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DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9216

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

OPEN FIELD SCORING RECORD NO. 770

SITE LOCATION:
U.S. ARMY YUMA PROVING GROUND

DEMONSTRATOR:
FOERSTER INSTRUMENTS INC.
140 INDUSTRY DRIVE
RIDC PARK WEST
PITTSBURG, PA 15275-1028

TECHNOLOGY TYPE/PLATFORM:
MAGNETOMETER FEREX DLG GPS/SLING

PREPARED BY:
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JULY 2006

Prepared for:
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14. ABSTRACT
This scoring record documents the efforts of Foerster Instruments, Inc. to detect and discriminate inert unexploded ordnance (UXO) utilizing the YPG Standardized UXO Technology Demonstration Site open field. Scoring Records have been coordinated by Mike Karwatka and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include, the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center.

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

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

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (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

JPG = Jefferson Proving Ground
HEAT = High explosive antitank

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 System Description (provided by demonstrator)

a. Foerster proposes fluxgate vertical gradient magnetic sensor technology coupled with Differential Global Positioning System (DGPS) positioning methods, specifically, the FOERSTER FEREX ® 4.032 geophysical sensor (fig. 1), the Leica 1200 series DGPS technology, and the Trimble 5700 DGPS technology. DGPS positioning is proposed for the survey at YPG.

Figure 1. Demonstrator's system, Magnetometer FEREX DLG GPS/sling.

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

c. The eight linear measurements range from 0 to 3 nanotesla (nT) to 0 to1000 nT and one logarithmic range. The unit displays a 0.3 nT resolution and may use up to four separate detection probes.

d. The FEREX 4.032 can be used in the data logger versions with the FEREX-DATALINE® software for computer assisted cartography and localization FEREX-DATALINE® 4.800 software is the analysis software that runs under Windows for interactive, graphical evaluation of measurements to calculate coordinates and positioning as well as size and depth of suspected ferromagnetic objects. DATALINE enables exact scaled reproduction of recorded and measured data by means of color-coded magnetic field value charts. ISO lines or 3D presentations can be displayed to additionally optimize the presentation of measurements. Data exports are possible with a selectable delimiter as a file for further editing or evaluation in other application programs.

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

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

g. Due to the unique project objectives, which include the necessity to accurately locate the geophysical sensor in "open" terrain (moguls, smooth surfaces, boulder fields, etc.) and partially obstructed areas (e.g., Saguaro cactus at YPG), Foerster intends to use both DGPS and fiducial/odometer modes of positioning if necessary. DGPS is the preferred positioning system for use at YPG due to the lack of tall, dense vegetation that could block the GPS satellite information. A dual frequency base station unit is deployed at a ground position of known location, and a dual frequency rover unit antenna is centered over the center-most probe of the FEREX 4.032. Position data are recorded in real-time within the unit data logger at 1.0 second intervals.

h. The FEREX DLG includes multiple interface drivers and is capable of linking to several common DGPS RTK systems, such as Trimble, Leica, and Ashtech. For YPG demonstration, the Leica 1200 will be used.

i. The Leica System 1200 GPS uses the newest SmartTrack measurement engine, and the antennas are matched perfectly to each other for the best possible receiver performance. The SmartCheck algorithms weigh and process SmartTrack measurements and deliver fast, accurate real-time kinematic (RTK). Centimeter accuracy positions are available continuously at rates of up to 20 Hz (hertz) and latency less than 0.03 seconds. With a suitable communication device, RTK ranges reach 30km or more. The DGPS units to be used will be rented from a separate vendor.

2.1.3 Data Processing Description (provided by demonstrator)

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

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

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

2.1.4 Data Submission Format

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

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

a. Overview of QC.

(1) Field personnel, data processors, and data interpreters will implement the QC program in a consistent fashion. In general, the QC program consists of a series of pre-project tests, and once the project has started, a test regimen is applied for each acquisition session. The test regimen includes functional checks to ensure the position and geophysical sensor instrumentation are functioning properly prior to and at the end of each data acquisition session, processing checks to ensure the data collected are of sufficient quality and quantity to meet the project objectives, and interpretation checks to ensure the processed data are representative of the

site conditions. Pre-project tests include functional checks to ensure the position and geophysical sensor instrumentation are operating within their defined parameters. Specific pre-project tests include the following:

(a) Five minute static tests for each FEREX 4.032 system.

(b) Cable integrity tests for each FEREX 4.032 system.

(c) Manufacturer-suggested functional checks for DGPS positioning systems.

(d) DGPS quality checks from the FEREX data logger screen.

(2) Specific functional checks during the data acquisition program are:

(a) Acquisition personnel metal check (ensure no metal on acquisition personnel).

(b) Static position system check (accuracy and repeatability of position).

(c) Static geophysical sensor check (repeat ability of measurements, influence of ambient noise).

(d) Static geophysical sensor check with test item (repeatability and comparability of measurements with metal present).

(e) Kinematic geophysical sensor check with test item (repeatability and comparability of measurements with sensor in motion).

(f) Repeatability of overall data (re-survey of portion of the survey area during each data acquisition session).

(g) Occupation of survey monuments to ensure comparability, accuracy, and repeatability of DGPS positioning systems.

b. Overview of QA.

(1) The QA procedures applied during the processing phase of the project are performed each day in the field to ensure the integrity of the data. Data that is not of sufficient quality and quantity to meet the project objectives is documented and recollected.

(2) Procedural checks during the processing of the data include:

(a) Evaluation of the static position and FEREX 4.032 data. FEREX 4.032 static noise above a pre-defined threshold is documented and a root cause analysis is performed prior to collecting additional data.

(b) Evaluation of the kinematic geophysical sensor check. These data allow the processor to qualitatively and quantitatively monitor the noise level and repeatability of the data over a "standard" item, as well as ensure the data have been merged correctly (i.e., the data contain no time or position shift, also known as "lag").

(c) Corner stake locations for the survey grid are compared to known survey data and verified.

(d) Sample density along transects is verified through statistics.

