENTAL COMMAND  
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1. The attached record entitled "The Standardized UXO Technology Demonstration Site Mine Grid Scoring Record No. 838" dated October 2007 is provided for review for public disclosure in accordance with AR 530-1 as supplemented. The scoring record is proposed for public release via the internet.

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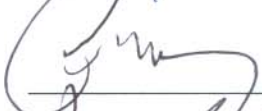
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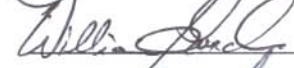
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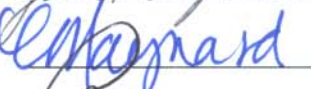
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| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                             |                              |                                          | Form Approved<br>OMB No. 0704-0188                          |                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|------------------------------|------------------------------------------|-------------------------------------------------------------|-------------------------------------------|
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| 1. REPORT DATE (DD-MM-YYYY)<br>October 2007                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                             | 2. REPORT TYPE<br>Final      |                                          | 3. DATES COVERED (From - To)<br>July through August 2006    |                                           |
| 4. TITLE AND SUBTITLE<br>STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE<br>MINE GRID SCORING RECORD NO. 838                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                             |                              |                                          | 5a. CONTRACT NUMBER                                         |                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              |                                          | 5b. GRANT NUMBER                                            |                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              |                                          | 5c. PROGRAM ELEMENT NUMBER                                  |                                           |
| 6. AUTHOR(S)<br>Teefy, Dennis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                             |                              |                                          | 5d. PROJECT NUMBER<br>8-CO-160-UXO-021                      |                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              |                                          | 5e. TASK NUMBER                                             |                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              |                                          | 5f. WORK UNIT NUMBER                                        |                                           |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>Commander<br>U.S. Army Aberdeen Test Center<br>ATTN: CSTE-DTC-AT-SL-E<br>Aberdeen Proving Ground, MD 21005-5059                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                             |                              |                                          | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br><br>ATC-9512 |                                           |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>Commander<br>U.S. Army Environmental Command<br>ATTN: IMAE-ATT<br>Aberdeen Proving Ground, MD 21010-5401                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                             |                              |                                          | 10. SPONSOR/MONITOR'S ACRONYM(S)                            |                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              |                                          | 11. SPONSOR/MONITOR'S REPORT<br>NUMBER(S)<br>Same as Item 8 |                                           |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br>Distribution unlimited                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                             |                              |                                          |                                                             |                                           |
| 13. SUPPLEMENTARY NOTES<br>None.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                             |                              |                                          |                                                             |                                           |
| 14. ABSTRACT<br><br>This Scoring Record documents the efforts of NAEVA Geophysics, Inc., to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Mine Grid. This Scoring Record was coordinated by Dennis Teefy and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.                                                                                                                                                                                                                                                                                         |                             |                              |                                          |                                                             |                                           |
| 15. SUBJECT TERMS<br><br>NAEVA, UXO Standardized Technology Demonstration Site, Mine Grid, Dual-Sensor Instrument/handheld, MEC.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                             |                              |                                          |                                                             |                                           |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                              | 17. LIMITATION OF<br>ABSTRACT<br><br>SAR | 18. NUMBER<br>OF<br>PAGES                                   | 19a. NAME OF RESPONSIBLE PERSON           |
| a. REPORT<br>Unclassified                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | b. ABSTRACT<br>Unclassified | c. THIS PAGE<br>Unclassified |                                          |                                                             | 19b. TELEPHONE NUMBER (Include area code) |

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## **SECTION 1. GENERAL INFORMATION**

### **1.1 BACKGROUND**

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

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

### **1.2 SCORING OBJECTIVES**

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

The evaluation objectives are as follows:

- a. To determine detection and discrimination effectiveness under realistic scenarios that may vary targets, geology, clutter, topography, and vegetation.
- b. To determine cost, time, and manpower requirements to operate the technology.
- c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.
- d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

#### **1.2.1 Scoring Methodology**

- a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection ( $P_d$ ) and the false alarms are reported as receiver-operating



characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive ( $P_{fp}$ ), and those that do not correspond to any known item, termed background alarms.

