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STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

OPEN FIELD SCORING RECORD NO. 857

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
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TECHNOLOGY TYPE/PLATFORM:
DUAL-SENSOR INSTRUMENT/HAND HELD

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14. ABSTRACT

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 Open Field. 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.

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

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

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

1.2 SCORING OBJECTIVES

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

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

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

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

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

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

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

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

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

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

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

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

1.2.2 Scoring Factors

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

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

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

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm Heat Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

HEAT = high-explosive antitank
JPG = Jefferson Proving Ground

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 System Description (provided by demonstrator)

AETC's dual-sensor instrument consists of an electromagnetic induction (EMI) sensor, a cesium vapor magnetometer, a fluxgate magnetometer, a handheld data acquisition computer, integrated power supply, interconnection cables, and deployment hardware (backpack, mounting pole, etc.). The fluxgate magnetometer records the large, abrupt changes in sensor orientation caused by changes in topography and vegetation conditions, allowing their effects to be removed from the final data set. An ArcSecond laser positioning system, fully integrated with the detection sensors, will provide real-time digital location data during the surveys. A Trimble 5700 Real-Time Kinematic (RTK) Global Positioning System (GPS) will be utilized at the start of the demonstrations to establish on-ground control markers (wooden stakes or equivalent) allowing quicker setup of the ArcSecond equipment during the geophysical surveys.

The EMI component of the instrument is a conventional GEM-3 developed and manufactured by Geophex Ltd. This sensor is a relatively recent version commonly referred to as the "enhanced GEM-3" to differentiate it from older vintages. The GEM-3 is a frequency domain sensor capable of operation at multiple user-selectable frequencies between 30 and 24 kHz. The GEM-3 can be used with 40-, 64-, or 96-cm-diameter coil heads. The 64-cm head will be used for this demonstration to maximize the depth of investigation as well as provide sufficient "real estate" around the coils for mounting of the magnetometer sensor. The 96-cm head would also accomplish these objectives, but it is not suitable for handheld deployment.

The magnetometer selected for the dual-sensor instrument is a Geometrics model G823A. This sensor has the Larmor signal decoupler and counter mounted in the preamp electronics package. Such a configuration negates the requirement for an additional console, thus reducing the complexity of the survey deployment mechanics. The sensor provides total magnetic field readings measured in nanoteslas (nT) at a 10-Hz sample rate in American Standard Code for Information Interchange (ASCII) format via a serial RS232 data connection.

Data positioning for this demonstration will be captured using laser positioning equipment designed by ArcSecond. The ArcSecond system configured for this application is composed of two or more remote beacons and an array of three sensors that are mounted on the structure of the dual-sensor carry assembly. The beacons transmit a timing pulse from two rotating lasers. Upon detection of these lasers, each sensor is provided with a measurement of the vertical and horizontal angle of the sensor position relative to the transmitting beacon. Given precise knowledge of each beacon's position and orientation, these angles are used to triangulate the sensor positions in three dimensions. Once the positions of each of the three positioning sensors in the array are known, the position and orientation of the geophysical sensors can be determined (assuming that the positioning sensor array is fixed rigidly to the geophysical sensor carry assembly).

On-ground control stakes for the demonstration will be established using a Trimble 5700 RTK GPS. The Trimble 5700 consists of a mobile GPS antenna and a base station utilizing a Trimble 5700 receiver. Real-time corrections from the GPS base receiver are broadcast to the roving GPS unit via a radio link using TRIMMARK™ 3 radio modems. This system provides positional updates at a rate of 1 Hz, with a horizontal accuracy of 3 cm.

NAEVA intends to fully map the Standardized Test Site at APG utilizing ATEC's dual-sensor detection system (fig. 1). Mapping at APG will include the calibration lanes, blind grid, and the open field site. All field areas will be surveyed in the prescribed order in a single orientation (e.g., north-south, east-west, etc.). As time permits, NAEVA may elect to remap certain portions or the entire site in a second orientation to provide better data for the discrimination of ordnance items.

Figure 1. NAEVA, dual-sensor instrument/handheld.

2.1.2 Data Processing Description (provided by demonstrator)

The geophysical data will be temporarily stored in the instrument logger during data collection and then downloaded into a laptop computer for on-site review and editing. The first step in evaluating the data will be conversion from raw instrument files into usable database files through the following steps:

Run GEMExport.exe to convert Geophex binary raw data to ASCII 'csv' files. The binary data file *{filename} GEM.gbf* will be split into a file for the GEM-3 data called {*filename*} GEM.csv and a separate file for the MAG data called *{filename} GEM_AUX.csv*.

Import the *{filename} GEM.csv* file into a geosoft database using the GEM.i3 template.

Import the *{filename} GEM_AUX.csv* file into a separate geosoft database (using the GEM_AUX.i3 template).

Edit the raw position data provided by ArcSecond to, if necessary, combine subsets of data into one data file for each sortie search and replace all semicolons with commas.

Use the macro in the reformat_macros_v2.xls to convert the edited position data file into a TBL file. Note that the time base used (dtb_time) is in milliseconds.

Merge the position data in the TBL file into each of the MAG and EM databases.

Using Geosoft's Oasis Montaj software, a track plot of the instrument's ArcSecond 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 are completed, the data will be electronically transferred to a remote site for analysis/target selection.

Geosoft's Oasis Montaj UXO software package will be used 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 all anomalies; selection of targets for intrusive characterization; and 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) and diurnal variations (MAG). The dual EMI/MAG sensor also requires the removal of the EM-induced magnetic signal from the magnetometer data. For most surveys, this signal is removed as part of the removal of long wavelength features. However, surveys conducted in areas where the sensor orientation relative to the earth's field is rapidly changing (usually due to rugged terrain) will require alternate magnetometer data collection procedures.

2.1.3 Data Submission Format

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

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

Overview of 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, during, 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 that 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.

A second location will be established over a buried item of known response, likely within the ground truth test pit. At the start and end of each field day, two lines will be collected bidirectionally across the item along the same survey line. The data will then be reviewed for consistent response and positioning and to determine an appropriate lag correction.

During Data Collection: Upon completion of the original collection of a data set, approximately 5 percent of the line footage for each surveyed area will be recollected as a check of instrument repeatability and positioning. The repeat lines will be saved to separate files and used to create profiles that provide direct comparison with the original data. Each profile will be evaluated for repeatability in both instrument response and data positioning.

Overview of QA:

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

Prior to the start of the demonstration, NAEVA will create a series of idealized control point locations dividing each survey area into approximately 0.5-acre cells. The X, Y point locations will then be loaded into the GPS rover. A two-person crew will use the rover to navigate to each control point location where a temporary survey marker will be placed. The purpose of the control points will be to facilitate quicker setup of the ArcSecond remote beacons. The GPS crew and equipment will be demobilized once all the control points have been marked.

All data will be collected with real-time laser positioning from an antenna mounted directly above the two sensors. Data will be collected at a rate of (approximately) ten readings/second, which equates to more than one reading per foot at a normal walking pace. Positional data will be logged at a rate of one reading/second. Existing control markers will be sufficient to maintain straight line profiling and to achieve full coverage within the calibration lanes and the blind grid. Additional measures will be necessary to maintain straight line profiling and to minimize the occurrence of gaps within the open field and mogul areas. Tape measures will be used in conjunction with the established control points (or control points surveyed in by NAEVA) to create a series of square survey cells to completely cover the area of investigation. 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 color codes painted on the ropes at 0.5-meter intervals facilitate straight line profiling with the instrumentation during data collection. While the ArcSecond positioning system has a listed accuracy of greater than 3 cm, the expected accuracy of resultant target selections is signified by a circle with a 1-foot radius around each target.

2.1.5 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org. The Blind Grid counterpart to this report is Scoring Record No. 842.

2.2 APG SITE INFORMATION

2.2.1 Location

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

2.2.2 Soil Type

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

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

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration grid	Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator to calibrate their equipment.
Blind grid	Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter, or nothing.
Open field	A 4-hectare (10-acre) site containing open areas, dips, ruts, and obstructions that challenge platform systems or handheld detectors. The challenges include a gravel road, wet areas, and trees. The vegetation height varies from 15 to 25 cm.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (14 through 16, 19 through 23, 26 through 30 June and 3 through 7 July 2006)

3.2 AREAS TESTED/NUMBER OF HOURS

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

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration lanes	3.50
Open field	121.16

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2006	Average Temperature, ^{o}F	Total Daily Precipitation, in.
14 Jun	71.77	0.09
15 Jun	76.46	0.00
16 Jun	78.94	0.01
19 Jun	80.11	0.09
20 Jun	79.28	0.01
21 Jun	81.67	0.00
22 Jun	82.70	0.01
23 Jun	81.39	0.20
26 Jun	77.71	2.34
27 Jun	78.04	1.78
28 Jun	81.37	0.78

TABLE 4. (CONT)

Date, 2006	Average Temperature, ^{o}F	Total Daily Precipitation, in.
29 Jun	81.22	0.07
30 Jun	77.35	0.00
03 Jul	84.11	0.00
04 Jul	84.24	0.17
05 Jul	77.61	2.66
06 Jul	72.75	0.52
07 Jul	75.16	0.00

3.3.2 Field Conditions

NAEVA surveyed the open field from the middle of June through the first week of July. The field was wet and muddy throughout the survey. Many areas of standing water were present throughout the survey.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, 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 1 hour and 25 minutes to perform the initial setup and mobilization. There was 43 hours and 55 minutes of daily equipment preparation and end of the day equipment break down lasted 7 hours and 10 minutes.