(3) Unreasonable FEREX 4.032 measurement values are documented and compared to the site cultural features map. Foerster has developed internal software to meet some of the needs during merging, processing, and interpretation of the data. QA measures applied during the interpretation of the data include:

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

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

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

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

(e) Comparison of the position and FEREX 4.032 data to the site features map (e.g., above-ground cultural features are documented. There should be variance in the track path). Interpreted data characteristics are compared to the known responses acquired during the initial test program (e.g., calibration lane).

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org. The blind grid counterpart to this report is Scoring Record No. 769.

2.2 YPG SITE INFORMATION

2.2.1 Location

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

2.2.2 Soil Type

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

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

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

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

2.2.3 Test Areas

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

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains the 15 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration.
Blind Grid	Contains 400 grid cells in a 0.16-hectare (0.39-acre) site. The center of each grid cell contains ordnance, clutter, or nothing.
Open Field	A 4-hectare (10-acre) site containing open areas, dips, ruts, and obstructions, including vegetation.

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SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (30 January through 6 February 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	1.83
Open Field	45.55

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

A YPG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on 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.
30 January	63.3	0.00
31 January	64.2	0.00
1 February	64.6	0.00
2 February	69.3	0.00
3 February	65.5	0.00
6 February	67.5	0.00
7 February	67.1	0.00

3.3.2 Field Conditions

The weather was warm and the field was dry during the Foerster's survey. Field conditions were excellent.

3.3.3 Soil Moisture

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

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and breakdown. A four-person crew took 30 minutes to perform the initial setup and mobilization. There was 10 hours and 59 minutes of daily equipment preparation and end of the day equipment breakdown lasted 1 hour and 35 minutes.

3.4.2 Calibration

Foerster spent a total of 1 hour and 50 minutes in the calibration lanes, of which 34 minutes was spent collecting data. Foerster also spent 12 minutes calibrating while surveying the open field.

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 14 hours and 51 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. Foerster spent an additional 3 hours and 23 minutes for breaks and lunches.

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

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Foerster spent a total time of 45 hours and 33 minutes in the open field area, 14 hours and 45 minutes of which was spent collecting data.

3.4.5 Demobilization

The Foerster survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 7 February 2006. On that day, it took the crew 1 hour and 5 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Foerster submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was also provided on 30 March 2006.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

Foerster surveyed the open field in a linear fashion and in grids ranging from 50x50 to 50x100 meters.

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.

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SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive. Figure 3 shows both probabilities plotted against their respective 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. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

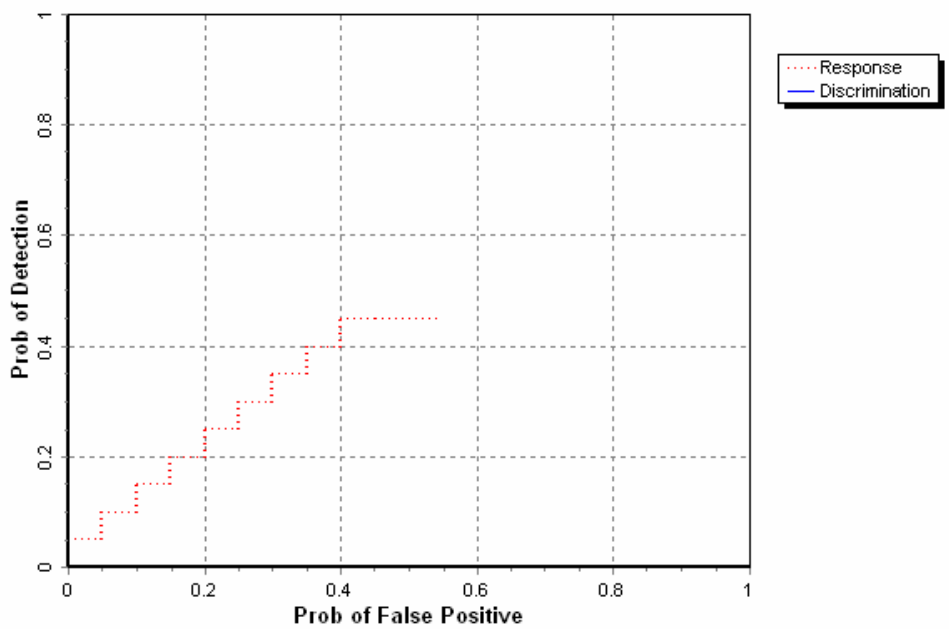

Figure 2. Magnetometer FEREX DLG GPS/sling open field probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

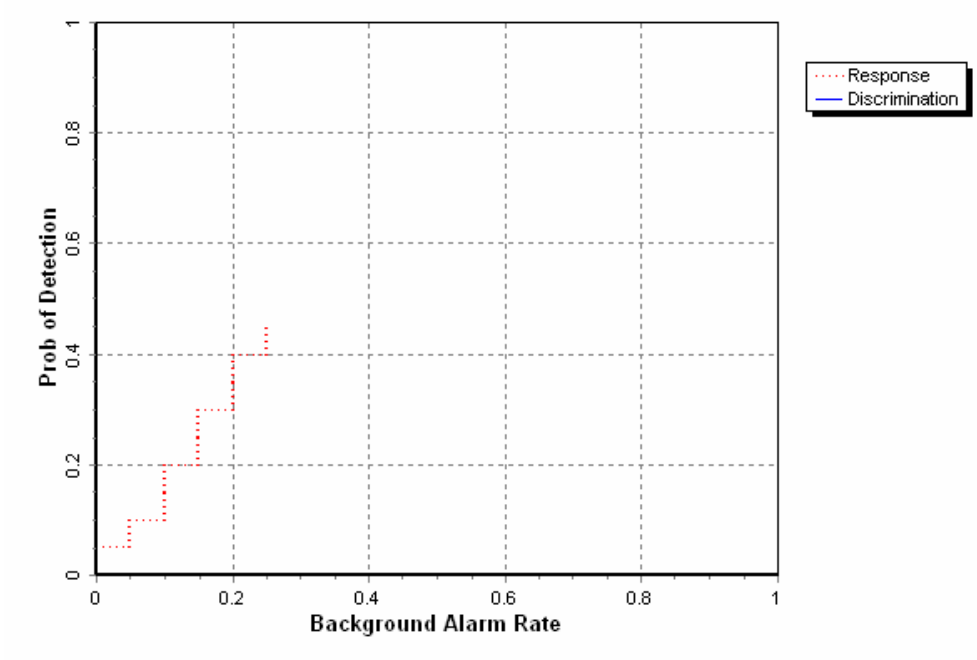

Figure 3. Magnetometer FEREX DLG GPS/sling open field probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 4 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored. Figure 5 shows both probabilities plotted against their respective 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.