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

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

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

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

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

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 STANDARDIZED INERT MINE TARGETS**

The standard inert mine targets emplaced in the test area 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).

**TABLE 1. STANDARDIZED INERT  
MINE TARGETS**

| <b>Type</b>               |
|---------------------------|
| TM-62 large metal mines   |
| AT VS 1.6 low metal mines |
| AP VS 5.0 low metal mines |
| AP M14 low metal mines    |

## **SECTION 2. DEMONSTRATION**

### **2.1 DEMONSTRATOR INFORMATION**

#### **2.1.1 Demonstrator Point of Contact (POC) and Address**

POC: Mr. John Breznick  
(434) 978 3187

Address: NAEVA Geophysics Inc.  
P.O. Box 7325  
Charlottesville, VA 22906

#### **2.1.2 System Description (provided by demonstrator)**

NAEVA will be using two instruments manufactured by CyTerra Corporation, the AN/PSS-14 and the LULU, in a comparison with the Geonics EM61 MK2 and the Geonics EM61 HH.

The AN/PSS-14 is a handheld mine detection system designed to accurately detect both metallic and nonmetallic landmines. The unit was originally designed for military countermine operations, but attempts are currently underway to adapt it for humanitarian demining applications. A handheld staff supports a single sensor that utilizes fully integrated ground penetrating radar (GPR) and metal detection to identify large and small, metallic, and nonmetallic mines. The GPR technology is based on a wide-band, coherent, stepped-frequency radar transceiver. The search head contains one transmit and two receive antennas. The transmit antenna produces continuous wave, low-power radar signals that are reflected back to the receive antennas by subsurface discontinuities and processed by the system. The metal detector consists of a flat annular coil that forms the diameter of the sensor head and surrounds the GPR antennas. The single coil acts as both transmitter and receiver. NAEVA will be testing the AN/PSS-14 at the Non-Metallic Test Stand at APG, as well as the calibration lanes, blind grid, and the mine grid. In the calibration lanes, blind grid, and mine grid, the instrument will be used to flag targets, the locations of which will be recorded later using RTK GPS.

The LULU represents a transition of the CyTerra AN/PSS-14 mine detection technology to provide the capability to detect buried utilities. The system incorporates a derivative of the AN/PSS-14 GPR. To make it suitable for utility detection, the frequency band and antenna size of the system were altered to increase the depth-detection range from shallow mine depths of inches to between 2 and 10 feet for utility detection. NAEVA and CyTerra feel that this increased depth of exploration may make the system suitable for detection of the deeper targets commonly associated with UXO remediation projects. The LULU will be employed only for follow-up at flagged target locations identified from the AN/PSS-14. Based on the results of this project, the frequencies and antenna size could be modified at a later date to maximize its UXO detection capabilities.

A Geonics EM61 MK2 will be used to map the calibration lanes, blind grid, and mine grid for a direct comparison with the results from the AN/PSS-14. The EM61 HH will be used on the Non-Metallic Test Stand, calibration lanes, blind grid, and mine grid. The coil size of the EM61 HH is similar to that of the AN/PSS-14, providing a good comparison of an electromagnetic (EM)-only instrument with the capabilities of the EM- and GPR-equipped AN/PSS-14.

On-ground control stakes for the demonstration will be established using an Ashtech ZFX RTK GPS. The Ashtech Z-FX system consists of a mobile GPS receiver and antenna (rover) and a fixed base station utilizing an Ashtech Z-FX receiver. Real-time corrections from the GPS base receiver are broadcast to the rover via a radio link using Pacific Crest radio modems. This system provides positional updates at a rate of 1 Hz, with a horizontal accuracy of 3 cm.



Figure 1. Demonstrator's system, EM/pushcart.

### **2.1.3 Data Processing Description (provided by demonstrator)**

For the Non-Metallic Test Stand portion of the demonstration, data collected with the AN/PSS-14 will be stored in a laptop computer. These data will be processed by CyTerra using proprietary software to quantify the responses from each of the tested inert OE items. Data will not be stored during the calibration lanes, blind grid, and mine grid surveys with the AN/PSS-14, as the instrument will be used to select targets in real time, with selected anomalies marked with PVC pin flags.