3.4.2 Calibration

NAEVA spent a total of 3 hours and 30 minutes in the calibration lanes, of which 1 hour and 40 minutes was spent collecting data. NAEVA also calibrated the instrument numerous occasions during the time spent in the open field. Open field calibrations totaled 3 hours and 35 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 5 hours and 55 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. NAEVA spent an additional 7 hours and 50 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. Six hours and 35 minutes was needed to resolve several equipment failures that occurred while surveying the open field. Some of the failures included the PVC handle breaking on the cart three separate occasions and the IPAQ being dropped in water while out in the field; all equipment was replaced. Additionally, the GPS system overheated and a brief cooldown was necessary prior to continuing forward.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

NAEVA spent a total time of 121 hours and 10 minutes in the open field area, 47 hours and 40 minutes of which was spent collecting data.

3.4.5 Demobilization

The NAEVA survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 6 and 7 July 2006. On those days, it took the crew 2 hours and 55 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

NAEVA submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data were also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

NAEVA surveyed the open field in a linear fashion and in different directions. NAEVA set up various size grids depending on their layout of the open site.

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, 4, and 6 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive for the EM sensor(s), MAG sensor(s) and combined EM/MAG picks respectively. Figure 3, 5, and 7 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Because of limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in Figures 4 and 5 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

