AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9787

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 891

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
VF WARNER AND ASSOCIATES INC.
6832 OLD DOMINION DRIVE
SUITE 206
MCLEAN, VA 22101

SENSYS GMBH
RABENFELDE 5
15526 BAD SAAROW
GERMANY

TECHNOLOGY TYPE/PLATFORM:
MAG AMOS/TOWED

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

AUGUST 2008

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

DISTRIBUTION UNLIMITED, AUGUST 2008.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 2008**	2. REPORT TYPE **Final**	3. DATES COVERED **16 Apr 2007 - 20 Apr 2007**

4. TITLE AND SUBTITLE **Standardized UXO Technology Demonstration Site Blind Grid Scoring Record No. 891 (VF Warner and Associates, Inc.)**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **McClung, J. Stephen**	5d. PROJECT NUMBER **8-CO-160-UXO-021** 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Commander U.S. Army Aberdeen Test Center ATTN: TEDT-AT-SLE Aberdeen Proving Ground, MD 21005-5059**	8. PERFORMING ORGANIZATION REPORT NUMBER **ATC-9787**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **Commander U.S. Army Environmental Command ATTN: IMAE-ATT Aberdeen Proving Ground, MD 21005-5401**	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **Same as Item 8**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
This scoring record documents the efforts of VF Warner and Associates Inc. to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. This Scoring Record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Soring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**46**	

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1. The attached document entitled "Scoring Record No. 891" dated August 2008 is provided for review for public disclosure in accordance with AR 530-1 as supplemented. The document is proposed for public release via the internet.

2. I, the undersigned, am aware of the intelligence interest in open source publications and in the subject matter of the information I have reviewed for intelligence purposes. I certify that I have sufficient technical expertise in the subject matter of this document and that, to the best of my knowledge, the net benefit of this public release outweighs the potential damage to the essential secrecy of all related ATC, DTC, ATEC, Army or other DOD programs of which I am aware.

NAME (Printed)	SIGNATURE	DATE
J. Stephen McClung	[signature]	August 2008

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DTC GO/SES	N/A		

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as

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
August 2008	Final	16, 18, and 20 April 2007

4. TITLE AND SUBTITLE STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE BLIND GRID SCORING RECORD NO. 891 (VF WARNER AND ASSOCIATES INC.)	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) McClung, J. Stephen	**5d. PROJECT NUMBER** 8-CO-160-UXO-021
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commander U.S. Army Aberdeen Test Center ATTN: TEDT-AT-SLE Aberdeen Proving Ground, MD 21005-5059	**8. PERFORMING ORGANIZATION REPORT NUMBER** ATC-9787
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Commander U.S. Army Environmental Command ATTN: IMAE-ATT Aberdeen Proving Ground, MD 21005-5401	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) Same as Item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution unlimited, August 2008.

13. SUPPLEMENTARY NOTES
None

14. ABSTRACT

This scoring record documents the efforts of VF Warner and Associates Inc. to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. This Scoring Record was coordinated by J. Stephen McClung 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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a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
Unclassified	Unclassified	Unclassified	SAR		

ACKNOWLEDGMENTS

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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 multiagency 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 funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP), and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

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

The evaluation objectives are as follows:

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

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

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

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

1.2.1 Scoring Methodology

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

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

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

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

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

1.2.2 Scoring Factors

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

a. Response Stage ROC curves:

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

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

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

b. Discrimination Stage ROC curves:

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

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

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

c. Metrics:

(1) Efficiency (E).

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

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

d. Other:

(1) Probability of Detection by Size and Depth.

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

(3) Location accuracy.

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

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

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

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

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are 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
	M75 Submunition

HEAT = high-explosive antitank.
JPG = Jefferson Proving Ground.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Mr. Robert M. Novogratz
703-448-0440

Address: VF Warner and Associates Inc.
6832 Old Dominion Drive, Suite 206
Mclean, VA 22101

2.1.2 System Description (provided by demonstrator)

a. The MAGNETO®-MX system is a multichannel, vehicle-based data acquisition system with online Differential Global Positioning System (DGPS) georeferencing that can be applied with different active (electromagnetic) and passive (magnetic) sensors. The number of channels used for data acquisition usually ranges from 8 to 32.