All data collected with the Geonics EM61 MK2 and EM61 HH will be processed using Geosoft's Oasis Montaj software. In the calibration lanes, blind grid, and mine grid a track plot of the instrument's GPS positions will be created to ensure that adequate data coverage had been achieved. Preliminary contour maps will then be created for field review of the data generated by each sensor within a survey area. Once in-field processing and review is completed, the data will be electronically transferred to a remote site for analysis/target selection.

Geosoft's Oasis Montaj UXO software package will be employed to post-process and contour the raw data and to identify potential UXO targets from each sensor's data. The program identifies peak amplitude responses of the frequency associated with, but not limited to, UXO items. Anomalies may generate multiple target designations depending on individual signature characteristics.

Standard geophysical data processing includes the following:

- Instrument drift correction (leveling).
- Lag correction.
- Digital filtering and enhancement (if necessary).
- Gridding of data.
- Selection of anomalies.
- Preparation of geophysical and target maps.

Once the steps described above have been completed, the data will be ready for fusion, advanced processing, and final dig list development. The processing steps required to remove unwanted signal from the geophysical data are usually site specific but there are general procedures that can be used. Low-pass filters are first applied to remove very high frequency responses from the geophysical data that are normally due to sensor noise and/or platform vibration. These filters can also be applied to the positioning data to remove variations in the positioning data that are of too high a frequency to be realistic. Demedian filters or similar processes that remove long wavelength features are useful for removing both geologic response as well as sensor drift (EM).

#### **2.1.4 Data Submission Format**

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

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

QC. To establish confidence in the data reliability, tests will be conducted in a systematic manner throughout the duration of the fieldwork. Various types of quality control data are generated prior to and after all data collection sessions.

Daily. A location identified as having no subsurface metal will be designated as a calibration point. Readings will be collected in a stationary position over the calibration point to ensure a stable and repeatable response is exhibited. During this time, a metallic item will be placed below the center of the sensors, and the instrument's response will be observed. The item will then be removed, and static readings continued. This test is performed daily to establish that the instrument is functioning properly, as indicated by a stable and repeatable response. The calibration point will also document the continued accurate performance of the laser positioning equipment.

QA. For purposes of this proposal, QA is defined as the procedures to be employed during the demonstration. All of the procedures are designed to provide excellent data quality while maximizing production during the field efforts.

All data in the calibration lanes, blind grid, and mine grid collected with the Geonics EM61 MK2 and EM61 HH will be positioned with RTK GPS using an antenna mounted directly above the sensor. Data will be collected at a rate of 1 Hz. Existing control markers will be sufficient to maintain straight line profiling and to achieve full coverage within the calibration lanes and the blind grid. Within each survey cell, data collection will be controlled using a series of marked survey ropes positioned at 25-foot intervals perpendicular to the survey line direction. Alternating colors painted on the ropes at 3-foot intervals facilitate straight line profiling with the instrumentation during data collection.

### **2.1.6 Additional Records**

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at [www.uxotestsites.org](http://www.uxotestsites.org). The correlating blind grid demonstration findings for this system can be found in scoring record No. 833.

## 2.2 APG SITE INFORMATION

### 2.2.1 Location

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

### 2.2.2 Soil Type

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

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

For more details concerning the soil properties at the APG test site, go to [www.uxotestsites.org](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 APG is included in Table 2.

**TABLE 2. TEST SITE AREAS**

| <b>Area</b>      | <b>Description</b>                                                                                                                           |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Calibration grid | Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator to calibrate their equipment. |
| Blind grid       | Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter, or nothing.               |
| Mine grid        | Contains 100 grid cells in a 0.02-hectare (0.05-acre) site. The center of each grid cell will contain a mine, clutter, or nothing.           |



### **SECTION 3. FIELD DATA**

#### **3.1 DATE OF FIELD ACTIVITIES (26 through 27 July and 3 August 2006)**

#### **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 | 3.00                   |
| Mine grid         | 1.08                   |

#### **3.3 TEST CONDITIONS**

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

An APG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on 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/PRECIPITATION DATA SUMMARY**

| <b>Date, 2006</b> | <b>Average Temperature, °F</b> | <b>Total Daily Precipitation, in.</b> |
|-------------------|--------------------------------|---------------------------------------|
| 26 July           | 84.25                          | 0.00                                  |
| 27 July           | 86.61                          | 0.05                                  |
| 3 August          | 92.49                          | 0.00                                  |

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

The weather was hot and the mine grid was dry during the survey.