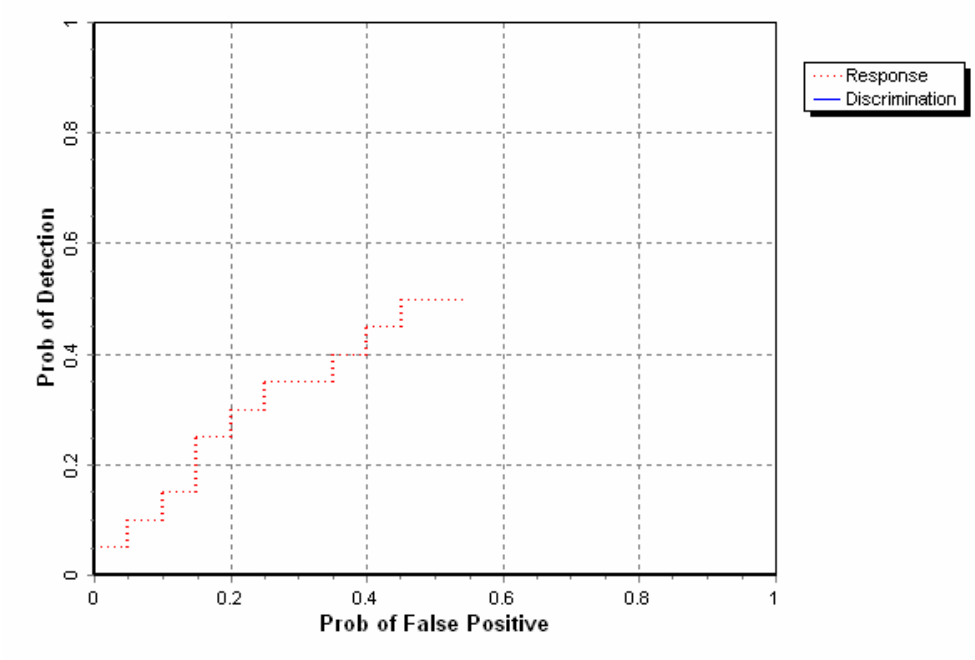

Figure 4. Magnetometer FEREX DLG GPS/sling open field probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

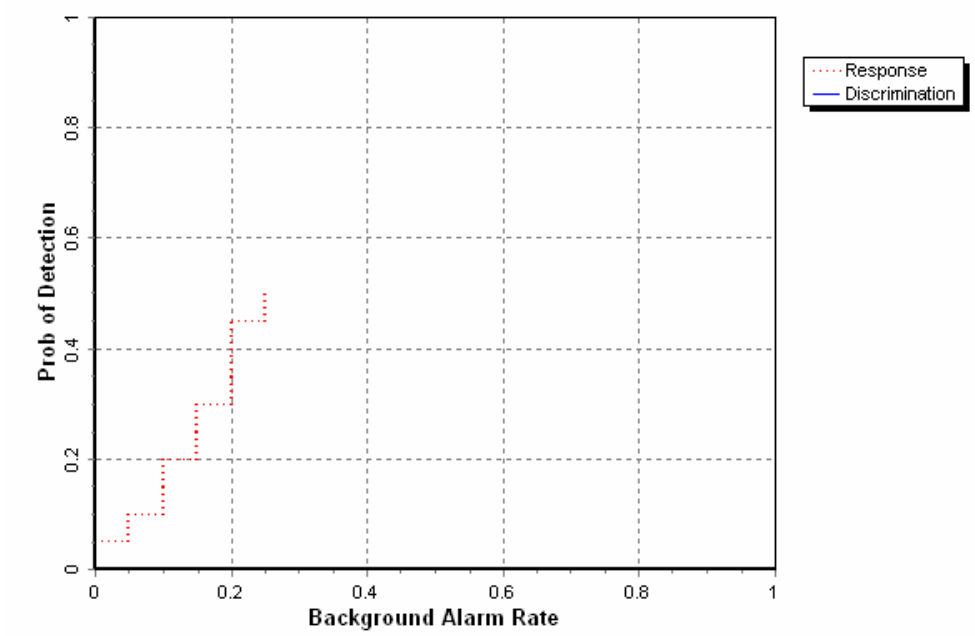

Figure 5. Magnetometer FEREX DLG GPS/sling blind grid probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the open field test, broken out by size, depth and nonstandard ordnance, are presented in Tables 5a and 5b (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnances emplaced. Depth is measured from the geometric center of anomalies.

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

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

TABLE 5a. SUMMARY OF OPEN FIELD RESULTS (FERROUS ONLY)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d 0.45		0.45	0.50	0.35	0.50 0.70		0.45	0.55	0.45
P_d Low 90% Conf	0.44	0.39	0.47 0.30		0.43	0.64	0.39	0.51	0.32
P_d Upper 90% Conf	0.50	0.47	0.57 0.39		0.53	0.77	0.47	0.62	0.54
P_{fp} 0.55		-	-	-	-	-	0.55	0.55	0.20
P_{fp} Low 90% Conf	0.53	-	-	-	-	-	0.53	0.51	0.05
P_{fp} Upper 90% Conf	0.56	-	-	-	-	-	0.57	0.58	0.45
BAR 0.	25	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	N/A	N/A	N/A	N/A	N/A N/	A	N/A	N/A N/	A
P_d Low 90% Conf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
P_d Upper 90% Conf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
P_{fp} N/	A	-	-	-	-	-		N/A	N/A
P_{fp} Low 90% Conf	N/A	-	-	-	-	-		N/A	N/A
P_{fp} Upper 90% Conf	N/A	-	-	-	-	-		N/A	N/A
BAR N	/A	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00.
Recommended Discrimination Stage Threshold: 0.50.