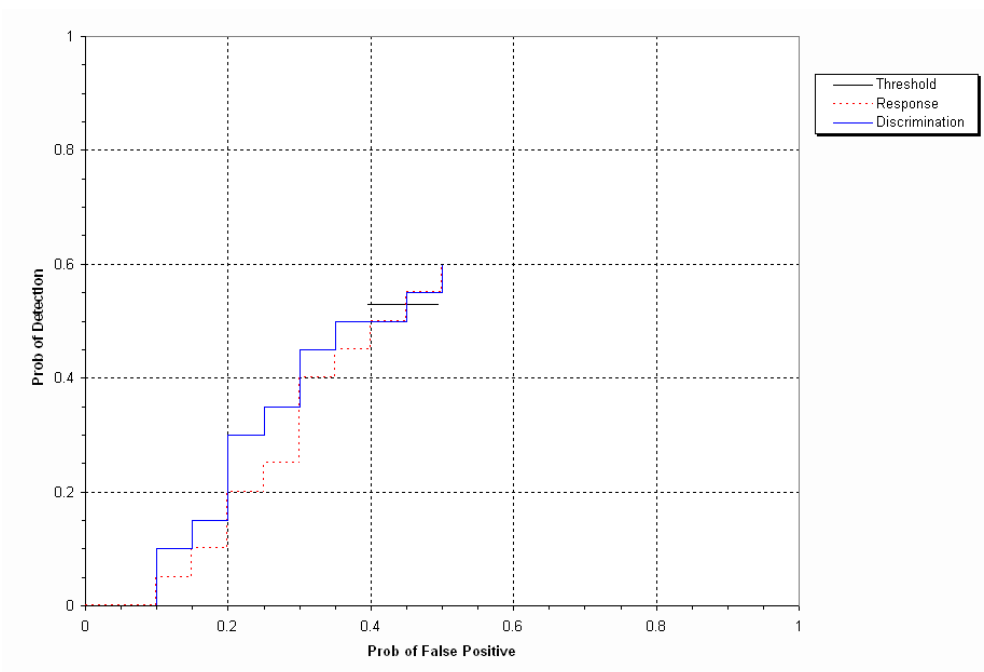

Figure 2. EM Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

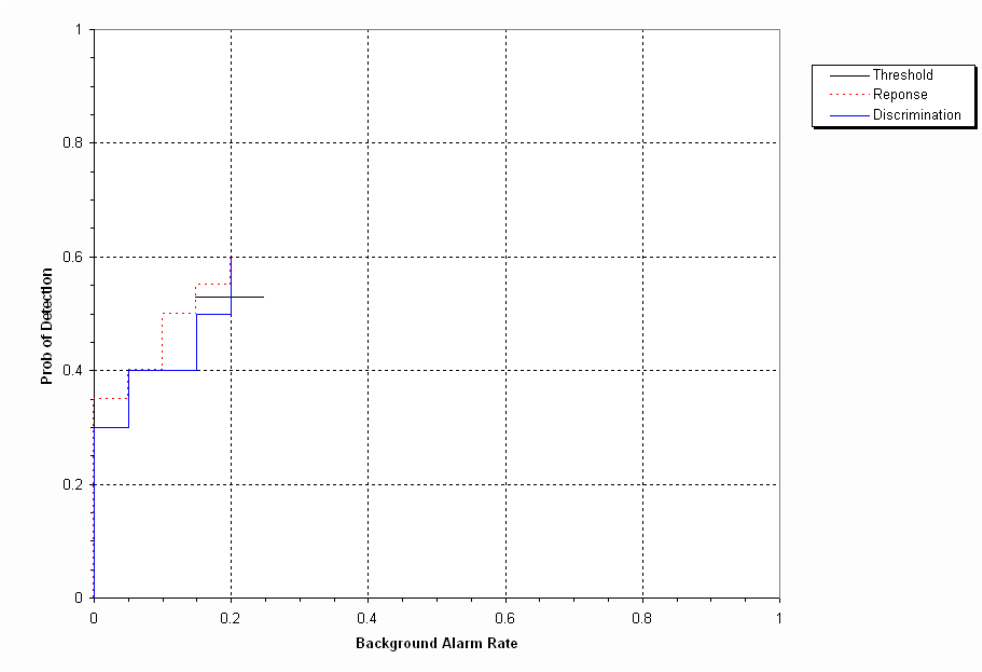

Figure 3. EM Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

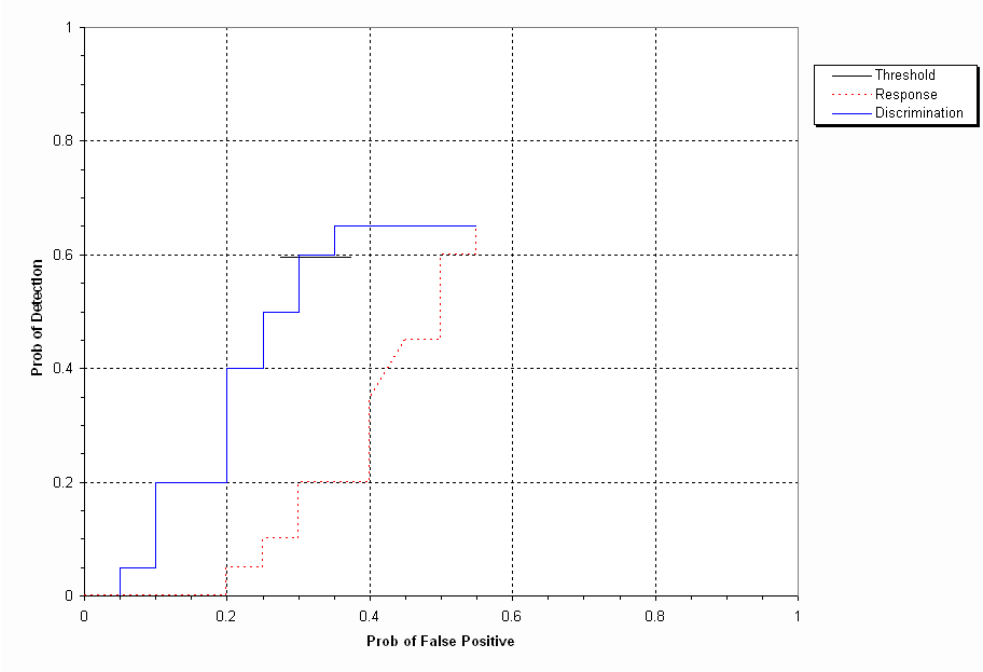

Figure 4. MAG Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

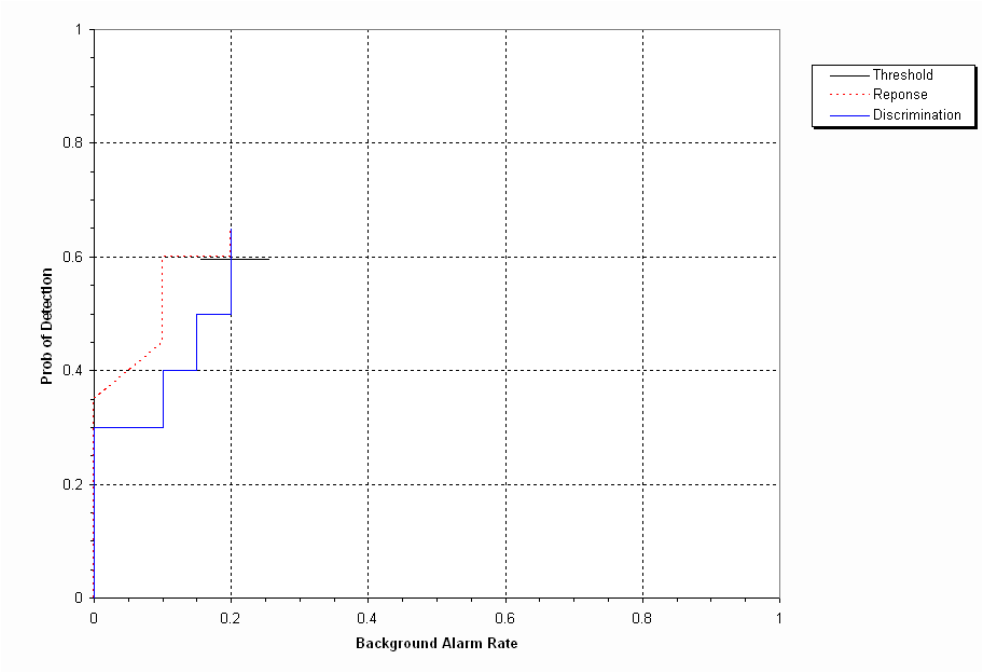

Figure 5. MAG Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

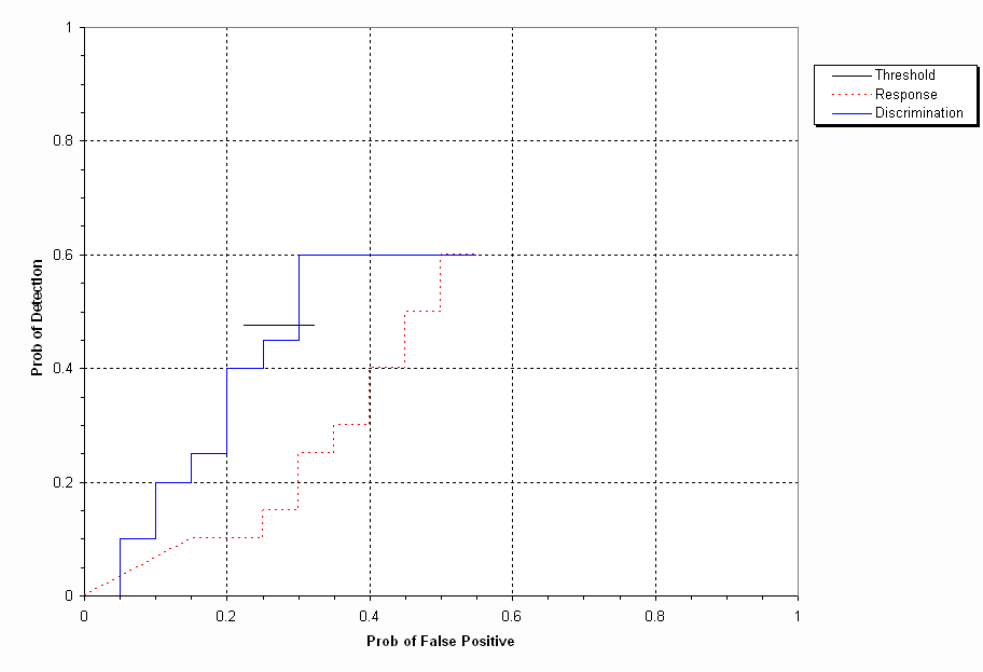

Figure 6. Combined Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

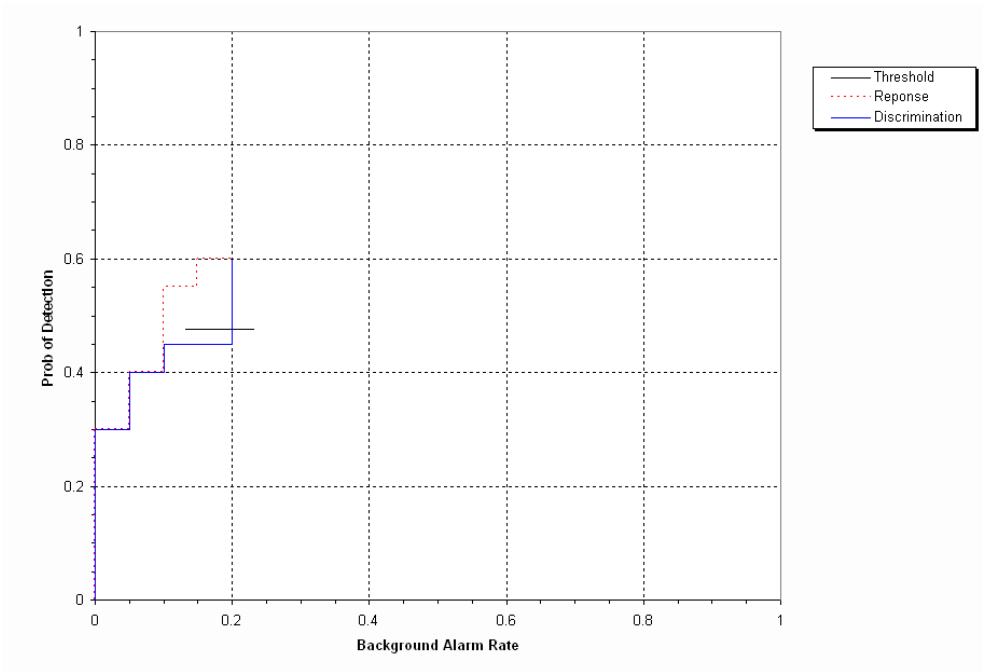

Figure 7. Combined Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8, 10, and 12 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored for the EM sensor(s), MAG sensor(s) and Combined EM/MAG picks respectively. Figure 9, 11, and 13 shows both probabilities plotted against their respective background alarm rate. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Because of limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in Figures 10 and 11 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

