



TECHNICAL PAPER

# STANDARDIZED UXO DEMONSTRATION SITES

## BLACKHAWK GEOSERVICES – SIMULTANEOUS MAGNETOMETRY AND PULSED EM/ MAN-PORTABLE – WOODS SCORING RECORD NO. 636



The Simultaneous Magnetometry and Pulsed EM in the man-portable platform is shown being demonstrated by Blackhawk Geoservices.

*The Simultaneous Magnetometry and Pulsed EM in the man-portable platform was demonstrated by Blackhawk Geoservices at the Aberdeen Proving Ground Standardized Demonstration Site's Woods Area.*

*This technical paper contains the results of that demonstration.*

*This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.*

### For more information

US Army Environmental Center  
Public Affairs Office  
410-436-2556, fax 410-436-1693  
e-mail: [usaecpao@aec.apgea.army.mil](mailto:usaecpao@aec.apgea.army.mil)  
<http://aec.army.mil>  
<http://www.uxotestsites.org>

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 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).

## DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

Simultaneous Magnetometry and Pulsed Electromagnetic (EM) recorded and controlled in one unit. The approach Blackhawk will demonstrate is a small hand towed trailer one-man EM/MAG system. The proposed AGS1-MK-II system will record four Cesium magnetometer sensors (Geometrics G822/A) as well as an EM61-MK-II system. The cesium vapor sensors will be sampled during the 'off' time of the EM pulse. When set for operation in 60 Hz power areas, the EM61 MK-II continuously emits electromagnetic pulses at a repetition rate of 75 Hz. Given a decay time of approximately 8 msec, this leaves a further 5 msec during which the larmor signals from the magnetometer systems can be counted and measured.

The AGS1-MK-II system uses proprietary counters implemented in FPGA (Field Programmable Gate Array) integrated circuits to measure the frequency of the larmor signal with a resolution of approximately 0.015 nT in a time of 5 msec. The actual measurement time used can be controlled by the operator from between 1.3 msec (resolution approximately 0.1nT) to 30 msec (0.001nT).

The sync output pulse of the EM61 MK-II is used to synchronize the counters of the AGS1-MK-II so that they begin a measurement of the larmor frequency at a programmable delay time after the falling edge of the 4 msec wide sync pulse.

The operation of the AGS1-MK-II and the recording of data is controlled over a single standard 115Kbaud RS232 link by a notebook PC running custom data acquisition software (AGS dat) under Windows 2000. The AGS1-MK-II uses

dual 32 bit embedded processors, each controlling 2 armor counters as well as sharing the handling of the data from the other sensors. The single logged file is then processed to give both a magnetic data grid and an EM data grid.

## PERFORMANCE SUMMARY

Results for the Woods test broken out by size, depth and nonstandard ordnance are presented in table below. 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. The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The Response Stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the Discrimination Stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and P<sub>fd</sub> was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results 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 the "Ferrous Only" table exhibits results based on the subset of the ground truth that is solely the ferrous anomalies. The second table exhibits results based on the full ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

## SUMMARY OF RESULTS FOR THE PULSED EM SENSOR

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>=1
<b>RESPONSE STAGE</b>									
P <sub>d</sub>	0.20	0.20	0.15	0.15	0.20	0.35	0.25	0.15	0.10
P <sub>d</sub> Low 90% Conf	0.15	0.15	0.08	0.08	0.12	0.21	0.17	0.08	0.03
P <sub>d</sub> Upper 90% Conf	0.23	0.27	0.22	0.19	0.28	0.52	0.30	0.21	0.28
P <sub>fa</sub>	0.25	-	-	-	-	-	0.20	0.30	0.25
P <sub>fa</sub> Low 90% Conf	0.24	-	-	-	-	-	0.18	0.28	0.14
P <sub>fa</sub> Upper 90% Conf	0.29	-	-	-	-	-	0.27	0.34	0.35
BAR	1.70	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
P <sub>d</sub>	0.20	0.20	0.15	0.15	0.20	0.35	0.25	0.15	0.10
P <sub>d</sub> Low 90% Conf	0.15	0.15	0.08	0.08	0.12	0.21	0.17	0.08	0.03
P <sub>d</sub> Upper 90% Conf	0.23	0.27	0.22	0.19	0.28	0.52	0.30	0.21	0.28
P <sub>fa</sub>	0.25	-	-	-	-	-	0.20	0.30	0.25
P <sub>fa</sub> Low 90% Conf	0.23	-	-	-	-	-	0.18	0.28	0.12
P <sub>fa</sub> Upper 90% Conf	0.29	-	-	-	-	-	0.26	0.34	0.32
BAR	1.50	-	-	-	-	-	-	-	-