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

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

### **3.4 FIELD ACTIVITIES**

#### **3.4.1 Setup/Mobilization**

These activities included initial mobilization and daily equipment preparation and break down. A two-person crew took 2 hours and 20 minutes to perform the initial setup and mobilization. There was 50 minutes of daily equipment preparation and no end of the day equipment break down.

#### **3.4.2 Calibration**

NAEVA spent a total of 3 hours in the calibration lanes, of which 35 minutes was spent collecting data. One other calibration exercise occurred in the blind grid totaling 20 minutes

#### **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 no site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. CyTerra/NAEVA spent no additional time 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 mine grid.

**3.4.3.3 Weather.** No weather delays occurred during the survey.

#### **3.4.4 Data Collection**

NAEVA spent a total time of 1 hour and 5 minutes in the Mine Grid area, 15 minutes of which was spent collecting data.

#### **3.4.5 Demobilization**

The CyTerra/NAEVA survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 3 August 2006. On that day, it took the crew 2 hours and 10 minutes to break down and pack up their equipment.

### **3.5 PROCESSING TIME**

CyTerra/NAEVA 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 time frame.

### **3.6 DEMONSTRATOR'S FIELD PERSONNEL**

Field Survey: Brian Neely  
Field Survey: Dan Hennessy

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

NAEVA surveyed the mine grid in a linear fashion, using a 2.5 feet of line spacing and surveying in a north to south direction.

### **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 ( $P_d^{\text{res}}$ ) and the discrimination stage ( $P_d^{\text{disc}}$ ) 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.

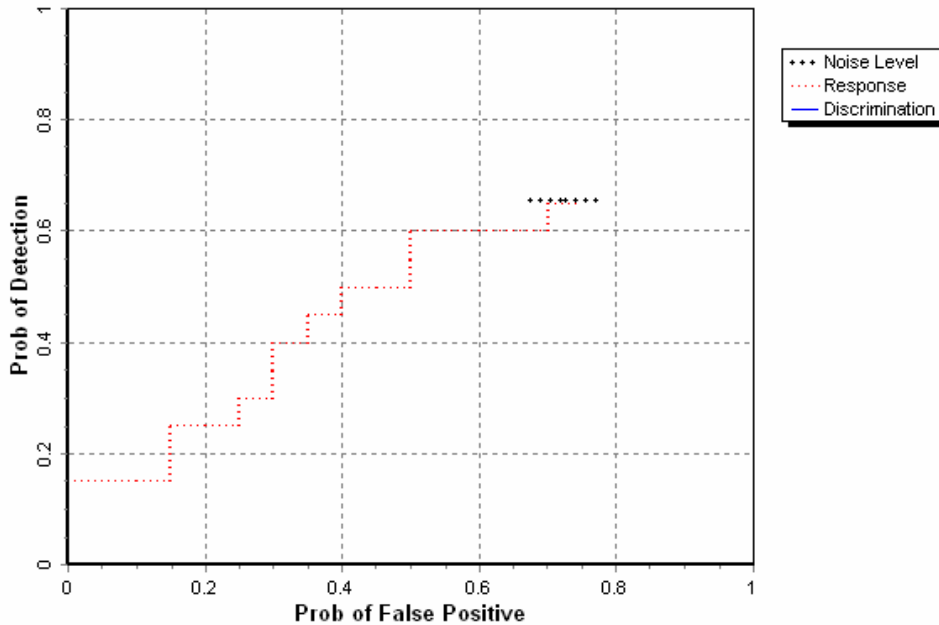


Figure 2. EM/pushcart mine grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