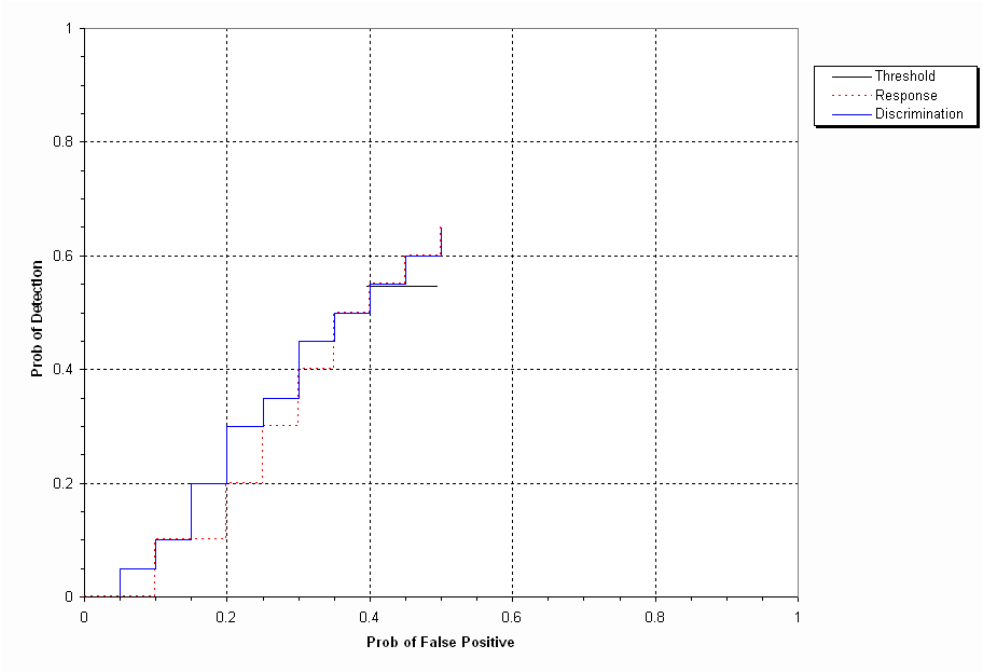

Figure 8. EM Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

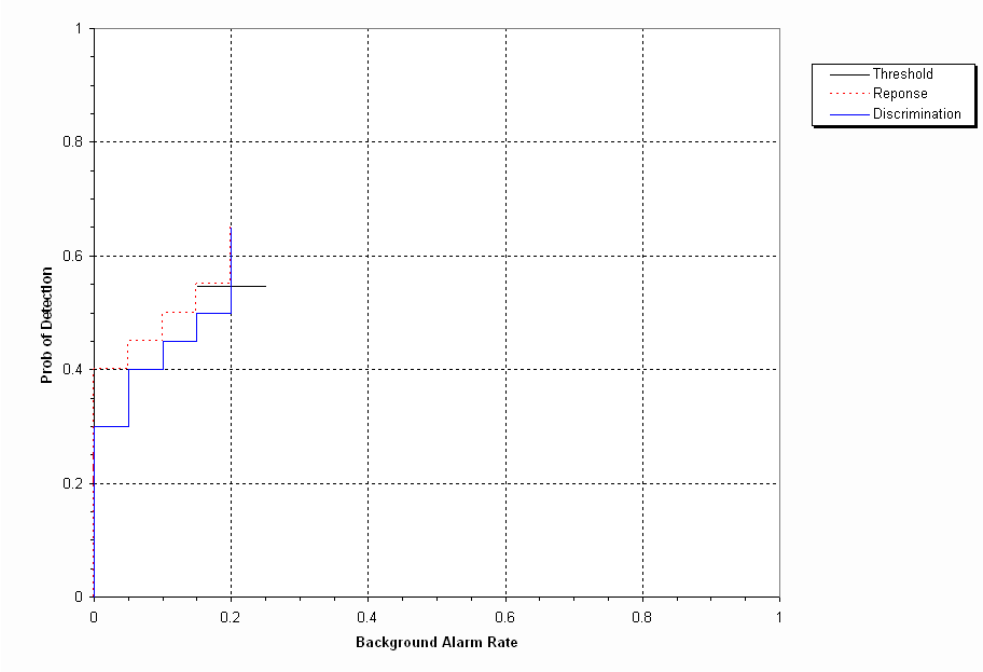

Figure 9. EM Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

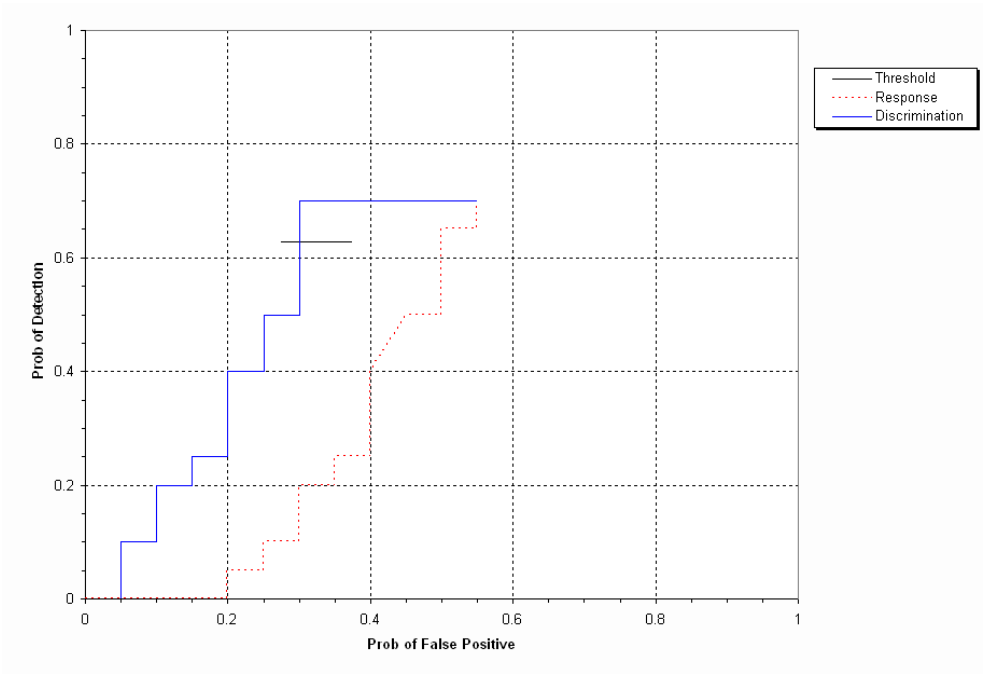

Figure 10. MAG Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

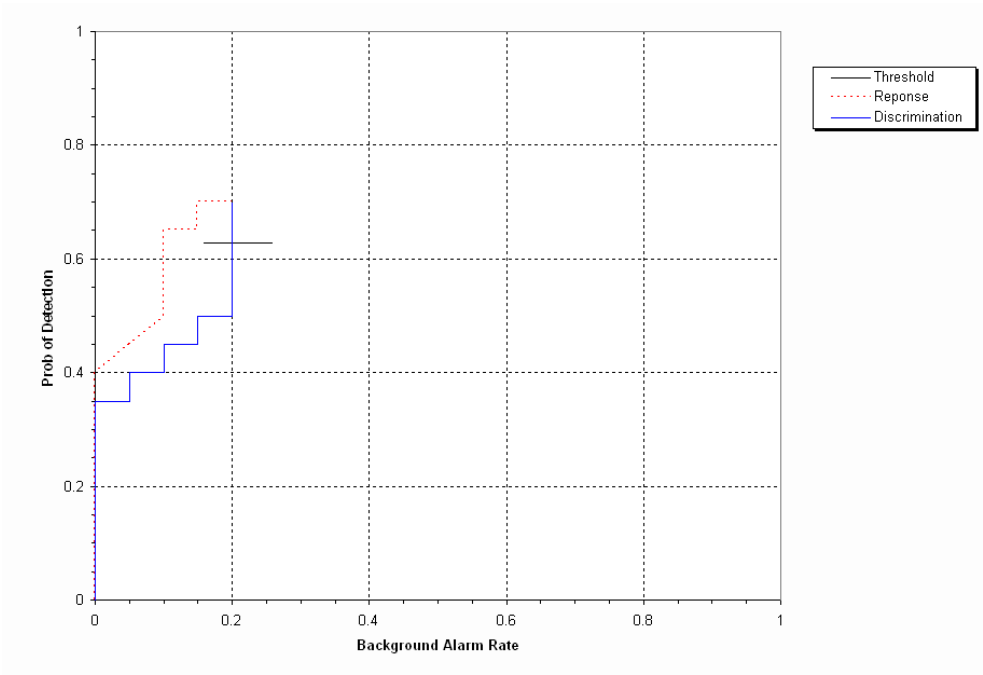

Figure 11. MAG Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

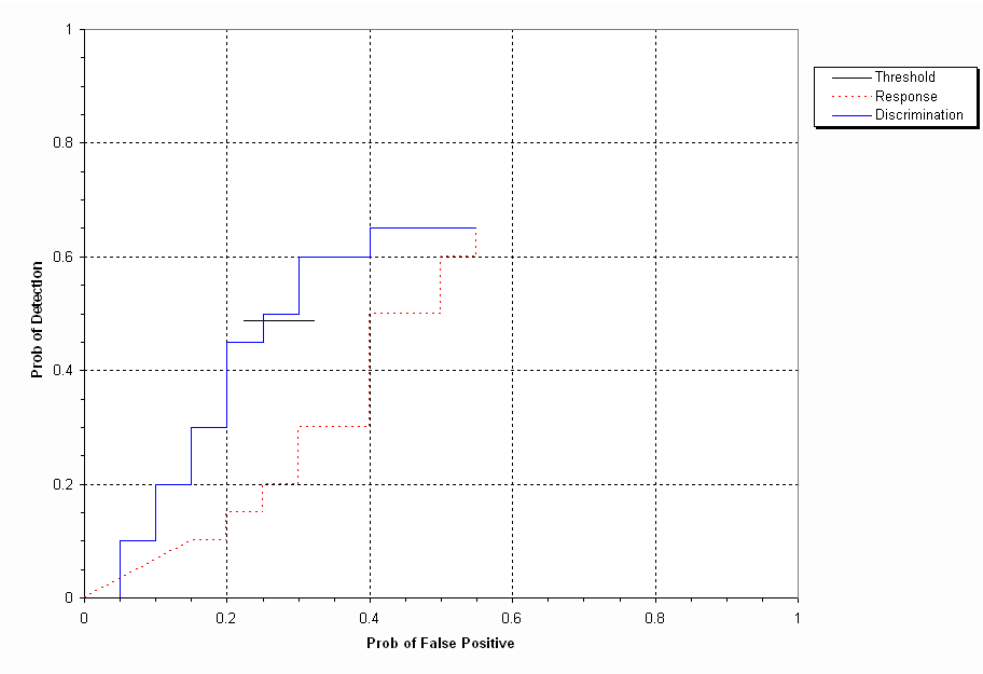

Figure 12. Combined Sensor open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