b. For the demonstration at Aberdeen Proving Ground, a system with eight fluxgate magnetometers (Foerster CON650 gradiometers) and RTK-DGPS georeferencing will be used. The spacing between the individual fluxgate sensors will be 25 cm (ca. 10 inches), totaling to a swath width of 2 m.

c. The MAGNETO®-MX system consists of the MX-compact hardware multiplexer electronic module, up to 32 fluxgate gradiometers (for the APG demonstration: eight fluxgate gradiometers), a robust, all-terrain trailer, the MonMX data acquisition, GPS georeferencing and online monitoring software, the data link monitoring Global Positioning System (DLMGPS) data visualization and data conversion software, and the MAGNETO® data interpretation and visualization software.

d. A special wheel suspension system ensures that the fluxgate sensors remain in vertical position relative to the terrain and at a constant distance from the ground. This design makes sure that reproducible magnetic field data are generated during the measurements. It also enables the data from the individual lanes to be combined into a complete map without the creation of “virtual objects”.

e. The measurement is based on the passive measurement of disturbances in the Earth’s magnetic field caused by ferromagnetic objects on the surface and in the subsurface. Using fluxgate gradiometer sensors, only the vertical component of the disturbed magnetic field is measured.

Sensitivity of sensors:	0.3 nT
Measurement range:	0 .. 10,000 nT
Scanning performance in hectares per hour (P = v × b):	1.08 hectares / h;
with a scanning width (b) of:	2.0 m
at a scanning velocity (v) of:	1.5 m / s
Attainable accuracy of location (x, y)	
with an object depth of < 0.4 m	0.25 m (circular error)
with an object depth of > 0.4 m	0.50 m (circular error)
Attainable accuracy of depth (z)	$\pm$ 0.3 m

f. Detection performance for ferrous and nonferrous metals: depending on object mass (size), induced and remanent magnetization and position in the Earth's magnetic field, and local disturbances, the system will detect objects made from ferromagnetic materials (iron, nickel, cobalt) at depths of up to 3 m below ground surface. For smaller objects (20-mm caliber and similar), maximum detection depth is usually around 0.5 m. For medium objects (artillery shells caliber 35 to 150 mm), maximum detection depth is usually 1.0 to 1.5 m below ground surface. For large objects (rockets, bombs), the maximum detection depth ranges from 2.0 to 5.0 m below ground surface. Nonferrous metal objects are not detected by the system.

Figure 1. Demonstrator's system, MAGNETO®-MX/towed.

2.1.3 Data Processing Description (provided by demonstrator)

a. The pre-processed sensor signals are recorded in a notebook computer and archived. These data are later used to produce an object location map and an accompanying list of objects during data interpretation.

b. In order to enable an exact assignment of coordinates of mapped objects, the current position of the sensor platform trailer is continuously calculated by means of differential GPS (real-time kinematic GPS), and then recorded together with the corresponding measurement data. Data are stored on the hard disk of the notebook computer in a binary format.

c. During the scanning process, the following information appears in real time on the display of the operator's notebook computer:

- the position of the sensor platform
- the *actual* route being traveled by the sensor platform trailer
- the *intended* route of travel of the sensor platform trailer
- the current measurement data visualized both numerically and graphically

This information ensures complete coverage during scanning operations.

d. The incoming sensor signals and the accompanying RTK-GPS coordinates are processed online. The eight-channel sensor electronics feature a resolution of 16 bits and a data repetition rate of 20 Hz per channel. The digitized measurement data and the RTK-GPS data are transmitted via an RS 232 interface.

e. The following software components are necessary for the acquisition, evaluation, and visualization of data: the MonMX data acquisition module, the DLMGPS coordinates transformation module, and the MAGNETO® data evaluation and visualization module.

f. During measurement operations, the MonMX software module carries out the time-synchronous recording of the GPS and sensor data on the Notebook. The real-time depiction of sensor data and visualization of the RTK-GPS status make it possible to conduct a qualitative evaluation of the measurement data during the actual measurement process. Moreover, to assure effective scanning of large areas, the current position of the vehicle, its direction of travel and the intended and actual path of the sensor platform are all depicted in real time. Following a measurement run, the recorded RTK-GPS information and sensor data are available on the notebook computer for further processing and analysis. The DLMGPS software is used for administering, transforming and depicting the GPS data in various coordinate systems.

g. Various export functions enable the exchange of data with the MAGNETO® evaluation and visualization module, as well as the conversion of data for use in other geophysical software systems.

h. With the aid of the MAGNETO® software module, the magnetic (fluxgate gradiometer) measurement data can be visualized and documented in various forms. This gives the user a rapid overview of the level of contamination in the area being scanned.

i. Furthermore, the module permits the interactive search for, and localization of, ferromagnetic objects within the scanned area. The position coordinates, depth and diameter of suspicious objects are calculated and recorded in object lists and on object maps.