TABLE 5b. SUMMARY OF OPEN FIELD RESULTS (FULL GROUND TRUTH)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d 0.45		0.45	0.50	0.35	0.50 0.70		0.45	0.55	0.45
P_d Low 90% Conf	0.44	0.39	0.47 0.30		0.43	0.64	0.39	0.51	0.32
P_d Upper 90% Conf	0.50	0.47	0.57 0.39		0.53	0.77	0.47	0.62	0.54
P_{fp} 0.55		-	-	-	-	-	0.55	0.55	0.20
P_{fp} Low 90% Conf	0.53	-	-	-	-	-	0.53	0.51	0.05
P_{fp} Upper 90% Conf	0.56	-	-	-	-	-	0.57	0.58	0.45
BAR 0.	25	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	N/A	N/A	N/A	N/A	N/A N/	A	N/A	N/A N/	A
P_d Low 90% Conf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
P_d Upper 90% Conf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
P_{fp} N/	A	-	-	-	-	-	N/A	N/A	N/A
P_{fp} Low 90% Conf	N/A	-	-	-	-	-	N/A	N/A	N/A
P_{fp} Upper 90% Conf	N/A	-	-	-	-	-	N/A	N/A	N/A
BAR N	/A	-	-	-	-	-	-	-	-

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

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

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejectio n rates are calculate d to quantif y the disc rimination 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 ef ficiency is b y def inition equal to one) and (2) at the oper ator se lected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	N/A	N/A	N/A
With No Loss of P_d N/A		N/A	N/A

At the demonstrator's recomm ended setting, the ordnance item s that were detected and correctly discrim inated were further scored on whether the ir cor rect ty pe could be identif ied (table 7). Correct type exam ples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnan ce item was provided to demonstrators prior to testing. For ex ample, the standard type for the three exam ple items are 20mmP, 105H, and 2.75in, respectively.

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

Size	Percentage Correct
Small 0.00	
Medium 0.00	
Large 0.00	
Overall 0.00	

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

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

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

	Mean	Standard Deviation
Northing 0.00		0.20
Easting -0.03		0.21
Depth 0.41		0.42

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	0.50	$47.50
Data Analyst	1	57.00	0.50	28.50
Field Support	2	28.50	0.50	28.50
SubTotal				**$104.50**
Calibration				
Supervisor 1		$95.00	2.03	$192.85
Data Analyst	1	57.00	2.03	115.71
Field Support	2	28.50	2.03	115.71
SubTotal				**$424.27**
Site Survey				
Supervisor 1		$95.00	45.55	$4,327.25
Data Analyst	1	57.00	45.55	2,596.35
Field Support	2	28.50	45.55	2,596.35
SubTotal				**$9,519.95**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor 1		$95.00	1.08	$102.60
Data Analyst	1	57.00	1.08	61.56
Field Support	2	28.50	1.08	61.56
Subtotal				**$225.72**
Total				**$10,274.44**

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 FERROUS ONLY GROUND TRUTH)

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 February of 2006. Due to the system utilizing 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 MAGNETOMETER FEREX DLG GPS/SLING (FERROUS ONLY)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d 0.85		0.85	0.85	0.85	0.80	0.95	0.90	0.80	0.55
P_d Low 90% Conf	0.77	0.74	0.73	0.74	0.63	0.75	0.83	0.67	0.28
P_d Upper 90% Conf	0.90	0.91	0.93	0.92	0.89	0.99	0.97	0.90	0.83
P_{fp} 0.95		-	-	-	-	-	0.95	1.00	0.00
P_{fp} Low 90% Conf	0.92	-	-	-	-	-	0.89	0.93	-
P_d Upper 90% Conf	0.98	-	-	-	-	-	0.97	1.00	-
P_{ba} 0.	20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d 0.85		0.85	0.85	0.85	0.80	0.95	0.90	0.80	0.55
P_d Low 90% Conf	0.77	0.74	0.73	0.74	0.63	0.75	0.83	0.67	0.28
P_d Upper 90% Conf	0.90	0.91	0.93	0.92	0.89	0.99	0.97	0.90	0.83
P_{fp} 0.95		-	-	-	-	-	0.95	1.00	0.00
P_{fp} Low 90% Conf	0.92	-	-	-	-	-	0.89	0.93	-
P_d Upper 90% Conf	0.98	-	-	-	-	-	0.97	1.00	-
P_{ba} 0.	20	-	-	-	-	-	-	-	-

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 would show P_d^{disc} versus their respective P_{fp} over all ordnance categories, but the information was not provided by the vendor. Figure 7 would use 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, but the information was not provided by the vendor. The ROC curves in this section are a sole reflection of the ferrous only survey.

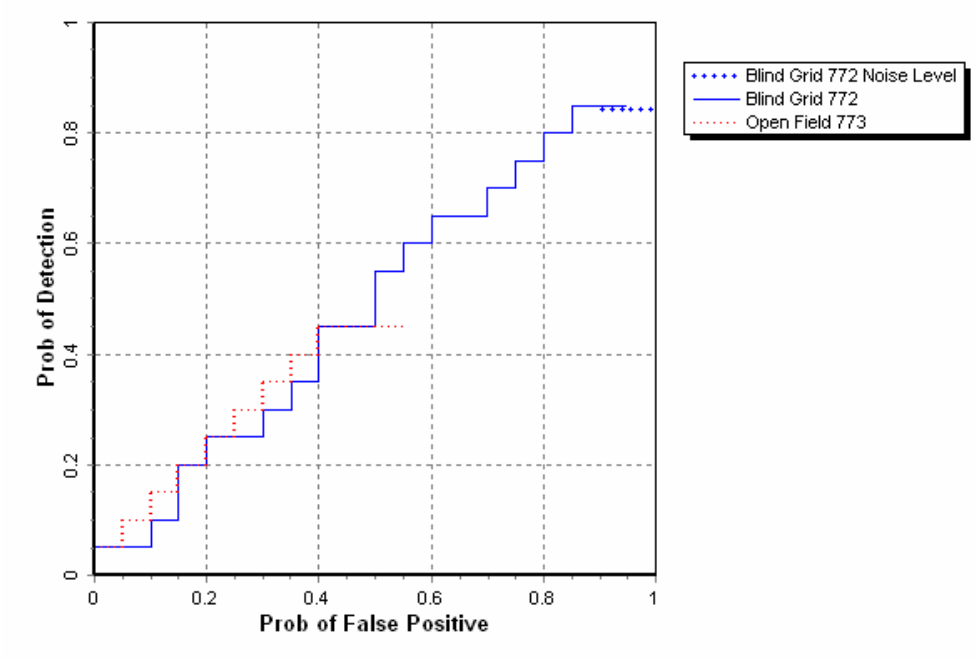

Figure 6. Magnetometer FEREX DLG GPS/sling P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

No Data Available

Figure 7. Magnetometer FEREX DLG GPS/sling 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 would show P_d^{disc} versus the respective P_{fp} over ordnance larger than 20 mm but the information was not provided by the vendor. Figure 9 would use 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, but the information was not provided for by the vendor.

