TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

TETRA TECH-FOSTER WHEELER GEONICS EM61 MKII/PUSHCART

BLIND GRID SCORING RECORD NO. 157

The Geonics EM61 MKII TDEM geophysical sensor, Arc Second Constellation (CST), and Leica Series 1100 Robotic Total Station (RTS) laser positioning system as demonstrated by Tetra Tech – Foster Wheeler, Inc.

The Geonics EM 61 MKII/Pushcart was demonstrated by Tetra Tech-Foster Wheeler, Inc. at the Aberdeen Proving Ground Blind Grid Area. This technical paper contains the results of that demonstration. This technical paper 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.

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, Maryland, and Yuma Proving Ground, 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 US Army Environmental Center. The US Army Aberdeen Test Center and the US Army Corps of Engineers Engineering Research and Development Center provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, and the Army Environmental Quality Technology Program.

DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

The Geonics EM61 MKII TDEM geophysical sensor, Arc Second Constellation (CST), and Leica Series 1100 Robotic Total Station (RTS) laser positioning systems were recently demonstrated at APG. The EM61 MKII uses time domain technology to facilitate the detection and discrimination of metallic objects. Two coils, 100 by 100 cm, are oriented in a horizontal coplanar fashion and separated by a vertical distance of 40 cm. The system utilizes either nonmagnetic wheels or a man-portable unit (terrain-dependent) with the lower coil 40 cm above the ground surface. In general, a transmit pulse of unipolar rectangular current (25 percent duty) of very short duration is applied to the lower coil. This primary current creates a primary magnetic field that induces eddy currents in nearby metal objects. The current flowing in the metal object creates a secondary magnetic field that is detected by both the lower and upper coils. The transmitter pulse frequency is 75 hertz (Hz), the pulse duration is 3.3 milliseconds, the peak power output is 50 watts, and the average power is 25 watts. Both coils possess zero decibels of gain.

The secondary magnetic field created by metal objects is sampled by the EM61 MKII electronics, which reside in the backpack, at times of 216 microseconds (ms), 366 ms, 660 ms on the bottom coil, and 660 ms on the top coil after the turn-off of the transmit pulse. Digital data for these four individual time gates

are integrated and recorded to a Juniper Allegro field computer at a rate of 12 Hz. The individual time gate data are converted into units of millivolts (mV), normalized, and gain is applied to each time gate by the EM61 MK2A software v1.22 on the Juniper Allegro field computer.

Safety hazards for the EM61 MKII equipment include electromagnetic radiation. The electromagnetic field of the system could potentially detonate some types of specialized ordnance. The hazards of electromagnetic radiation to ordnance (HERO) distance for the EM61 MKII is 20 cm. The US Army Corps of Engineers recommends a ground clearance of at least 40 cm when electrically fuzed ordnance is present.

The CST consists of four laser transmitters and a field computer for logging the position data via wireless modem. Four Trimble Spectra Precision LS920 Laser Transmitters are positioned in a diamond or square geometry over 1/2 to 1 acre depending on the tree density. The transmitters are leveled, and an automatic routine calculates the relative x-y-z plane between the transmitters to a tolerance of 1 inch or less. A laser detector "wand" (i.e., receiver) is centered over the EM61 MKII coils on a Tetra Tech Foster Wheeler (TtFW)-designed fiberglass doghouse. The detector wand receives the laser pulses from the four transmitters simultaneously, and computes a position based on the known position of the laser transmitters. Only two of the laser transmitters are necessary to compute a reliable position to a relative accuracy of approximately 1 inch. The position data are updated at 2 to 3 Hz and sent via wireless modem to the field computer for storage. The Leica Series 1100 RTS consists of a laser-based total station survey instrument (transmitter), prism (receiver), and RCS 100 remote control. The transmitter is positioned over a ground position point of known location, and an x-y-z Cartesian coordinate system is defined by occupying an additional known ground position with the receiver prism. The receiver prism is mounted on a TtFW doghouse centered over the EM61 MKII coils, and the RTS automatically tracks the prism at distances of several thousand feet to an accuracy of approximately 1 inch. Position data for the receiver prism are updated at a rate of 3 to 4 Hz and stored on a Personal Computer Memory Card International Association (PCMCIA) card located on the robotic total station.

In the densely wooded area, the CST laser-based positioning system was integrated with the EM61 MKII geophysical sensor, and used as a two-man tethered system, or in areas where the surface terrain was judged to be smooth, as a one-man cart. The four transmitters were organized in a diamond or square geometry over an area 1/2 to 1 acre in size, depending on the area-specific vegetation density. At least two of the laser transmitter locations were surveyed with the RTS instrument (located at a known control point) in order to position the data in the requested coordinate system.

The RTS laser-based system was used in conjunction with the EM61 MKII in the areas outside of the dense woods. The survey area was divided into two-acre plots (grids), and a wood survey lathe was positioned at predefined grid corners using the RTS.

For this demonstration, a transect spacing of no more than 2 to 2.5 feet was required when using the proposed geophysical sensor to detect and discriminate objects as small as 20-mm projectiles.

Performance Summary

Results for the Blind Grid test, broken out by size, depth, and nonstandard ordnance, are presented in the 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 ordnances emplaced. Depth is measured from the closest point of anomaly to the ground surface.

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 positives 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.

Blind Grid Scoring Summary

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.95	0.95	0.95	0.95	0.95	1.00	1.00	0.95	0.80
P_d Low 90% Conf	0.91	0.90	0.84	0.88	0.84	0.79	0.94	0.87	0.58
P_{fp}	0.85	-	-	-	-	-	0.85	0.80	1.00
P_{fp} Low 90% Conf	0.77	-	-	-	-	-	0.74	0.71	0.63
P_{bs}	0.10	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.75	0.85	0.65	0.85	0.70	0.80	0.90	0.80	0.35
P_d Low 90% Conf	0.70	0.76	0.53	0.74	0.55	0.55	0.81	0.67	0.19
P_{fp}	0.65	-	-	-	-	-	0.60	0.65	1.00
P_{fp} Low 90% Conf	0.58	-	-	-	-	-	0.49	0.56	0.63
P_{bs}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.0
Recommended Discrimination Stage Threshold: 1.0

Note: *The Response Stage noise level and recommended Discrimination Stage threshold values are provided by the demonstrator.*