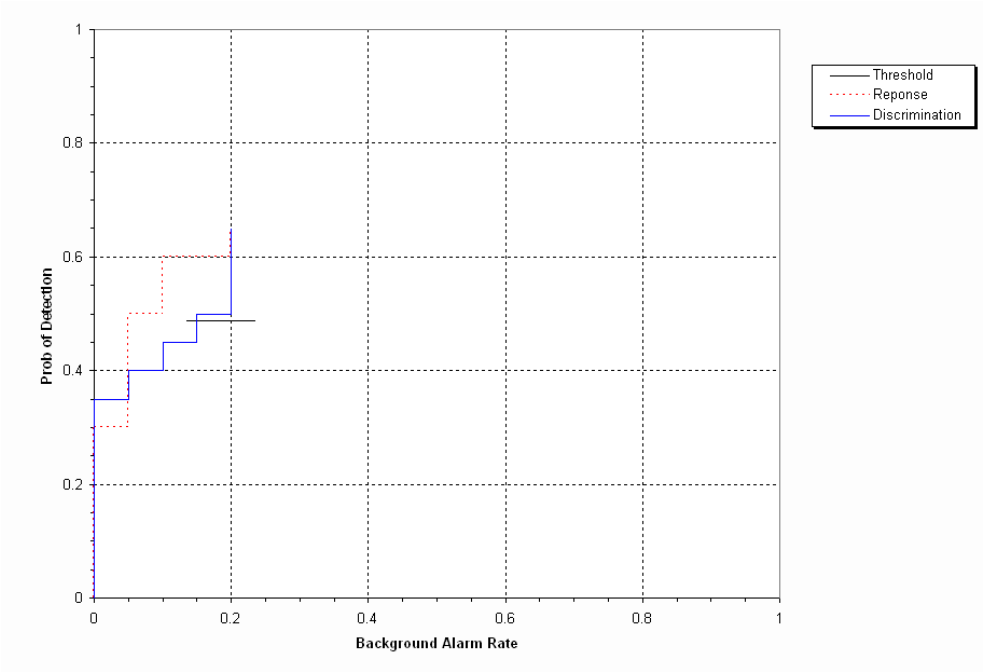

Figure 13. Combined Sensor open field probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the open field test broken out by sensor type, size, depth, and nonstandard ordnance are presented in Table 5a, b, and c (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.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Because of limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the summary presented in Table 5b is split exhibiting results based on the subset of the ground truth that is solely the ferrous anomalies and the full ground truth for comparison purposes.

All other tables presented in this section are based on scoring against the ferrous only ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

TABLE 5a. SUMMARY OF OPEN FIELD RESULTS FOR THE DUAL-SENSOR INSTRUMENT (EM SENSOR)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.60	0.70	00.50	0.50	0.65	0.75	0.70	0.55	0.40
P_d Low 90% Conf	0.59	0.64	0.46	0.45	0.62	0.69	0.68	0.49	0.33
P_d Upper 90% Conf	0.66	0.72	0.57	0.56	0.71	0.83	0.76	0.61	0.51
P_{fp}	0.55	-	-	-	-	-	0.55	0.50	0.55
P_{fp} Low 90% Conf	0.51	-	-	-	-	-	0.52	0.49	0.38
P_{fp} Upper 90% Conf	0.55	-	-	-	-	-	0.58	0.55	0.74
BAR	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.60	0.45	0.50	0.55	0.60	0.60	0.50	0.30
P_d Low 90% Conf	0.50	0.54	0.38	0.43	0.49	0.52	0.57	0.43	0.22
P_d Upper 90% Conf	0.57	0.62	0.49	0.54	0.59	0.68	0.66	0.55	0.39
P_{fp}	0.45	-	-	-	-	-	0.40	0.50	0.45
P_{fp} Low 90% Conf	0.42	-	-	-	-	-	0.37	0.46	0.26
P_{fp} Upper 90% Conf	0.47	-	-	-	-	-	0.43	0.52	0.62
BAR	0.20	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00
Recommended Discrimination Stage Threshold: 218.50

TABLE 5b. SUMMARY OF OPEN FIELD RESULTS FOR THE DUAL-SENSOR INSTRUMENT (MAG SENSOR)

Ferrous Only Ground Truth									
				By Size			By Depth, m		
Metric	Overall	Standard	Nonstandard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.65	0.70	0.55	0.60	0.65	0.80	0.75	0.60	0.45
P_d Low 90% Conf	0.62	0.68	0.47	0.53	0.59	0.71	0.73	0.52	0.35
P_d Upper 90% Conf	0.69	0.76	0.60	0.66	0.69	0.84	0.81	0.65	0.53
P_{fp}	0.55	-	-	-	-	-	0.50	0.60	0.65
P_{fp} Low 90% Conf	0.54	-	-	-	-	-	0.49	0.56	0.43
P_{fp} Upper 90% Conf	0.58	-	-	-	-	-	0.55	0.62	0.79
BAR	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.60	0.70	0.45	0.60	0.60	0.55	0.75	0.55	0.20
P_d Low 90% Conf	0.56	0.63	0.39	0.53	0.56	0.47	0.70	0.48	0.15
P_d Upper 90% Conf	0.63	0.72	0.51	0.66	0.66	0.63	0.79	0.61	0.30
P_{fp}	0.35	-	-	-	-	-	0.35	0.30	0.25
P_{fp} Low 90% Conf	0.31	-	-	-	-	-	0.32	0.28	0.11
P_{fp} Upper 90% Conf	0.35	-	-	-	-	-	0.38	0.33	0.44
BAR	0.20	-	-	-	-	-	-	-	-
Full Ground Truth									
				By Size			By Depth, m		
Metric	Overall	Standard	Nonstandard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.60	0.65	0.50	0.50	0.65	0.80	0.70	0.55	0.45
P_d Low 90% Conf	0.57	0.62	0.46	0.43	0.59	0.71	0.65	0.47	0.35
P_d Upper 90% Conf	0.64	0.70	0.57	0.54	0.69	0.84	0.74	0.60	0.52
P_{fp}	0.55	-	-	-	-	-	0.50	0.60	0.65
P_{fp} Low 90% Conf	0.54	-	-	-	-	-	0.49	0.56	0.43
P_{fp} Upper 90% Conf	0.58	-	-	-	-	-	0.55	0.62	0.79
BAR	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.60	0.45	0.50	0.60	0.55	0.65	0.50	0.20
P_d Low 90% Conf	0.52	0.57	0.38	0.43	0.56	0.47	0.63	0.44	0.15
P_d Upper 90% Conf	0.59	0.65	0.49	0.54	0.66	0.63	0.71	0.56	0.30
P_{fp}	0.35	-	-	-	-	-	0.35	0.30	0.25
P_{fp} Low 90% Conf	0.31	-	-	-	-	-	0.32	0.28	0.11
P_{fp} Upper 90% Conf	0.35	-	-	-	-	-	0.38	0.33	0.44
BAR	0.20	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00
Recommended Discrimination Stage Threshold: 290.00

TABLE 5c. SUMMARY OF OPEN FIELD RESULTS FOR THE DUAL-SENSOR INSTRUMENT (COMBINED EM/MAG RESULTS)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.60	0.70	0.50	0.50	0.65	0.75	0.70	0.55	0.40
P_d Low 90% Conf	0.59	0.64	0.46	0.43	0.62	0.69	0.68	0.48	0.33
P_d Upper 90% Conf	0.65	0.72	0.57	0.55	0.72	0.83	0.76	0.61	0.51
P_{fp}	0.55	-	-	-	-	-	0.55	0.55	0.55
P_{fp} Low 90% Conf	0.53	-	-	-	-	-	0.51	0.54	0.38
P_{fp} Upper 90% Conf	0.58	-	-	-	-	-	0.57	0.60	0.74
BAR	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.50	0.55	0.40	0.45	0.50	0.45	0.60	0.45	0.10
P_d Low 90% Conf	0.44	0.49	0.32	0.39	0.47	0.36	0.54	0.39	0.07
P_d Upper 90% Conf	0.51	0.57	0.43	0.50	0.57	0.52	0.63	0.52	0.19
P_{fp}	0.25	-	-	-	-	-	0.25	0.30	0.20
P_{fp} Low 90% Conf	0.25	-	-	-	-	-	0.25	0.25	0.07
P_{fp} Upper 90% Conf	0.29	-	-	-	-	-	0.30	0.31	0.37
BAR	0.20	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00
Recommended Discrimination Stage Threshold: 484.50

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

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION (All results based on combined EM/MAG data set)

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

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.77	0.51	0.14
With No Loss of P_d	1.00	0.03	0.00

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 8). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket." A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	22.7
Medium	7.9
Large	31.3
Overall	17.1

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the blind grid, only depth errors are calculated, since (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)

	Mean	Standard Deviation
Northing	-0.01	0.14
Easting	-0.01	0.15
Depth	0.01	0.32

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SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor," the second person was designated "data analyst," and the third and following personnel were considered "field support." Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the calibration lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	1.42	134.90
Data analyst	1	57.00	1.42	80.94
Field support	0	28.50	0.00	0.00
Subtotal				**$215.84**
Calibration				
Supervisor	1	$95.00	7.08	672.60
Data analyst	1	57.00	7.08	403.56
Field support	0	28.50	0.00	0.00
Subtotal				**$1076.16**
Site Survey				
Supervisor	1	$95.00	121.16	11510.20
Data analyst	1	57.00	121.16	6906.12
Field support	0	28.50	0.00	0.00
Subtotal				**$18416.32**

See notes at end of table.