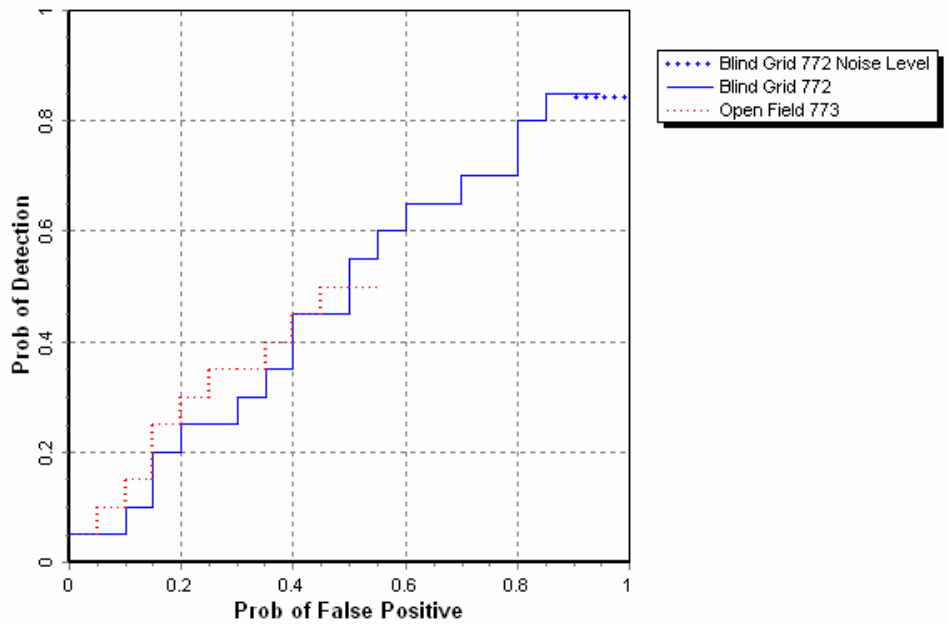

Figure 8. Magnetometer FEREX DLG GPS/sling P_d^{res} versus the respective P_{fp} for ordnance larger than 20 mm.

No Data Available

Figure 9. Magnetometer FEREX DLG GPS/sling P_d^{disc} versus the respective P_{fp} for ordnance larger than 20 mm.

6.4 STATISTICAL COMPARISONS

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

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

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

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

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.

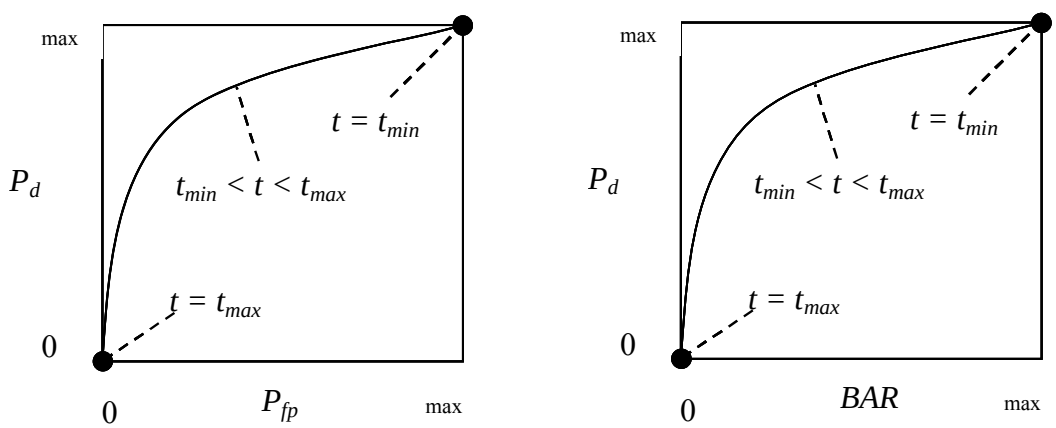

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[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 3.84 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 3.84, 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 3.84, 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 3.84, 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

Date: 30 January 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 6.	8	0.00
0800 7.	5	0.00
0900 9.	3	0.00
1000 12	.5	0.00
1100 16	.8	0.00
1200 19	.0	0.00
1300 20	.7	0.00
1400 22	.1	0.00
1500 22	.9	0.00
1600 23	.7	0.00
1700 23	.7	0.00
Date: 31 January 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 7.	1	0.00
0800 6.	8	0.00
0900 11	.1	0.00
1000 13	.9	0.00
1100 18	.1	0.00
1200 20	.0	0.00
1300 21	.5	0.00
1400 22	.3	0.00
1500 23	.2	0.00
1600 23	.2	0.00
1700 23	.0	0.00
Date: 01 February 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 8.	0	0.00
0800 8.	4	0.00
0900 10	.8	0.00
1000 15	.2	0.00
1100 18	.7	0.00
1200 20	.4	0.00
1300 21	.8	0.00
1400 23	.0	0.00
1500 23	.7	0.00
1600 24	.0	0.00
1700 23	.8	0.00