Response Stage Noise Level: 1.00

Recommended Discrimination Stage Threshold: 0.00

## SUMMARY OF RESULTS FOR THE SIMULTANEOUS MAGNETOMETRY SENSOR

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>=1
<b>Ferrous only Ground Truth</b>									
<b>RESPONSE STAGE</b>									
P <sub>d</sub>	0.20	0.25	0.15	0.15	0.25	0.25	0.30	0.10	0.15
P <sub>d</sub> Low 90% Conf	0.17	0.17	0.10	0.09	0.19	0.13	0.24	0.06	0.04
P <sub>d</sub> Upper 90% Conf	0.26	0.30	0.27	0.23	0.38	0.41	0.40	0.18	0.32
P <sub>fa</sub>	0.35	-	-	-	-	-	0.35	0.35	0.30
P <sub>fa</sub> Low 90% Conf	0.31	-	-	-	-	-	0.30	0.29	0.17
P <sub>fa</sub> Upper 90% Conf	0.38	-	-	-	-	-	0.38	0.37	0.41
BAR	1.75	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
P <sub>d</sub>	0.20	0.25	0.15	0.15	0.25	0.25	0.30	0.10	0.15
P <sub>d</sub> Low 90% Conf	0.17	0.17	0.10	0.09	0.19	0.13	0.24	0.06	0.04
P <sub>d</sub> Upper 90% Conf	0.26	0.30	0.27	0.23	0.38	0.41	0.40	0.18	0.32
P <sub>fa</sub>	0.30	-	-	-	-	-	0.35	0.35	0.25
P <sub>fa</sub> Low 90% Conf	0.29	-	-	-	-	-	0.28	0.29	0.14
P <sub>fa</sub> Upper 90% Conf	0.35	-	-	-	-	-	0.38	0.37	0.37
BAR	1.45	-	-	-	-	-	-	-	-
<b>(Full Ground Truth)</b>									
<b>RESPONSE STAGE</b>									
P <sub>d</sub>	0.20	0.20	0.15	0.15	0.25	0.25	0.25	0.10	0.10
P <sub>d</sub> Low 90% Conf	0.15	0.17	0.08	0.08	0.19	0.13	0.19	0.07	0.03
P <sub>d</sub> Upper 90% Conf	0.24	0.28	0.22	0.19	0.38	0.41	0.33	0.19	0.29
P <sub>fa</sub>	0.35	-	-	-	-	-	0.35	0.35	0.30
P <sub>fa</sub> Low 90% Conf	0.30	-	-	-	-	-	0.29	0.29	0.19
P <sub>fa</sub> Upper 90% Conf	0.38	-	-	-	-	-	0.38	0.37	0.42
BAR	1.75	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
P <sub>d</sub>	0.20	0.20	0.15	0.15	0.25	0.25	0.25	0.10	0.10
P <sub>d</sub> Low 90% Conf	0.15	0.17	0.08	0.08	0.19	0.13	0.19	0.07	0.03
P <sub>d</sub> Upper 90% Conf	0.24	0.28	0.22	0.19	0.38	0.41	0.33	0.19	0.28
P <sub>fa</sub>	0.35	-	-	-	-	-	0.30	0.35	0.25
P <sub>fa</sub> Low 90% Conf	0.29	-	-	-	-	-	0.28	0.29	0.17
P <sub>fa</sub> Upper 90% Conf	0.35	-	-	-	-	-	0.37	0.37	0.39
BAR	1.45	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.00

Recommended Discrimination Stage Threshold: 0.00

## SUMMARY OF RESULTS FOR THE COMBINED SENSORS

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>=1
<b>RESPONSE STAGE</b>									
P <sub>d</sub>	0.25	0.30	0.20	0.15	0.30	0.35	0.20	0.15	0.20
P <sub>d</sub> Low 90% Conf	0.20	0.22	0.13	0.12	0.22	0.21	0.25	0.11	0.07
P <sub>d</sub> Upper 90% Conf	0.30	0.34	0.28	0.24	0.40	0.52	0.39	0.25	0.35
P <sub>fa</sub>	0.40	-	-	-	-	-	0.35	0.40	0.40
P <sub>fa</sub> Low 90% Conf	0.36	-	-	-	-	-	0.33	0.38	0.27
P <sub>fa</sub> Upper 90% Conf	0.42	-	-	-	-	-	0.42	0.44	0.51
BAR	2.55	-	-	-	-	-	-	-	-
<b>DISCRIMINATION STAGE</b>									
P <sub>d</sub>	0.25	0.25	0.20	0.15	0.30	0.35	0.20	0.15	0.20
P <sub>d</sub> Low 90% Conf	0.20	0.21	0.13	0.11	0.22	0.21	0.24	0.11	0.07
P <sub>d</sub> Upper 90% Conf	0.29	0.33	0.28	0.23	0.40	0.52	0.37	0.25	0.35
P <sub>fa</sub>	0.35	-	-	-	-	-	0.35	0.40	0.30
P <sub>fa</sub> Low 90% Conf	0.34	-	-	-	-	-	0.31	0.35	0.22
P <sub>fa</sub> Upper 90% Conf	0.40	-	-	-	-	-	0.40	0.44	0.45
BAR	2.00	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.50

Recommended Discrimination Stage Threshold: 0.00

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

To view the full Scoring Record for this demonstration and for all other demonstrations conducted at the Aberdeen and Yuma Proving Grounds in support of the Standardized UXO Technology Demonstration Sites Program please visit our Web site at:

[www.uxotestsites.org](http://www.uxotestsites.org)