TABLE 9 (CONT)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	2.92	277.40
Data analyst	1	57.00	2.92	166.44
Field support	0	28.50	0.00	0.00
Subtotal				$443.84
Total				**$20152.16**

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 (BASED ON COMBINED EM/MAG DATA SETS)

6.1 SUMMARY OF RESULTS FROM BLIND GRID DEMONSTRATION

Table 10 shows the results from the blind grid survey conducted prior to surveying the open field during the same site visit in September of 2006. Because the system utilizes magnetometer type sensors, all results presented in the following section have been based on performance scoring against the ferrous only ground truth anomalies. For more details on the blind grid survey results reference section 2.1.6.

TABLE 10. SUMMARY OF BLIND GRID RESULTS FOR THE DUAL-SENSOR INSTRUMENT

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.75	0.80	0.75	0.70	0.80	0.90	0.95	0.65	0.65
P_d Low 90% Conf	0.70	0.69	0.62	0.59	0.70	0.66	0.86	0.54	0.43
P_d Upper 90% Conf	0.83	0.86	0.84	0.79	0.90	0.99	0.98	0.76	0.79
P_{fp}	0.85	-	-	-	-	-	0.90	0.80	0.65
P_{fp} Low 90% Conf	0.77	-	-	-	-	-	0.79	0.71	0.33
P_{fp} Upper 90% Conf	0.88	-	-	-	-	-	0.94	0.87	0.91
P_{ba}	0.10	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.70	0.75	0.70	0.65	0.75	0.80	0.90	0.55	0.55
P_d Low 90% Conf	0.64	0.63	0.56	0.57	0.60	0.55	0.82	0.45	0.38
P_d Upper 90% Conf	0.77	0.81	0.79	0.77	0.83	0.95	0.97	0.69	0.74
P_{fp}	0.60	-	-	-	-	-	0.70	0.55	0.50
P_{fp} Low 90% Conf	0.55	-	-	-	-	-	0.61	0.46	0.20
P_{fp} Upper 90% Conf	0.69	-	-	-	-	-	0.81	0.66	0.80
P_{ba}	0.10	-	-	-	-	-	-	-	-

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. The ROC curves in this section are a sole reflection of the ferrous only survey.

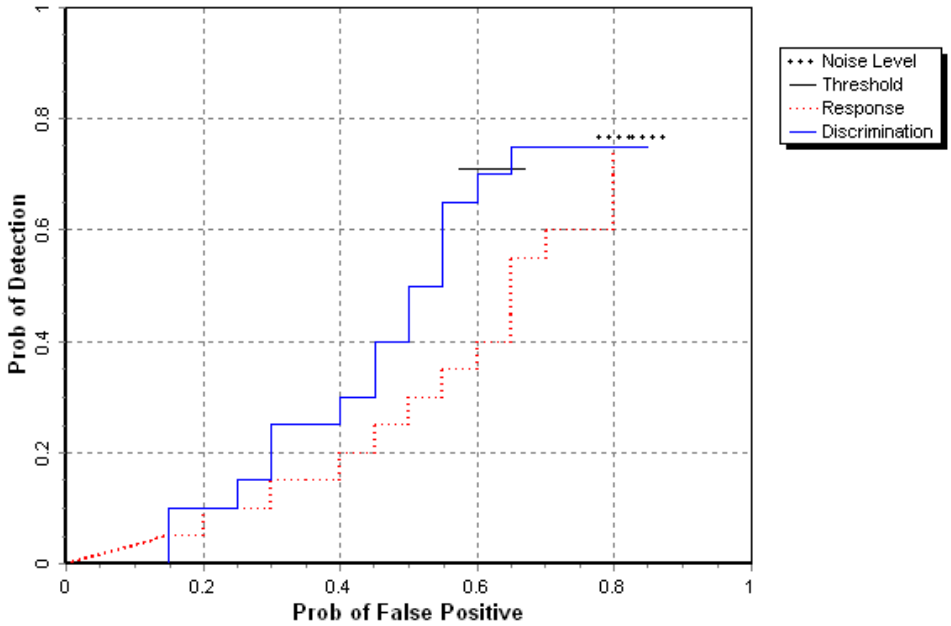

Figure 6. Dual-Sensor Instrument P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

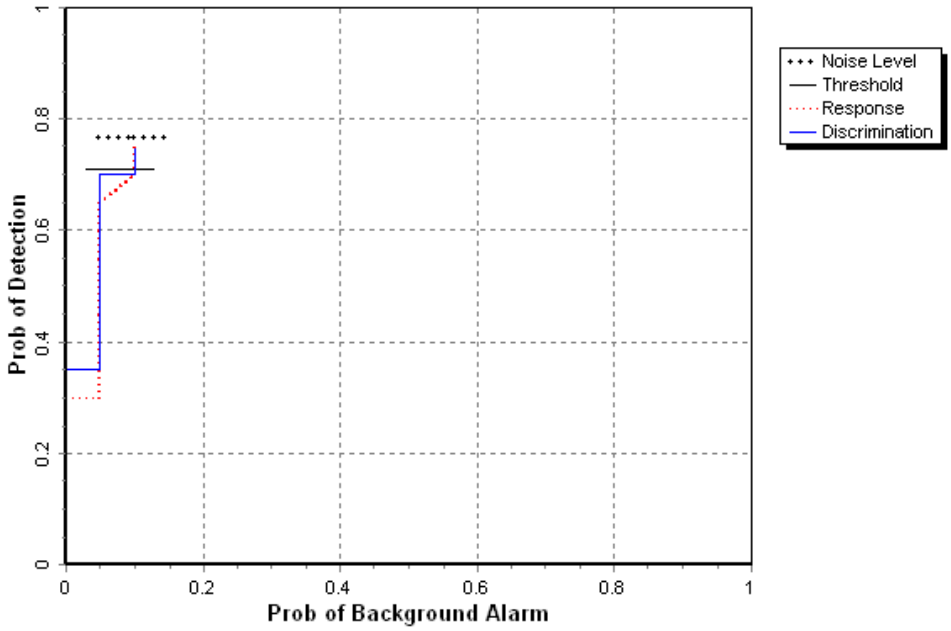

Figure 7. Dual-Sensor Instrument P_d^{disc} versus the respective P_{fp} over all ordnance categories combined.

6.3 COMPARISON OF ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8 shows the P_d^{res} versus the respective probability of P_{fp} over ordnance larger than 20 mm. Figure 9 shows P_d^{disc} versus the respective P_{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.

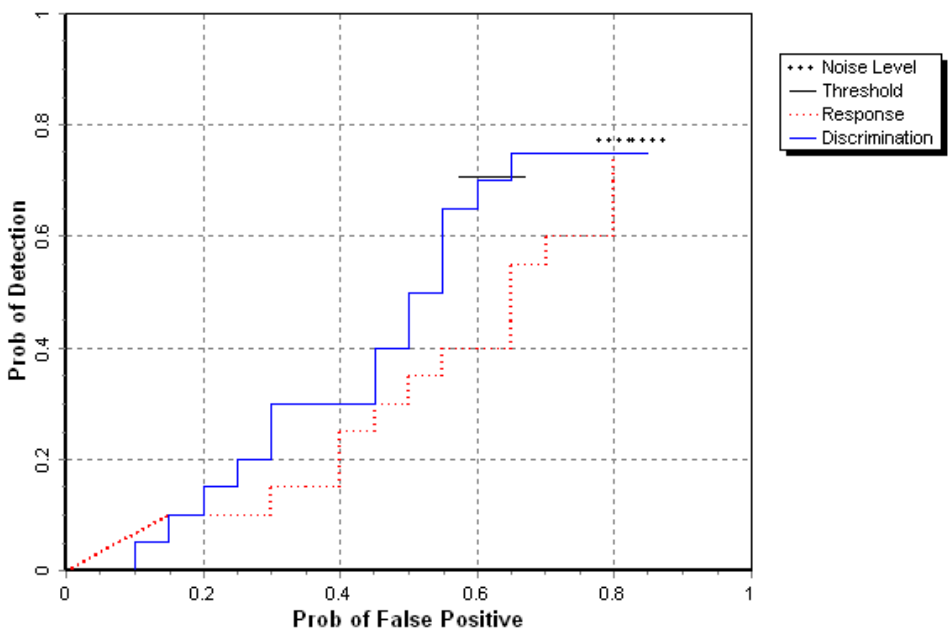

Figure 8. Dual-Sensor Instrument P_d^{res} versus the respective P_{fp} for ordnance larger than 20 mm.