Date: 02 February 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 8.	2	0.00
0800 9.	5	0.00
0900 11	.3	0.00
1000 16	.6	0.00
1100 18	.8	0.00
1200 21	.5	0.00
1300 22	.6	0.00
1400 23	.2	0.00
1500 23	.3	0.00
1600 23	.7	0.00
1700 23	.4	0.00
Date: 03 February 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 8.	2	0.00
0800 8.	5	0.00
0900 13	.0	0.00
1000 15	.1	0.00
1100 18	.5	0.00
1200 21	.7	0.00
1300 23	.8	0.00
1400 25	.4	0.00
1500 26	.5	0.00
1600 27	.3	0.00
1700 27	.7	0.00
Date: 06 February 2006		
Time	**Average Temperature, ^{o}C**	**Average Precipitation, in.**
0700 11	.6	0.00
0800 11	.2	0.00
0900 14	.0	0.00
1000 16	.4	0.00
1100 19	.4	0.00
1200 21	.5	0.00
1300 22	.2	0.00
1400 23	.2	0.00
1500 23	.9	0.00
1600 24	.5	0.00
1700 24	.3	0.00

Date: 07 February 2006		
Time	**Average Temperature, °C**	**Average Precipitation, in.**
0700 NA		NA
0800 N	A	NA
0900 N	A	NA
1000 N	A	NA
1100 N	A	NA
1200 N	A	NA
1300 N	A	NA
1400 N	A	NA
1500 N	A	NA
1600 N	A	NA
1700 N	A	NA

(Page B-4 Blank)

APPENDIX C. SOIL MOISTURE

Date: 30 January 2006
Times: 0900, 1230

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.6	1.7
	6 to 12	2.2	2.2
	12 to 24	3.6	3.6
	24 to 36	3.7	3.7
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.7	1.7
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.9	5.0
Desert Extreme	0 to 6	1.7	3.8
	6 to 12	1.7	3.8
	12 to 24	3.3	3.2
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 31 January 2006
Times: 0730, 1230

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.6	1.8
	6 to 12	2.2	2.2
	12 to 24	3.6	3.6
	24 to 36	3.7	3.7
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.7	1.6
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.9	5.1
Desert Extreme	0 to 6	1.7	6.7
	6 to 12	1.7	3.8
	12 to 24	3.3	3.2
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 01 February 2006
Times: 0800, 1300

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.8	1.7
	6 to 12	2.1	2.2
	12 to 24	3.6	3.6
	24 to 36	3.7	3.7
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.7	1.7
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.8	5.0
Desert Extreme	0 to 6	1.6	1.4
	6 to 12	1.8	1.9
	12 to 24	3.2	3.2
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 02 February 2006
Times: 0745, 1230

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.8	1.7
	6 to 12	2.2	2.2
	12 to 24	3.6	3.6
	24 to 36	3.7	3.7
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.7	1.6
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.9	4.9
Desert Extreme	0 to 6	1.7	1.6
	6 to 12	1.8	1.9
	12 to 24	3.2	3.3
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 03 February 2006
Times: 0745, 1330

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.8	1.8
	6 to 12	2.2	2.1
	12 to 24	3.6	3.6
	24 to 36	3.7	3.7
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.7	1.7
	6 to 12	6.5	3.9
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.5	4.8
Desert Extreme	0 to 6	1.6	1.7
	6 to 12	1.8	1.8
	12 to 24	3.1	3.3
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 06 February 2006
Times: 0745, 1330

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.8	1.7
	6 to 12	2.2	2.0
	12 to 24	3.6	3.5
	24 to 36	3.7	3.9
	36 to 48	4.1	4.1
Mogul Area	0 to 6	1.8	1.6
	6 to 12	9.4	2.9
	12 to 24	3.8	3.8
	24 to 36	4.7	4.7
	36 to 48	4.8	4.8
Desert Extreme	0 to 6	1.7	1.8
	6 to 12	1.8	1.8
	12 to 24	3.2	3.1
	24 to 36	4.0	4.0
	36 to 48	4.0	4.0

Date: 07 February 2006
Times: 0745, NA

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Calibration Area	0 to 6	1.7	NA
	6 to 12	2.2	NA
	12 to 24	3.6	NA
	24 to 36	3.7	NA
	36 to 48	4.1	NA
Mogul Area	0 to 6	1.7	NA
	6 to 12	1.8	NA
	12 to 24	3.9	NA
	24 to 36	4.7	NA
	36 to 48	4.7	NA
Desert Extreme Area	0 to 6	1.7	NA
	6 to 12	1.8	NA
	12 to 24	3.3	NA
	24 to 36	4.0	NA
	36 to 48	4.0	NA

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
01/30/2006	4	CALIBRATION LANES	1157	1213	16	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
01/30/2006	4	CALIBRATION LANES	1213	1243	30	INITIAL SETUP	INITIAL CALIBRATION OF EQUIPMENT	GPS	NA	LINEAR	SUNNY	WARM
01/30/2006	4	CALIBRATION LANES	1243	1306	23	COLLECTING DATA	RAN CALIBRATION FIELD NORTH TO SOUTH, WEST TO EAST/CAL A	GPS	NA	LINEAR	SUNNY	WARM
01/30/2006	4	CALIBRATION LANES	1306	1347	41	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
01/30/2006	4	CALIBRATION LANES	1347	1406	19	BREAK/LUNCH	BREAK	NA	NA	NA	SUNNY	WARM
01/30/2006	4	BLIND TEST GRID	1406	1435	29	COLLECTING DATA	RAN BLIND CALIBRATION FIELD SOUTH TO NORTH	GPS	NA	LINEAR	SUNNY	WARM
01/30/2006	4	BLIND TEST GRID 1435		1500	25	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
01/30/2006	4	BLIND TEST GRID 1500		1630	90	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	SUNNY	WARM
01/31/2006	4	OPEN FIELD	724	1057	213	DAILY START, STOP	SETUP OF EQUIPMENT AND MAPPING OUT AREA OF OPEN FIELD	NA	NA	NA	CLEAR	COLD
01/31/2006	4	OPEN FIELD	1057	1128	31	COLLECTING DATA	RAN OPEN FIELD EAST TO WEST IN 50 X 100 METER GRID (A2 AND A3)	GPS	NA	LINEAR	SUNNY	WARM
01/31/2006	4	OPEN FIELD	1128	1146	18	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DID NOT COMPLETE GRID, INSPECTING DATA TO SEE IF IT IS GOOD	NA	NA	NA	SUNNY WINDY	COOL