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 were 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)

QA: Measurement and GPS data are continuously monitored by the operator during the scanning process. Prior to the measurements, the sensors are compensated on a compensation field free of anomalies. During data acquisition the system maintains synchronization to the GPS-timing, and all raw data are stored stamped with coordinates in intervals of 1 second. Raw data are automatically stored in multiple numbered files. QA with respect to the completeness of the surveyed area is ensured, as any “white space” may be filled by navigating into the required areas to obtain full coverage of the area under investigation.

QC: All information relating to one individual project is saved along with the measurement data itself, including the sensor type, the number of channels and their connection to information layers, the relative position of sensors with respect to the GPS-antenna, the compensation values for each channel, and the base naming convention for automatic data storage and file numbering. Sensors are compensated for offsets automatically to reduce errors. The raw data are checked for anomalies directly after the measurement through visualization in MAGNETO®. The visualization allows checking for anomalies between traces and shifts in the data over the investigated area. Furthermore, the software allows for the compensation of systematic errors (trace compensation, etc.) in the visualization while no original data are altered.

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.

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, which is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods, and wetlands.

2.2.2 Soil Type

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

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

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org 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 equipment calibration.
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.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (16, 18, and 20 April 2007)

3.2 AREAS TESTED/NUMBER OF HOURS

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

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration lanes	0.25
Blind grid	1.75

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 represent 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, 07	Average Temperature, ^{o}F	Total Daily Precipitation, in.
16 Apr	45.0	0.00
18 Apr	49.3	0.00
20 Apr	62.3	0.00

3.3.2 Field Conditions

VF Warner surveyed the blind grid 18 April 2007. The weather was cool and the field was wet due to rain prior to testing.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: calibration, mogul, open field, 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 breakdown. A two-person crew took 4 hours and 20 minutes to perform the initial setup and mobilization. There was 45 minutes of daily equipment preparation, and end of the day equipment breakdown lasted 45 minutes.

3.4.2 Calibration

VF Warner spent a total of 15 minutes in the calibration lanes, all of which was spent collecting data.

3.4.3 Downtime Occasions

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

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for no site usage time. These activities included changing out batteries and routine data checks to ensure the data were being properly recorded/collected. VF Warner spent no additional time for breaks and lunches.

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

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

VF Warner spent a total time of 1 hour and 45 minutes in the blind grid area, 15 minutes of which was spent collecting data.

3.4.5 Demobilization

The VF Warner survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 20 April 2007. On that day, it took the crew 3 hours and 45 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

VF Warner submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was provided January 2008.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Geophysics: Dr. Andreas Fischer
Geophysics: Dr. Kay Winkelmann
Advisor: Bob Novogratz

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

VF Warner surveyed the blind grid in a linear fashion. The line spacing used was the width of the array itself. They surveyed in an east to west direction.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

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 is shown in Figure 2. Both probabilities plotted against their respective background alarm rate are shown in Figure 3. 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 nonferrous anomalies. Due to limitations of the magnetometer, the nonferrous 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.