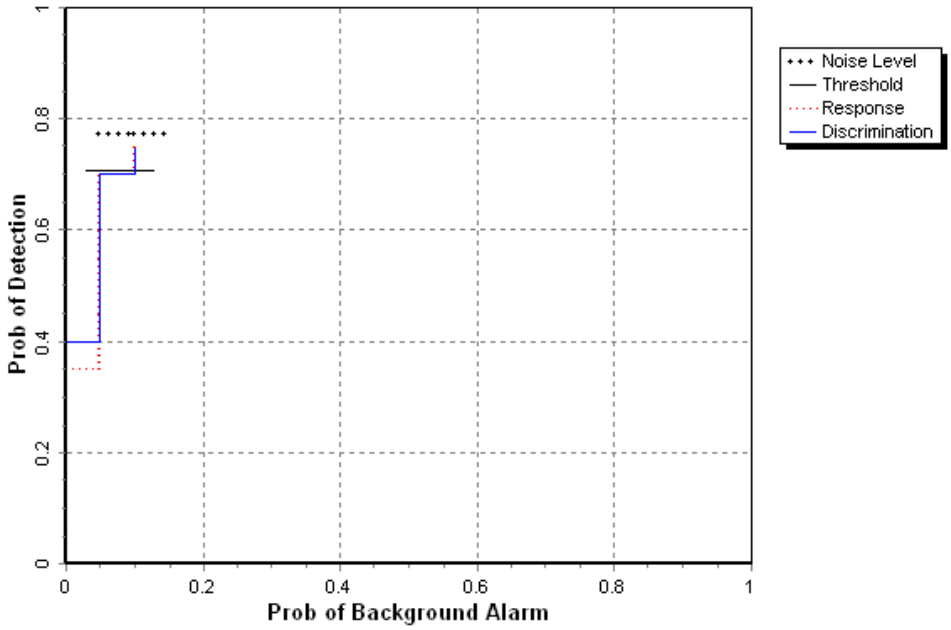

Figure 9. Dual-Sensor Instrument P_d^{disc} versus the respective P_{fp} for ordnance larger than 20 mm.

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 are located in Appendix A.

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

Metric	Small	Medium	Large	Overall
P_d^{res}	Significant	Not Significant	Not Significant	Significant
P_d^{disc}	Significant	Significant	Significant	Significant
P_{fp}^{res}	Not Significant	Not Significant	Not Significant	Significant
P_{fp}^{disc}	-	-	-	Significant
Efficiency	-			Significant
Rejection rate	-	-	-	Significant

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SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g. TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/ (No. of emplaced ordnance in the test site).

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

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

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

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

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

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

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to nonordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

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

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

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

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

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

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

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

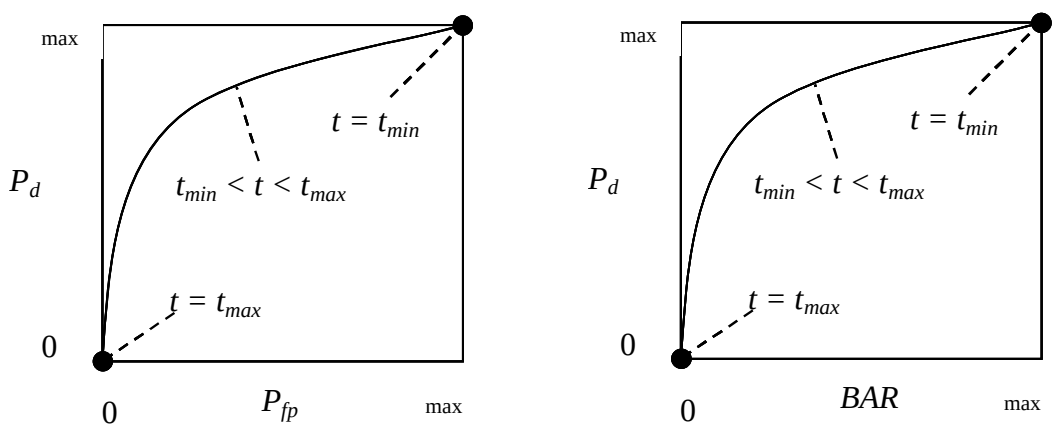

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})]$).

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind grid	Open field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

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

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

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

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APPENDIX B. DAILY WEATHER LOGS

Time, EST	Average Temperature, °F	Total Precipitation, in.
14 June 2006		
0700	65.9	0.00
0800	70.1	0.00
0900	71.6	0.00
1000	72.6	0.00
1100	72.6	0.00
1200	73.7	0.00
1300	74.1	0.00
1400	73.1	0.00
1500	72.7	0.00
1600	71.9	0.00
1700	71.2	0.00
5 July 2006		
0700	74.6	0.00
0800	76.0	0.00
0900	78.2	0.00
1000	80.0	0.00
1100	81.7	0.00
1200	80.6	0.05
1300	77.2	0.01
1400	76.2	0.66
1500	75.4	0.01
1600	77.0	0.00
1700	76.8	0.00
6 July 2006		
0700	69.1	0.00
0800	68.3	0.00
0900	68.6	0.00
1000	69.3	0.00
1100	69.8	0.00
1200	72.0	0.00
1300	73.3	0.00
1400	75.5	0.00
1500	77.3	0.00
1600	78.1	0.00
1700	78.9	0.00

Time, EST	Average Temperature, °F	Total Precipitation, in.
7 July 2006		
0700	66.8	0.00
0800	69.8	0.00
0900	71.6	0.00
1000	73.4	0.00
1100	74.8	0.00
1200	76.1	0.00
1300	77.8	0.00
1400	78.7	0.00
1500	78.5	0.00
1600	80.0	0.00
1700	79.3	0.00

APPENDIX C. SOIL MOISTURE

Date: 5 July 2006			
Times: 1000 and 1230 hours			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	46.3	46.3
	6 to 12	65.3	65.3
	12 to 24	46.8	46.8
	24 to 36	56.1	56.1
	36 to 48	63.0	63.0
Wooded area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open area	0 to 6	18.0	18.0
	6 to 12	20.3	20.3
	12 to 24	19.1	19.1
	24 to 36	24.1	24.1
	36 to 48	27.1	27.1
Calibration lanes	0 to 6	11.2	11.1
	6 to 12	31.3	31.2
	12 to 24	33.2	33.1
	24 to 36	36.7	36.6
	36 to 48	37.2	37.1
Blind grid/moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date: 6 July 2006			
Times: 1000 hours			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	46.8	46.9
	6 to 12	65.3	65.4
	12 to 24	47.3	47.7
	24 to 36	56.8	56.9
	36 to 48	63.7	63.8
Wooded area	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Open area	0 to 6	18.7	18.8
	6 to 12	20.5	20.6
	12 to 24	19.4	19.3
	24 to 36	24.3	24.5
	36 to 48	27.3	27.6
Calibration lanes	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA
Blind grid/moguls	0 to 6	NA	NA
	6 to 12	NA	NA
	12 to 24	NA	NA
	24 to 36	NA	NA
	36 to 48	NA	NA