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
01/31/2006	4	OPEN FIELD	1146	1252	66	COLLECTING DATA	STARTING GRID OVER RUNNING OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (A2 AND A3)	GPS	NA	LINEAR	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1252	1339	47	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY/ WINDY	COOL
01/31/2006	4	OPEN FIELD	1339	1415	36	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1415	1443	28	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	MAPPING OUT THE NEXT 50 X 100 GRID AREA (A4 AND A5)	NA	NA	NA	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1443	1550	67	COLLECTING DATA	RAN OPEN FIELD EAST TO WEST IN 50 X 100 METER GRID (A4 AND A5). NOTE: MIDWAY THROUGH THE GRID, THE UNIT QUIT TRACKING SO THE CENTER PORTION OF THE GRID WAS REDONE	GPS	NA	LINEAR	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1550	1556	6	BREAK/LUNCH	BREAK	NA	NA	NA	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1556	1619	23	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY WINDY	COOL
01/31/2006	4	OPEN FIELD	1619	1640	21	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	SUNNY WINDY	COOL
02/01/2006	4	OPEN FIELD	721	846	85	DAILY START, STOP	SETUP OF EQUIPMENT AND MAPPING OUT AREA OF OPEN FIELD (GRID C2 AND C3)	NA	NA	NA	PARTLY CLOUDY	COLD

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/01/2006	4	OPEN FIELD	846	849	3	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST. NOTE: THE RUN WAS AN AREA MISSED ON 1/31/2006 IN THE A4 AND A5 GRID	GPS	NA	NA	PARTLY CLOUDY	COLD
02/01/2006	4	OPEN FIELD	849	929	40	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA/SETTING UP TO RUN GRIDS B4 AND B5	NA	NA	NA	PARTLY CLOUDY	COLD
02/01/2006	4	OPEN FIELD	929	940	11	BREAK/LUNCH	BREAK	NA	NA	NA	PARTLY CLOUDY	COLD
02/01/2006	4	OPEN FIELD	940	1009	29	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (B4 AND B5)	GPS	NA	LINEAR	PARTLY CLOUDY	WARM
02/01/2006	4	OPEN FIELD	1009	1056	47	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA. NOTE: AGAIN MID WAY THROUGH THE GRID, THE UNIT QUIT TRACKING.	NA	NA	NA	PARTLY CLOUDY	WARM
02/01/2006	4	OPEN FIELD	1056	1128	32	COLLECTING DATA	RAN OPEN FIELD WEST TO EEAST IN 50 X 100 METER GRID (B4 AND B5), CONTINUED	GPS	NA	LINEAR	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1128	1147	19	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1147	1216	29	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1216	1239	23	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRIDS B2 AND B3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/01/2006	4	OPEN FIELD	1239	1333	54	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (B2 & B3) NOTE: DUE TO THE ISSUE WITH THE SYSTEM (SEE 1009 MST) THE GRID AREA IS BEING SPLIT BETWEEN THE NORTH AND SOUTH SIDES OF THE GRIDS. THE DATA IS BEING STORED TO THE SYSTEM BETWEEN THE TWO RUNS	GPS	NA	LINEAR	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1333	1346	13	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRIDS C2 AND C3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1346	1438	52	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (C2 & C3). RAN AS ONE NOT SPLIT (SEE 1239 MST)	GPS	NA	LINEAR	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1438	1506	28	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRIDS C4 AND C5 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/01/2006	4	OPEN FIELD	1506	1516	10	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (C4 AND C5); INCOMPLETE, GPS BATTERY DEAD.	GPS	NA	LINEAR	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1516	1536	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
02/01/2006	4	OPEN FIELD	1536	1557	21	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	747	942	115	DAILY START, STOP	SETUP OF EQUIPMENT AND MAPPING OUT AREA OF OPEN FIELD (GRID C4 AND C5)	NA	NA	NA	CLEAR	COLD
02/02/2006	4	OPEN FIELD	942	1020	38	COLLECTING DATA	CONTINUED/COMPLETED OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (C4 AND C5).	GPS	NA	LINEAR	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1020	1032	12	BREAK/LUNCH	BREAK	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1032	1107	35	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRIDS D2 AND D3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1107	1205	58	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (D2 AND D3)	GPS	NA	LINEAR	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/02/2006	4	OPEN FIELD	1205	1214	9	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	SETUP OF EQUIPMENT AND MAPPING OUT AREA OF OPEN FIELD (GRID D4 AND D5)	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1214	1236	22	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1236	1303	27	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1303	1359	56	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (D4 AND D5).	GPS	NA	LINEAR	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1359	1408	9	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA. NOTE: NO DATA WAS RECEIVED, GRIDS(D4 AND D5) WILL BE REDONE	NA	NA	NA	SUNNY	WARM
02/02/2006	4	OPEN FIELD	1408	1446	38	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	THE UNITS (SN 00725) INTERNAL BATTERY DIED AND THE UNIT WAS SWAPPED OUT WITH ONE IN THE SAME SN 15	NA	NA	NA	PARTLY CLOUDY	WARM
02/02/2006	4	OPEN FIELD	1446	1539	53	COLLECTING DATA	RE-RAN OPEN FIELD EAST TO WEST IN 50 X 100 METER GRID (D4 AND D5), DUE TO LOSING DATA (SEE 1408 MST). NOTE: 2/3 OF THE WAY THROUGH THE GRID AREA, THE OPERATOR WAS SWITCHED OUT WITH ANOTHER OPERATOR	GPS	NA	LINEAR	PARTLY CLOUDY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/02/2006	4	OPEN FIELD	1539	1559	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	PARTLY CLOUDY	WARM
02/02/2006	4	OPEN FIELD	1559	1618	19	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	PARTLY CLOUDY	WARM
02/03/2006	4	OPEN FIELD	717	1011	174	DAILY START, STOP	SETUP OF EQUIPMENT (TRACKING UNIT SN 15 WAS REMOVED AND UNIT SN 00725 WAS REINSTALLED, UNITS HAVE AN INTERNAL RECHARGEABLE BATTERY) AND MAPPING OUT AREA OF OPEN FIELD (GRIDS E, F AND G)	NA	NA	NA	CLEAR	COLD
02/03/2006	4	OPEN FIELD	1011	1038	27	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN E5 GRID	GPS	NA	LINEAR	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1038	1104	26	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID F5 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1104	1123	19	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN F5 GRID	GPS	NA	LINEAR	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/03/2006	4	OPEN FIELD	1123	1145	22	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID G4 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1145	1225	40	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN G4 GRID	GPS	NA	LINEAR	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1225	1251	26	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1251	1342	51	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1342	1409	27	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID E2 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1409	1436	27	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN E2 GRID	GPS	NA	LINEAR	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1436	1455	19	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID E3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS. THE UNIT WAS ALSO CHANGED FROM THE BACKPACK MODE TO THE WHEELED MODE	NA	NA	NA	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1455	1520	25	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN E3 GRID	GPS	NA	LINEAR	SUNNY	WARM
02/03/2006	4	OPEN FIELD	1520	1542	22	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/03/2006	4	OPEN FIELD	1542	1600	18	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	SUNNY	WARM
02/06/2006	4	OPEN FIELD	727	817	50	DAILY START, STOP	SETUP OF EQUIPMENT AND MAPPING OUT AREA OF OPEN FIELD (GRID E4)	NA	NA	NA	CLEAR	COLD
02/06/2006	4	OPEN FIELD	817	838	21	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 50 METER GRID (E4)	GPS	NA	LINEAR	SUNNY	WARM
02/06/2006	4	OPEN FIELD	838	857	19	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID F4 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/06/2006	4	OPEN FIELD	857	919	22	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 50 METER GRID (F4)	GPS	NA	LINEAR	SUNNY	WARM
02/06/2006	4	OPEN FIELD	919	931	12	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID F2 AND F3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM
02/06/2506	4	OPEN FIELD	931	1015	44	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (F2 AND F3)	GPS	NA	LINEAR	SUNNY	WARM
02/06/2006	4	OPEN FIELD	1015	1035	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	PREPARING GRID G2 AND G3 FOR THE COLLECTION OF DATA; ROPING AND MEASURING OFF GRIDS	NA	NA	NA	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/06/2006	4	OPEN FIELD	1035	1130	55	COLLECTING DATA	RAN OPEN FIELD WEST TO EAST IN 50 X 100 METER GRID (G2 AND G3)	GPS	NA	LINEAR	SUNNY	WARM
02/06/2006	4	OPEN FIELD	1130	1417	167	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA. OPEN FIELD IS COMPLETE. RE-CONFIGURING THE UNIT BY MOVING THE PROBES TO A QUARTER OF THE DISTANCE APART. PURPOSE IS TO RE-RUN A PORTION OF THE CALIBRATION GRID IN AN ATTEMPT TO VERIFY SOME OF THE SMALLER TYPES OF UXO	NA	NA	NA	SUNNY	WARM
02/06/2006	4	OPEN FIELD	1417	1448	31	BREAK/LUNCH	LUNCH	NA	NA	NA	SUNNY	WARM
02/06/2006	4	CALIBRATION LANES	1448	1459	11	COLLECTING DATA	RE-RUNNING A PORTION OF THE CALIBRATION FIELD (SEE 1130 MST). RUNNING SOUTH TO NORTH ON THE SOUTHEAST SIDE OF THE FIELD	GPS	NA	LINEAR	SUNNY	WARM
02/06/2006	4	OPEN FIELD	1459	1503	4	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	SUNNY	WARM
02/06/2006	4	OPEN FIELD	1503	1519	16	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	NA	SUNNY	WARM