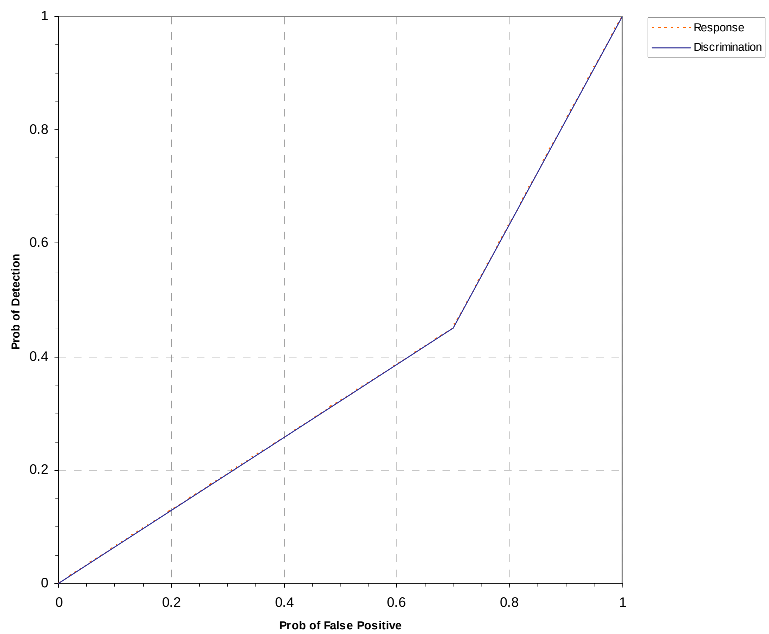

Figure 2. MAG AMOS/towed blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

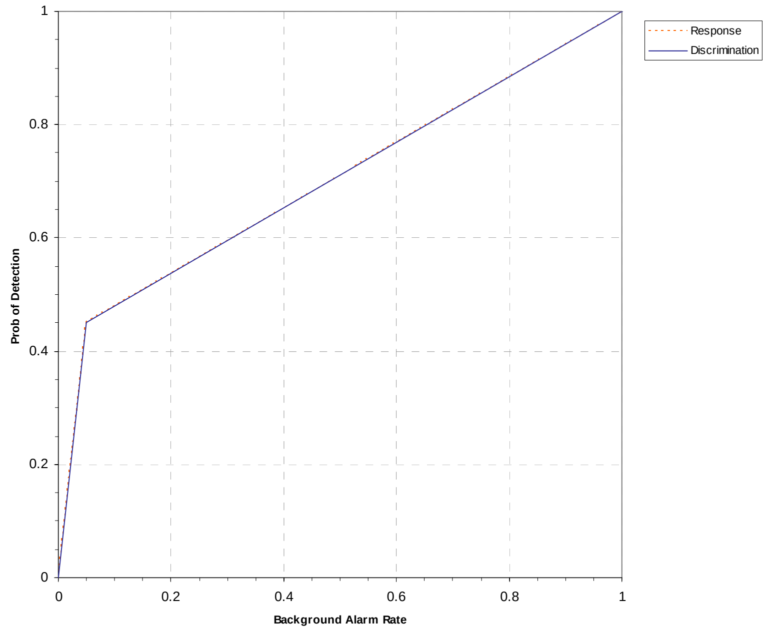

Figure 3. MAG AMOS/towed blind grid probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

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 is shown in Figure 4. Both probabilities plotted against their respective background alarm rate are shown in Figure 5. 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.