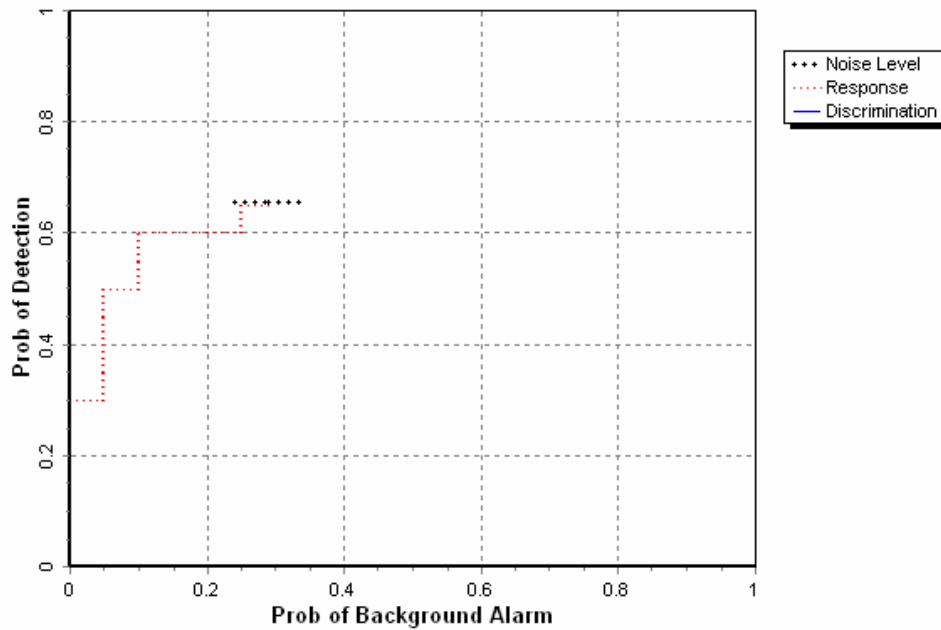


Figure 3. EM/pushcart mine grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

## 4.2 PERFORMANCE SUMMARIES

Results for the mine grid 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 MINE GRID RESULTS  
FOR THE EM/PUSHCART**

| <b>Metric</b>               | <b>Overall</b> |
|-----------------------------|----------------|
| <b>RESPONSE STAGE</b>       |                |
| $P_d$                       | 0.65           |
| $P_d$ Low 90% Conf          | 0.52           |
| $P_d$ Upper 90% Conf        | 0.77           |
| $P_{fp}$                    | 0.75           |
| $P_{fp}$ Low 90% Conf       | 0.61           |
| $P_{fp}$ Upper 90% Conf     | 0.82           |
| $P_{ba}$                    | 0.30           |
| <b>DISCRIMINATION STAGE</b> |                |
| $P_d$                       | NA             |
| $P_d$ Low 90% Conf          | NA             |
| $P_d$ Upper 90% Conf        | NA             |
| $P_{fp}$                    | NA             |
| $P_{fp}$ Low 90% Conf       | NA             |
| $P_{fp}$ Upper 90% Conf     | NA             |
| $P_{ba}$                    | NA             |

Response Stage Noise Level: NA

Recommended Discrimination Stage Threshold: NA

NA = not available

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

#### **4.3 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**

|                       | <b>Efficiency (E)</b> | <b>False Positive<br/>Rejection Rate</b> | <b>Background Alarm<br/>Rejection Rate</b> |
|-----------------------|-----------------------|------------------------------------------|--------------------------------------------|
| At Operating Point    | NA                    | NA                                       | NA                                         |
| With No Loss of $P_d$ | NA                    | NA                                       | NA                                         |

#### 4.4 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 and mine grids, 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)**

|       | <b>Mean</b> | <b>Standard Deviation</b> |
|-------|-------------|---------------------------|
| Depth | NA          | NA                        |