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/07/2006	3	OPEN FIELD	730	752	22	DAILY START, STOP	SETUP OF EQUIPMENT AND MAPPING OUT AREA ON THE OPEN FIELD NEAR THE FENCE ON THE FIELD. NOTE: AREA WILL BE RUN NORTH TO SOUTH TO GET CLOSER TO THE FENCE TO COLLECT DATA	NA	NA	NA	CLEAR	COLD
02/07/2006	3	OPEN FIELD	752	804	12	CALIBRATION	PERFORMED STATIC POSITION SYSTEM TEST IN AN AREA OUTSIDE OF THE CALIBRATION FIELD. PERFORMED 5 MINUTES WITH NOTHING IN THE AREA AND THEN 5 MINUTES WITH A KNOWN OBJECT (HEAVY ROUND STEEL BALL). TESTING ACCURACY OF THE SYSTEM	NA	NA	NA	CLEAR	COLD
02/07/2006	3	OPEN FIELD	804	830	26	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	MAPPING OUT THE AREA AROUND THE FENCE ON THE FIELD	NA	NA	NA	CLEAR	COLD
02/07/2006	3	OPEN FIELD	830	833	3	COLLECTING DATA	RUN AREA NORTH TO SOUTH AROUND THE FENCE (SEE 0730 MST)	GPS	NA	LINEAR	CLEAR	COLD
02/07/2006	3	OPEN FIELD	833	909	36	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	DOWNLOADING AND INSPECTING DATA	NA	NA	NA	CLEAR	COLD

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

Date	No. of People	Area-Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
02/07/2006	3	OPEN FIELD	909	1002	53	COLLECTING DATA	AREAS AROUND THE CACTUS AND TREES ON THE OPEN FIELD	GPS	NA	LINEAR	SUNNY	WARM
02/07/2006	3	OPEN FIELD	1002	1107	65	DEMOBILIZATION	BREAKING DOWN AND BOXING UP EQUIPMENT FOR SHIPMENT	NA	NA	NA	SUNNY	WARM

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

APPENDIX E. REFERENCES

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

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

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

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

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

APPENDIX F. ABBREVIATIONS

APG = Aberdeen Proving Ground
ASCII = American Standard Code for Information Interchange.
ATC = U.S. Army Aberdeen Test Center
ATSS = Aberdeen Test and Support Services
DGPS = Differential Global Positioning System
ERDC = U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP = Environmental Security Technology Certification Program
EQT = Army Environmental Quality Technology Program
GPS = Global Positioning System
Hz = hertz
JPG = Jefferson Proving Ground
LLC = Limited Liability Company
MEDTC = Military Environmental Technology Demonstration Center
nT = nanotesla
POC = point of contact
QA = quality assurance
QC = quality control
ROC = receiver-operating characteristic
RTK = real time kinematic
SERDP = Strategic Environmental Research and Development Program
USAEC = U.S. Army Environmental Center
UTM - universe transverse mercator
UXO = unexploded ordnance
YPG = U.S. Army Yuma Proving Ground

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