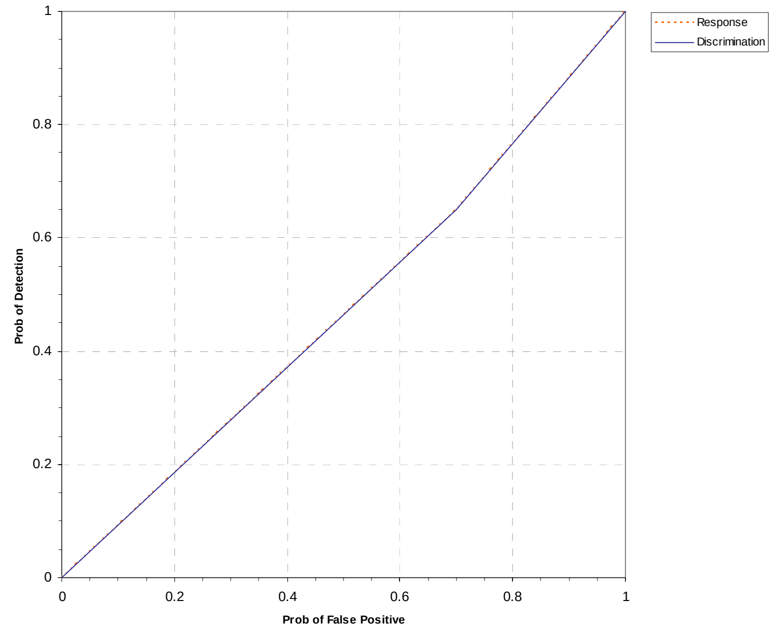

Figure 4. MAG AMOS/towed blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

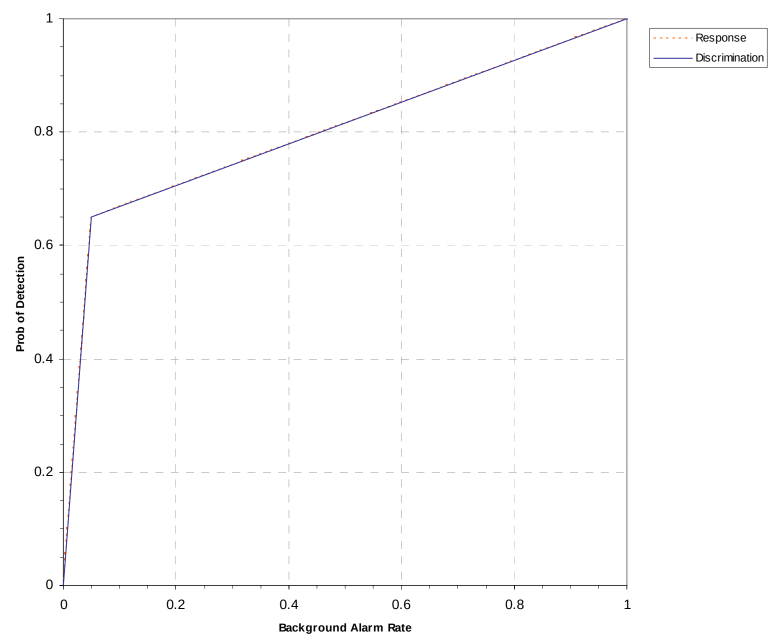

Figure 5. MAG AMOS/towed blind grid probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the blind grid 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 Tables 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 BLIND GRID 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	0.55	0.60	0.50	0.35	0.65	0.90	0.45	0.70	0.45
P_d Low 90% Conf	0.48	0.48	0.38	0.22	0.54	0.66	0.32	0.56	0.28
P_d Upper 90% Conf	0.64	0.69	0.66	0.47	0.78	0.99	0.60	0.80	0.66
P_{fp}	0.70	-	-	-	-	-	0.60	0.80	0.50
P_{fp} Low 90% Conf	0.63	-	-	-	-	-	0.49	0.71	0.20
P_{fp} Upper 90% Conf	0.76	-	-	-	-	-	0.70	0.87	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.60	0.50	0.35	0.65	0.90	0.45	0.70	0.45
P_d Low 90% Conf	0.48	0.48	0.38	0.22	0.54	0.66	0.32	0.56	0.28
P_d Upper 90% Conf	0.64	0.69	0.66	0.47	0.78	0.99	0.60	0.80	0.66
P_{fp}	0.70	-	-	-	-	-	0.60	0.80	0.50
P_{fp} Low 90% Conf	0.63	-	-	-	-	-	0.49	0.71	0.20
P_{fp} Upper 90% Conf	0.76	-	-	-	-	-	0.70	0.87	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: -9805.3.
Recommended Discrimination Stage Threshold: 1.00.

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

TABLE 5b. SUMMARY OF BLIND GRID RESULTS (FULL GROUND TRUTH)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.50	0.55	0.40	0.25	0.65	0.90	0.35	0.65	0.45
P_d Low 90% Conf	0.40	0.43	0.29	0.15	0.54	0.66	0.24	0.51	0.26
P_d Upper 90% Conf	0.55	0.63	0.52	0.34	0.78	0.99	0.47	0.74	0.63
P_{fp}	0.70	-	-	-	-	-	0.60	0.80	0.50
P_{fp} Low 90% Conf	0.63	-	-	-	-	-	0.49	0.71	0.20
P_{fp} Upper 90% Conf	0.76	-	-	-	-	-	0.70	0.87	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.50	0.55	0.40	0.25	0.65	0.90	0.35	0.65	0.45
P_d Low 90% Conf	0.40	0.43	0.29	0.15	0.54	0.66	0.24	0.51	0.26
P_d Upper 90% Conf	0.55	0.63	0.52	0.34	0.78	0.99	0.47	0.74	0.63
P_{fp}	0.70	-	-	-	-	-	0.60	0.80	0.50
P_{fp} Low 90% Conf	0.63	-	-	-	-	-	0.49	0.71	0.20
P_{fp} Upper 90% Conf	0.76	-	-	-	-	-	0.70	0.87	0.80
P_{ba}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: -9805.3.
Recommended Discrimination Stage Threshold: 1.00.