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
14 June	4	CALIBRATION LANES	0740	0905	85	INITIAL SETUP		GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	4	CALIBRATION LANES	0905	0925	20	CALIBRATION		GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	4	CALIBRATION LANES	0925	1010	45	COLLECTING DATA		GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	4	CALIBRATION LANES	1010	1045	35	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	4	CALIBRATION LANES	1045	1100	15	COLLECTING DATA	1.5-FOOT LINE SPACING	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	4	CALIBRATION LANES	1100	1155	55	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK/ DOWNLOAD DATA	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	BLIND TEST GRID	1155	1215	20	COLLECTING DATA		GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	BLIND TEST GRID	1215	1320	65	DOWNTIME DUE TO EQUIPMENT FAILURE	GPS FAILURE, NO SATELLITES	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	BLIND TEST GRID	1320	1450	90	COLLECTING DATA		GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	BLIND TEST GRID	1450	1505	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	OPEN FIELD	1505	1610	65	DAILY START, STOP	SET UP GRIDS OPEN FIELD 100X150-FOOT GRID	GPS	LINEAR	CLOUDY, WARM	MUDDY
14 June	2	OPEN FIELD	1610	1645	35	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, WARM	MUDDY
15 June	2	OPEN FIELD	0740	0900	80	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	0900	0915	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	0915	1020	65	DAILY START, STOP	SET UP GRID 100X150 FEET	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1020	1115	55	COLLECTING DATA	1.5-FOOT LINE SPACING	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1115	1125	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1125	1230	65	DAILY START, STOP	SET UP GRID 100X200 FEET	GPS	LINEAR	SUNNY, WARM	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
15 June	2	OPEN FIELD	1230	1310	40	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1310	1415	65	DOWNTIME DUE TO EQUIPMENT FAILURE	BROKEN PVC HANDLE ON CART, REPLACED	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1415	1440	25	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1440	1450	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1450	1625	95	DAILY START, STOP	SET UP GRID	GPS	LINEAR	SUNNY, WARM	MUDDY
15 June	2	OPEN FIELD	1625	1705	40	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	0740	0900	80	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	0900	0920	20	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	0920	1035	75	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1035	1100	25	BREAK/LUNCH		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1100	1120	20	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1120	1130	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1130	1210	40	DAILY START, STOP		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1210	1305	55	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1305	1410	65	DAILY START, STOP		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1410	1435	25	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1435	1510	35	DOWNTIME DUE TO EQUIPMENT FAILURE	BROKEN PVC HANDLE ON CART, REPLACED	GPS	LINEAR	SUNNY, WARM	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
16 June	2	OPEN FIELD	1510	1625	75	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
16 June	2	OPEN FIELD	1625	1655	30	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	0805	0910	65	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	0910	0925	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	0925	1055	90	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1055	1225	90	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1225	1310	45	BREAK/LUNCH		GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1310	1350	40	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1350	1445	55	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1445	1500	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1500	1540	40	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1540	1605	25	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
19 June	2	OPEN FIELD	1605	1620	15	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
20 June	2	OPEN FIELD	0740	0900	80	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	0900	0910	10	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	0910	1035	85	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1035	1100	25	BREAK/LUNCH		GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1100	1235	95	COLLECTING DATA	100X200-FOOT GRID, 1.5-FOOT LINE SPACING	GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1235	1300	25	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY, RAIN	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
20 June	2	OPEN FIELD	1300	1325	25	BREAK/LUNCH	LUNCH	GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1325	1430	65	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1430	1555	85	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
20 June	2	OPEN FIELD	1555	1645	50	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, RAIN	MUDDY
21 June	2	OPEN FIELD	0745	0835	50	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	0835	0850	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	0850	0945	55	COLLECTING DATA	100X200-FOOT GRID, 1.5-FOOT LINE SPACING	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	0945	1050	65	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1050	1155	65	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1155	1205	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1205	1230	25	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1230	1325	55	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1325	1420	55	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1420	1605	105	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1605	1625	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
21 June	2	OPEN FIELD	1625	1645	20	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
22 June	2	OPEN FIELD	0740	0825	45	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	0825	0905	40	WEATHER ISSUE	LIGHTNING ADVISORY	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	0905	0955	50	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
22 June	2	OPEN FIELD	0955	1005	10	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1005	1030	25	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1030	1155	85	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1155	1240	45	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1240	1310	30	BREAK/LUNCH	LUNCH	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1310	1355	45	DOWNTIME DUE TO EQUIPMENT FAILURE	GPS SYSTEM OVERHEATED	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1355	1505	70	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1505	1525	20	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1525	1635	70	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1635	1650	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	CLOUDY, RAIN	MUDDY
22 June	2	OPEN FIELD	1650	1710	20	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, RAIN	MUDDY
23 June	2	OPEN FIELD	0745	0905	80	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	0905	0920	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	0920	1045	85	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1045	1140	55	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1140	1205	25	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1205	1245	40	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1245	1315	30	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1315	1335	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	SUNNY, WARM	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
23 June	2	OPEN FIELD	1335	1505	90	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
23 June	2	OPEN FIELD	1505	1535	30	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
26 June	2	OPEN FIELD	0810	0955	105	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	0955	1005	10	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	1005	1120	75	DOWNTIME DUE TO EQUIPMENT FAILURE	GPS FAILURE, NEEDED TO CHANGE BATTERY, CHANGED	GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	1120	1150	30	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	1150	1315	85	WEATHER ISSUE	LIGHTNING ADVISORY	GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	1315	1600	165	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
26 June	2	OPEN FIELD	1600	1625	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	0840	955	75	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	0955	1010	15	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1010	1100	50	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1100	1110	10	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1110	1135	25	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1135	1150	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1150	1230	40	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1230	1240	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DATA CHECK/ DOWNLOAD DATA	GPS	LINEAR	CLOUDY, RAIN	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
27 June	2	OPEN FIELD	1240	1605	205	DOWNTIME DUE TO EQUIPMENT FAILURE	iPAQ GOT WET, REPLACED	GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1605	1620	15	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
27 June	2	OPEN FIELD	1620	1645	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, RAIN	MUDDY
28 June	2	OPEN FIELD	0750	0845	55	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	0845	0855	10	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	0855	1200	185	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	1200	1305	65	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	1305	1340	35	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	1340	1455	75	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	1455	1550	55	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
28 June	2	OPEN FIELD	1550	1615	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	0750	0905	75	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	0905	0920	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	0920	1015	55	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1015	1025	10	BREAK/LUNCH		GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1025	1300	155	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1300	1320	20	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1320	1405	45	DOWNTIME DUE TO EQUIPMENT FAILURE	BROKEN PVC HANDLE ON CART, REPLACED	GPS	LINEAR	SUNNY, WARM	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
29 June	2	OPEN FIELD	1405	1535	90	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1535	1550	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
29 June	2	OPEN FIELD	1550	1615	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	0745	1040	175	DAILY START, STOP	EQUIPMENT/ GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1040	1055	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1055	1245	110	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1245	1305	20	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1305	1320	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1320	1455	95	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1455	1505	10	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1505	1515	10	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1515	1530	15	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY, WARM	MUDDY
30 June	2	OPEN FIELD	1530	1550	20	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	0755	0900	65	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	0900	0915	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	0915	1105	110	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	1105	1210	65	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	1210	1320	70	DAILY START, STOP		GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	1320	1400	40	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	CHANGE BATTERY	GPS	LINEAR	SUNNY, WARM	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
3 July	2	OPEN FIELD	1400	1445	45	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
3 July	2	OPEN FIELD	1445	1505	20	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0750	0815	25	DAILY START, STOP	EQUIPMENT SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0815	0830	15	CALIBRATION		GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0830	0905	35	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0905	0910	5	DAILY START, STOP	GRID SETUP	GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0910	0930	20	COLLECTING DATA		GPS	LINEAR	SUNNY, WARM	MUDDY
4 July	2	OPEN FIELD	0930	0955	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	SUNNY, WARM	MUDDY
5 July	2	OPEN FIELD	0750	0950	120	DAILY START, STOP	EQUIPMENT/ GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
5 July	2	OPEN FIELD	0950	1000	10	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
5 July	2	CALIBRATION LANES	1000	1040	40	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
5 July	2	OPEN FIELD	1040	1215	95	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
5 July	2	OPEN FIELD	1215	1240	25	BREAK/LUNCH	LUNCH	GPS	LINEAR	CLOUDY, RAIN	MUDDY
5 July	2	OPEN FIELD	1240	1305	25	DAILY START, STOP	BREAKDOWN	GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	0745	1010	145	DAILY START, STOP	EQUIPMENT/ GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	1010	1020	10	CALIBRATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	1020	1305	165	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	1305	1340	35	BREAK/LUNCH		GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	1340	1350	10	DAILY START, STOP	GRID SETUP	GPS	LINEAR	CLOUDY, RAIN	MUDDY

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

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
6 July	2	OPEN FIELD	1350	1415	25	COLLECTING DATA		GPS	LINEAR	CLOUDY, RAIN	MUDDY
6 July	2	OPEN FIELD	1415	1555	100	DEMOBILIZATION		GPS	LINEAR	CLOUDY, RAIN	MUDDY
7 July	2	OPEN FIELD	0815	0930	75	DEMOBILIZATION		GPS	LINEAR	CLOUDY, WARM	MUDDY

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

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

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APPENDIX F. ABBREVIATIONS

APG	=	U.S. Army Aberdeen Proving Ground
ASCII	=	American Standard Code for Information Interchange
ATC	=	U.S. Army Aberdeen Test Center
DMM	=	discarded military munitions
EM	=	electromagnetic
EMI	=	electromagnetic induction
EQT	=	Army Environmental Quality Technology Program
ERDC	=	U.S. Army Corps of Engineers Engineer Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
GPS	=	Global Positioning System
HEAT	=	high-explosive antitank
JPG	=	Jefferson Proving Ground
MEC	=	munitions and explosives of concern
POC	=	point of contact
PVC	=	polyvinyl chloride
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real-time kinematic
SERDP	=	Strategic Environmental Research and Development Program
UXO	=	unexploded ordnance
USAEC	=	U.S. Army Environmental Command
YPG	=	U.S. Army Yuma Proving Ground

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