## **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**

|                      | <b>No. People</b> | <b>Hourly Wage</b> | <b>Hours</b> | <b>Cost</b>     |
|----------------------|-------------------|--------------------|--------------|-----------------|
| <b>Initial setup</b> |                   |                    |              |                 |
| Supervisor           | 1                 | \$95.00            | 2.33         | \$221.35        |
| Data analyst         | 1                 | 57.00              | 2.33         | 132.81          |
| Field support        | 0                 | 28.50              | 2.33         | 0.00            |
| Subtotal             |                   |                    |              | <b>\$354.16</b> |
| <b>Calibration</b>   |                   |                    |              |                 |
| Supervisor           | 1                 | \$95.00            | 3.33         | \$316.35        |
| Data analyst         | 1                 | 57.00              | 3.33         | 189.81          |
| Field support        | 0                 | 28.50              | 3.33         | 0.00            |
| Subtotal             |                   |                    |              | <b>\$506.16</b> |
| <b>Site survey</b>   |                   |                    |              |                 |
| Supervisor           | 1                 | \$95.00            | 1.08         | \$102.60        |
| Data analyst         | 1                 | 57.00              | 1.08         | 61.56           |
| Field support        | 0                 | 28.50              | 1.08         | 0.00            |
| Subtotal             |                   |                    |              | <b>\$164.16</b> |

See notes at end of table.



**TABLE 9 (CONT)**

|                       | <b>No. People</b> | <b>Hourly Wage</b> | <b>Hours</b> | <b>Cost</b>      |
|-----------------------|-------------------|--------------------|--------------|------------------|
| <b>Demobilization</b> |                   |                    |              |                  |
| Supervisor            | 1                 | \$95.00            | 2.16         | \$205.20         |
| Data analyst          | 0                 | 57.00              | 2.16         | 0.00             |
| Field support         | 0                 | 28.50              | 2.16         | 0.00             |
| Subtotal              |                   |                    |              | \$205.20         |
| Total                 |                   |                    |              | <b>\$1229.68</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 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  $R_{\text{halo}}$  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., nonordnance item) buried by the government at a specified location in the test site.

**$R_{\text{halo}}$ :** A predetermined 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  $R_{\text{halo}}$  of any item (clutter or ordnance), the declaration with the highest signal output within the  $R_{\text{halo}}$  will be utilized. For the purpose of this program, a circular halo 0.5 meter in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meter in length. When ordnance items are longer than 0.6 meter, 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 or mine 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 ( $P_d^{\text{res}}$ ):  $P_d^{\text{res}} = (\text{No. of response-stage detections})/(\text{No. of emplaced ordnance in the test site})$ .

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 ( $ba^{\text{res}}$ ): An anomaly in a Blind Grid and/or Mine 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 and/or Mine 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 nonordnance 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 ( $ba^{\text{disc}}$ ): An anomaly in a blind and/or mine 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.

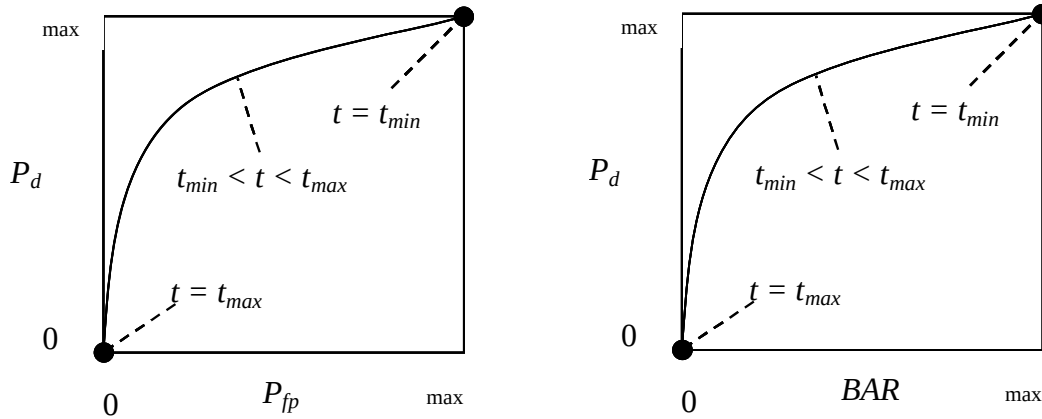


Figure A-1. ROC curves for open-field testing. Each curve applies to both the response and discrimination stages.

<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 and/or mine 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  $t_{min}$ ) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage,  $t^{disc}$ .

False Positive Rejection Rate ( $R_{fp}$ ):  $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$ ; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage  $t_{min}$ ). 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 ( $R_{ba}$ ):

BLIND GRID and/or MINE 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      |
|---------------------|---------------|------------|-------------|
| $P_d^{\text{res}}$  | 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.



