TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

SHAW ENVIRONMENTAL, INC. UXO MAPPER EM61 PUSHCART

BLIND GRID SCORING RECORD NO. 199

The UXO Mapper EM61 Pushcart as demonstrated by Shaw Environmental, Inc. at the Yuma Proving Ground, Arizona.

The UXO Mapper EM61 Pushcart *was demonstrated by Shaw Environmental, Inc. at the Yuma Proving Ground Blind Grid 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.*

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

Shaw's geophysical mapping technology is an engineered combination of off-the-shelf geophysical sensors, innovative navigation technologies, a flexible/configurable deployment system, and customized data acquisition software. For this demonstration, an EM61 configuration has been selected. The Shaw UXO Mapper has both hardware and software components:

- Leica TSP1100 Robotic Total Station (RTS) for in-the-tree and open-area navigation
- Crossbow 3-axis gyro system
- Shaw's composite material cart-deployment system
- Off-the-shelf electromagnetic (EM61-MKII) sensor
- Software for the data acquisition system for sensor, navigation and gyro data collection
- Software to achieve robust navigation and sensor time-base synchronization
- Software to implement realtime telemetry and data merging

System hardware consists of four integrated components: 1) geophysical sensors such as an array of magnetometer or electromagnetic (EM) sensors (selected for this demonstration), 2) Shaw's composite-material cart survey system, 3) the Leica TPS1100 dual laser RTS, and 4) the Crossbow solid state gyro. Shaw's UXO Mapper was engineered as a mapping device that can be customized to adapt to a wide range of conditions seen on UXO sites.

Customizations available for survey optimization include the number, spacing, and height of the sensors; the number of wheels (2 or 4) and wheel diameter; the forward sensor distances relative to the wheel base; and handle configuration to push, pull, or tow the system, allowing the flexibility to customize the configuration of the equipment to respond to local site conditions and maximize data quality.

For navigation, the Shaw UXO Mapper uses RTS technology. The Leica TSP1100 RTS is a motorized robotic total station that uses automatic target recognition to track the location of the prism, and has a highly accurate distance/azimuth measurement system to produce +5 mm +2 ppm accuracy which translates to 0.25 inches (3-D) at distances up to 1400 feet.

The Shaw UXO Mapper has three software components. First, customized RTS firmware is used to track the roving prism. Developed specifically for Shaw's UXO mapping applications, this firmware allows for rapid collection of data to 4 hertz and outputs solutions to the base station and rover units. The firmware enables the user to optimize prism-tracking parameters for rapid recovery of lock if obstructed by trees during a survey. Second, Shaw's data control software determines precise time synchronization between the RTS and sensor time bases, ensuring accurate collection of all data. Third, Shaw's software for data merging accommodates various sensor navigation geometries used during data collection and provides a robust framework to spatially configure sensors relative to each other and with respect to the prism location. Additionally, this software allows RTS and sensor data to be merged in either a straightforward interpolation mode for open areas or in a hybrid switching mode that alternates to "dead reckoning" for the brief periods when the RTS is obstructed in the woods.

This composite and fiberglass cart system deploys magnetometers, gradiometers, or electromagnetic sensors. The device has been modified to replace the standard configuration of the EM61 cart system. This adaptation is critical to collection of high fidelity data, as the operator has enhanced control of the sensor in terms of sensor orientation.

Shaw's standard data processing includes data leveling, statistical data assessment, grid generation, and customized data filtering to accentuate target signatures. Shaw uses software from the sensor manufacturers, in-house software, and Geosoft's Oasis Montaj and UX-Detect Software and MATLAB to complete all tasks. Collected field data are downloaded from the data acquisition system as American Standard Code for Information Interchange (ASCII) XYZ files. Custom Shaw software is used to download the data and for initial review, generation of summary statistics, and conversion data formats, gridding, and analysis.

The EM data are analyzed in two ways. First, the location of the target is defined by defining the point of maximum response in the data. Next, the transient decay curve shapes, based on the four time gates in the EM data for each target, are modeled to define target type based on templates defined from known responses of various UXO and non-UXO control targets.

Shaw's target detection and analysis methods for the EM data form the basis of the target discrimination process.

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 detected and discriminated ordnance of a certain caliber range. The results are relative to the number of ordnances emplaced. Depth is measured from the geometric center of the 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.

Summary of Blind Grid Results

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.70	0.75	0.70	0.70	0.70	0.85	0.80	0.70	0.15
P_d Low 90% Conf	0.64	0.63	0.55	0.56	0.54	0.66	0.72	0.56	0.01
P_{fp}	0.85	-	-	-	-	-	0.85	0.95	0.00
P_{fp} Low 90% Conf	0.82	-	-	-	-	-	0.77	0.87	-
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.50	0.60	0.45	0.60	0.65	0.60	0.60	0.15
P_d Low 90% Conf	0.46	0.41	0.45	0.35	0.45	0.44	0.47	0.43	0.01
P_{fp}	0.60	-	-	-	-	-	0.60	0.70	0.00
P_{fp} Low 90% Conf	0.55	-	-	-	-	-	0.52	0.54	-
P_{ba}	0.00	-	-	-	-	-	-	-	-

Response Stage Noise Level: 3.40
Recommended Discrimination Stage Threshold: 6.95

Note: *The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.*

SERDP Strategic Environmental Research and Development Program · ESTCP · ARMY Environmental Quality Technology Program · Aberdeen Test Center