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 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	1.00	0.00	0.00
With No Loss of P_d	1.00	0.00	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 7). 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 types for the three example items are 20 mmP, 105 H, and 2.75 in., respectively.

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

Size	Percentage Correct
Small	0.0
Medium	0.0
Large	0.0
Overall	0.0

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

4.5 LOCATION ACCURACY

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

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

	Mean	Standard Deviation
Depth	-0.309	0.454

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	4.33	$411.35
Data analyst	1	57.00	4.33	246.81
Field support		28.50		
Subtotal				**$658.16**
Calibration				
Supervisor	1	$95.00	0.25	$23.75
Data analyst	1	57.00	0.25	14.25
Field support		28.50		
Subtotal				**$38.00**
Site survey				
Supervisor	1	$95.00	1.75	$166.25
Data analyst	1	57.00	1.75	99.75
Field support		28.50		
Subtotal				**$266.00**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	3.75	$356.25
Data analyst	1	57.00	3.75	213.75
Field support		28.50		
Subtotal				$570.00
Total				**$1532.16**

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, and downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO BLIND GRID DEMONSTRATION

No comparisons to date.

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

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

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

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 non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{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.

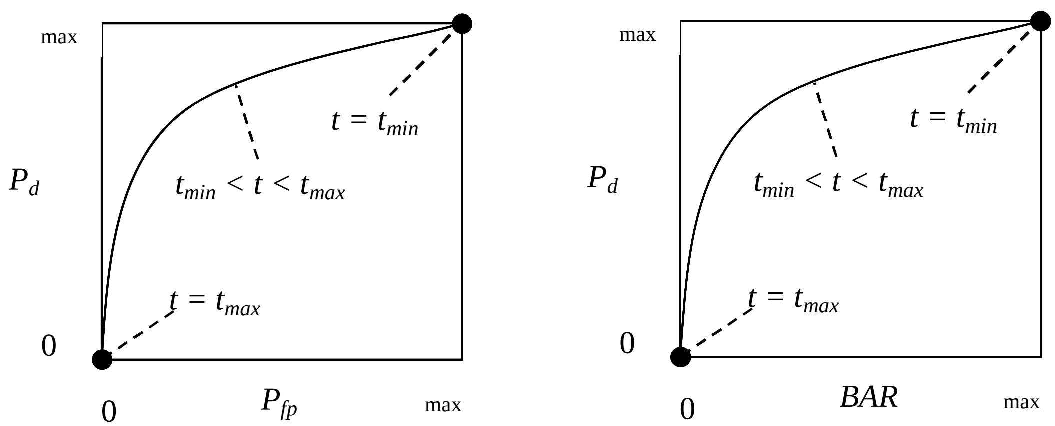

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

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[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 non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

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

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

Background Alarm Rejection Rate (R_{ba}):

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

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

CHI-SQUARE COMPARISON EXPLANATION:

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

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

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

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

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

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

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

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

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

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

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

APPENDIX B. DAILY WEATHER LOGS

Date, 2007	Time, EST	Average Temperature, °F	Total Precipitation, in.
16 April	0700	44.2	0.00
	0800	45.3	0.00
	0900	46.0	0.00
	1000	46.6	0.00
	1100	45.0	0.00
	1200	45.0	0.00
	1300	45.3	0.00
	1400	45.3	0.00
	1500	43.5	0.00
	1600	44.2	0.00
	1700	45.0	0.00
17 April	0700	45.1	0.00
	0800	45.7	0.00
	0900	46.6	0.00
	1000	47.3	0.00
	1100	49.3	0.00
	1200	52.7	0.00
	1300	54.1	0.00
	1400	53.4	0.00
	1500	52.9	0.00
	1600	52.3	0.00
	1700	52.2	0.00
18 April	0700	43.9	0.00
	0800	46.2	0.00
	0900	48.2	0.00
	1000	48.2	0.00
	1100	48.7	0.00
	1200	49.1	0.00
	1300	50.7	0.00
	1400	51.8	0.00
	1500	51.6	0.00
	1600	52.0	0.00
	1700	52.0	0.00
19 Apr	0700	48.0	0.00
	0800	49.6	0.00
	0900	50.7	0.00
	1000	50.4	0.00
	1100	51.3	0.00
	1200	53.1	0.00