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

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

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

## APPENDIX B. DAILY WEATHER LOGS

| Date, 2006 | Time, EST | Avg Temp, °F | Max Temp, °F | Min Temp, °F | Avg RH, % | Total Precip, in. |
|------------|-----------|--------------|--------------|--------------|-----------|-------------------|
| 27 July    | 0700      | 79.6         | 80.6         | 78.9         | 90        | 0.00              |
| 27 July    | 0800      | 81.3         | 82.5         | 80.3         | 87        | 0.00              |
| 27 July    | 0900      | 82.6         | 84.2         | 81.0         | 84        | 0.00              |
| 27 July    | 1000      | 85.0         | 86.1         | 83.8         | 78        | 0.00              |
| 27 July    | 1100      | 87.0         | 87.9         | 85.9         | 75        | 0.00              |
| 27 July    | 1200      | 88.1         | 89.3         | 87.1         | 74        | 0.00              |
| 27 July    | 1300      | 89.2         | 90.4         | 88.4         | 69        | 0.00              |
| 27 July    | 1400      | 90.8         | 91.7         | 89.8         | 59        | 0.00              |
| 27 July    | 1500      | 91.3         | 91.8         | 90.8         | 59        | 0.00              |
| 27 July    | 1600      | 90.4         | 91.7         | 88.2         | 60        | 0.00              |
| 27 July    | 1700      | 87.4         | 88.7         | 85.8         | 73        | 0.00              |
| 3 August   | 0700      | 82.0         | 84.0         | 79.6         | 88        | 0.00              |
| 3 August   | 0800      | 85.6         | 87.7         | 83.9         | 79        | 0.00              |
| 3 August   | 0900      | 88.8         | 90.5         | 87.2         | 72        | 0.00              |
| 3 August   | 1000      | 91.3         | 92.2         | 90.1         | 66        | 0.00              |
| 3 August   | 1100      | 92.8         | 94.2         | 91.7         | 63        | 0.00              |
| 3 August   | 1200      | 94.4         | 95.0         | 93.6         | 60        | 0.00              |
| 3 August   | 1300      | 95.4         | 96.1         | 94.8         | 59        | 0.00              |
| 3 August   | 1400      | 96.7         | 97.3         | 95.9         | 54        | 0.00              |
| 3 August   | 1500      | 97.1         | 97.6         | 96.6         | 51        | 0.00              |
| 3 August   | 1600      | 96.9         | 97.5         | 96.4         | 50        | 0.00              |
| 3 August   | 1700      | 96.4         | 96.9         | 95.6         | 51        | 0.00              |

## APPENDIX C. SOIL MOISTURE

| Date: 27 July 2006        |            |               |               |
|---------------------------|------------|---------------|---------------|
| Times: 800 and 1500 hours |            |               |               |
| Probe Location:           | Layer, in. | AM Reading, % | PM Reading, % |
| Wet area                  | 0 to 6     | NA            |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Wooded area               | 0 to 6     |               |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Open area                 | 0 to 6     |               |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Calibration lanes         | 0 to 6     | 11.2          | 11.1          |
|                           | 6 to 12    | 26.9          | 26.8          |
|                           | 12 to 24   | 28.3          | 28.2          |
|                           | 24 to 36   | 24.8          | 24.7          |
|                           | 36 to 48   | 28.2          | 28.1          |
| Blind grid/moguls         | 0 to 6     | 12.1          | 12.0          |
|                           | 6 to 12    | 18.5          | 18.2          |
|                           | 12 to 24   | 20.3          | 20.2          |
|                           | 24 to 36   | 22.5          | 22.4          |
|                           | 36 to 48   | 24.2          | 24.2          |