Date, 2007	Time, EST	Average Temperature, °F	Total Precipitation, in.
19 April	1300	52.9	0.00
	1400	53.8	0.00
	1500	54.7	0.00
	1600	55.0	0.00
	1700	55.6	0.00
20 April	0700	44.8	0.00
	0800	51.6	0.00
	0900	56.7	0.00
	1000	59.9	0.00
	1100	63.0	0.00
	1200	65.5	0.00
	1300	66.7	0.00
	1400	67.8	0.00
	1500	68.9	0.00
	1600	69.6	0.00
	1700	70.3	0.00

APPENDIX C. SOIL MOISTURE

Date: 16 April 2007			
Times: 1000 through 1600			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	55.2	55.6
	6 to 12	48.7	49.8
	12 to 24	69.3	69.7
	24 to 36	68.7	69.3
	36 to 48	72.2	72.1
Wooded area	0 to 6	N/A	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open area	0 to 6	38.7	38.5
	6 to 12	39.3	39.4
	12 to 24	45.1	44.8
	24 to 36	48.3	48.6
	36 to 48	49.2	49.6
Calibration lanes	0 to 6	11.2	11.4
	6 to 12	15.9	15.7
	12 to 24	24.7	24.9
	24 to 36	28.9	28.8
	36 to 48	32.3	32.3
Blind grid/moguls	0 to 6	12.7	12.8
	6 to 12	10.2	10.4
	12 to 24	24.8	24.7
	24 to 36	18.8	18.9
	36 to 48	26.3	26.3

Date: 17 April 2007			
Times: 0900 through 1430			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	55.7	55.6
	6 to 12	48.7	49.8
	12 to 24	69.3	69.7
	24 to 36	68.7	69.3
	36 to 48	72.2	72.1
Wooded area	0 to 6	N/A	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open area	0 to 6	38.8	38.6
	6 to 12	39.7	39.8
	12 to 24	45.3	45.3
	24 to 36	48.9	48.7
	36 to 48	49.8	49.7
Calibration lanes	0 to 6	11.7	11.8
	6 to 12	15.8	15.5
	12 to 24	24.9	24.5
	24 to 36	29.2	29.1
	36 to 48	33.3	33.3
Blind grid/moguls	0 to 6	12.9	12.8
	6 to 12	10.7	10.6
	12 to 24	25.2	25.3
	24 to 36	19.4	19.1
	36 to 48	26.8	26.7

Date: 18 April 2007			
Times: 1000 through 1445			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	55.5	55.3
	6 to 12	48.6	48.6
	12 to 24	69.5	69.4
	24 to 36	68.9	68.8
	36 to 48	72.0	71.7
Wooded area	0 to 6	N/A	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open area	0 to 6	38.5	38.4
	6 to 12	39.7	39.5
	12 to 24	45.0	44.9
	24 to 36	48.4	48.3
	36 to 48	49.5	49.6
Calibration lanes	0 to 6	11.5	11.4
	6 to 12	15.7	15.6
	12 to 24	24.3	24.4
	24 to 36	29.1	28.7
	36 to 48	33.7	33.6
Blind grid/moguls	0 to 6	12.5	12.6
	6 to 12	10.5	10.4
	12 to 24	25.1	25.0
	24 to 36	18.9	18.8
	36 to 48	26.6	26.5

Date: 19 April 2007			
Times: 1000 through 1400			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	55.2	55.2
	6 to 12	48.5	48.4
	12 to 24	69.2	69.3
	24 to 36	68.6	68.4
	36 to 48	71.5	71.3
Wooded area	0 to 6	N/A	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open area	0 to 6	38.3	38.2
	6 to 12	39.4	39.3
	12 to 24	44.7	44.6
	24 to 36	48.2	48.1
	36 to 48	49.4	49.3
Calibration lanes	0 to 6	11.2	11.1
	6 to 12	15.5	15.3
	12 to 24	24.1	24.0
	24 to 36	28.5	28.4
	36 to 48	33.5	33.3
Blind grid/moguls	0 to 6	12.4	12.2
	6 to 12	10.3	10.3
	12 to 24	24.8	24.7
	24 to 36	18.6	18.5
	36 to 48	26.3	26.4