| Date: 3 August 2006       |            |               |               |
|---------------------------|------------|---------------|---------------|
| Times: 900 and 1330 hours |            |               |               |
| Probe Location:           | Layer, in. | AM Reading, % | PM Reading, % |
| Wet area                  | 0 to 6     | NA            |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Wooded area               | 0 to 6     |               |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Open area                 | 0 to 6     |               |               |
|                           | 6 to 12    |               |               |
|                           | 12 to 24   |               |               |
|                           | 24 to 36   |               |               |
|                           | 36 to 48   |               |               |
| Calibration lanes         | 0 to 6     | 9.8           | 9.6           |
|                           | 6 to 12    | 25.5          | 25.3          |
|                           | 12 to 24   | 26.8          | 26.6          |
|                           | 24 to 36   | 23.5          | 23.4          |
|                           | 36 to 48   | 26.6          | 26.5          |
| Blind grid/moguls/mine    | 0 to 6     | 10.8          | 10.7          |
|                           | 6 to 12    | 17.0          | 17.0          |
|                           | 12 to 24   | 18.7          | 18.6          |
|                           | 24 to 36   | 21.2          | 21.1          |
|                           | 36 to 48   | 22.7          | 22.6          |

| Date, 2006 | 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 |
|------------|---------------|-------------------|-------------------|------------------|---------------|-----------------------------------|-------------------------------|--------------|----------------------------|---------|------------------|
| 26 July    | 2             | CALIBRATION LANES | 0740              | 1000             | 140           | INITIAL SET-UP                    |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1000              | 1145             | 105           | DAILY START, STOP                 | SET UP GRID                   | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1300              | 1340             | 40            | DAILY START, STOP                 | SET UP GRID                   | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1340              | 1400             | 20            | COLLECTING DATA                   |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1400              | 1445             | 45            | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHANGE BATTERY                | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1445              | 1540             | 55            | COLLECTING DATA                   |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1540              | 1555             | 15            | CALIBRATION                       |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 26 July    | 2             | CALIBRATION LANES | 1555              | 1625             | 30            | DAILY START, STOP                 | EQUIPMENT BREAKDOWN           | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | MINE GRID         | 0910              | 0935             | 25            | DAILY START, STOP                 | EQUIPMENT SET UP              | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | MINE GRID         | 0935              | 0950             | 15            | CALIBRATION                       |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | MINE GRID         | 0950              | 1010             | 20            | COLLECTING DATA                   |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | BLIND GRID        | 1010              | 1105             | 55            | DAILY START, STOP                 | EQUIPMENT SET UP              | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | BLIND GRID        | 1105              | 1150             | 45            | COLLECTING DATA                   |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | BLIND GRID        | 1150              | 1250             | 60            | BREAK/LUNCH                       |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 27 July    | 2             | BLIND GRID        | 1250              | 1355             | 65            | COLLECTING DATA                   |                               | GPS          | NA                         | LINEAR  | Cloudy, Warm     |
| 3 August   | 1             | BLIND GRID        | 1140              | 1350             | 130           | DEMOBILIZATION                    | DEMOBILIZATION                | GPS          | NA                         | LINEAR  | Cloudy, 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.

## APPENDIX F. ABBREVIATIONS

|       |   |                                                                       |
|-------|---|-----------------------------------------------------------------------|
| APG   | = | Aberdeen Proving Ground                                               |
| ATC   | = | U.S. Army Aberdeen Test Center                                        |
| DMM   | = | discarded military munitions                                          |
| EM    | = | electromagnetic                                                       |
| ERDC  | = | U.S. Army Corps of Engineers Engineer Research and Development Center |
| ESTCP | = | Environmental Security Technology Certification Program               |
| EQT   | = | Army Environmental Quality Technology Program                         |
| GPR   | = | ground penetrating radar                                              |
| GPS   | = | Global Positioning System                                             |
| HEAT  | = | high-explosive antitank                                               |
| JPG   | = | Jefferson Proving Ground                                              |
| MEC   | = | munitions and explosives of concern                                   |
| NA    | = | not available                                                         |
| OE    | = |                                                                       |
| POC   | = | point of contact                                                      |
| QA    | = | quality assurance                                                     |
| QC    | = | quality control                                                       |
| ROC   | = | receiver-operating characteristic                                     |
| RTK   | = | real-time kinematic                                                   |
| SERDP | = | Strategic Environmental Research and Development Program              |
| USAEC | = | U.S. Army Environmental Command                                       |
| UXO   | = | unexploded ordnance                                                   |
| YPG   | = | U.S. Army Yuma Proving Ground                                         |

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