Date: 20 April 2007			
Times: 1100 through 1600			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	55.1	55.0
	6 to 12	48.1	48.1
	12 to 24	69.1	69.0
	24 to 36	68.4	68.1
	36 to 48	71.2	71.0
Wooded area	0 to 6	N/A	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open area	0 to 6	38.2	38.0
	6 to 12	39.3	39.1
	12 to 24	44.4	44.4
	24 to 36	48.0	47.7
	36 to 48	49.2	48.8
Calibration lanes	0 to 6	11.1	11.0
	6 to 12	15.2	15.2
	12 to 24	23.7	23.5
	24 to 36	28.2	28.1
	36 to 48	33.3	33.4
Blind grid/moguls	0 to 6	12.1	12.0
	6 to 12	10.2	10.1
	12 to 24	24.5	24.4
	24 to 36	18.2	18.1
	36 to 48	26.2	26.0

APPENDIX D. DAILY ACTIVITY LOG

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
4/16/2007	3	CALIBRATION LANES	830	1250	260	INITIAL SETUP	MOBILIZATION	GPS	LINEAR	RAIN MUDDY	WINDY
4/16/2007	3	OPEN FIELD	1250	1455	125	COLLECTING DATA	COLLECTING DATA 1/3 IN BLIND GRID AND 1/3 IN CAL LANE 1/3 IN OPEN FIELD, E TO W	GPS	LINEAR	RAIN MUDDY	WINDY
4/16/2007	3	OPEN FIELD	1455	1525	30	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	RAIN MUDDY	WINDY
4/17/2007	2	OPEN FIELD	720	815	55	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	MUDDY	WINDY
4/17/2007	2	OPEN FIELD	815	1310	295	COLLECTING DATA	COLLECT DATA	GPS	LINEAR	MUDDY	WINDY
4/17/2007	2	OPEN FIELD	1310	1430	80	BREAK/LUNCH	BREAK/LUNCH	GPS	LINEAR	MUDDY	WINDY
4/17/2007	2	OPEN FIELD	1430	1650	140	COLLECTING DATA	COLLECT DATA	GPS	LINEAR	MUDDY	WINDY
4/17/2007	2	OPEN FIELD	1650	1715	25	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	MUDDY	WINDY
4/18/2007	2	BLIND TEST GRID	715	800	45	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	MUDDY	CLOUDY
4/18/2007	2	BLIND TEST GRID	800	845	45	COLLECTING DATA	COLLECTING DATA 1/3 IN BLIND GRID AND 1/3 IN CAL LANE 1/3 IN OPEN FIELD, E TO W	GPS	LINEAR	MUDDY	CLOUDY
4/18/2007	2	BLIND TEST GRID	845	900	15	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	MUDDY	CLOUDY
4/20/2007	2	OPEN FIELD	715	935	140	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	MUDDY	SUNNY
4/20/2007	2	OPEN FIELD	935	1010	35	COLLECTING DATA	COLLECT DATA	GPS	LINEAR	MUDDY	SUNNY
4/20/2007	2	OPEN FIELD	1010	1355	225	DEMOBILIZATION	DEMOBILIZATION	GPS	LINEAR	MUDDY	SUNNY

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

APPENDIX E. REFERENCES

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

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

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

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

APPENDIX F. ABBREVIATIONS

ADST	=	Aberdeen Data Services Team
APG	=	Aberdeen Proving Ground
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test Support Services
BAH	=	Booz Allen Hamilton
DGPS	=	Differential Global Positioning System
DLMGPS	=	data link monitoring Global Positioning System
DMM	=	discarded military munitions
ERDC	=	U.S. Army Corps of Engineers Engineering 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
METDC	=	Military Environmental Technology Demonstration Center
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real time kinematic
SERDP	=	Strategic Environmental Research and Development Program
USAEC	=	U.S. Army Environmental Command
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground

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