Aberdeen Proving Ground, Maryland

STANDARDIZED UXO DEMONSTRATION SITES

GEO CENTERS MULTI-SENSOR SURFACE TOWED ORDNANCE LOCATION SYSTEM (STOLS)

BLIND GRID SCORING RECORD NO. 40

The Multi-sensor STOLS was Demonstrated by GEO-CENTER, Inc.

MULTI-SENSOR STOLS

The STOLS is a Towed Vehicular array that was demonstrated at the Aberdeen Test Center by GEO-CENTER, Inc. This technical sheet contains the results of that demonstration. This technical sheet 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 Demonstration Sites Program.

BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground, 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 Standardize 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 simultaneous electromagnetic (EM) and magnetometry system (multisensor Surface Towed Ordnance Location System (STOLS)) is a towed vehicular array developed by GEO-CENTERS and CEHNC with funding from ESTCP under project UX-0208.

The system simultaneously collects both total field magnometer (Mag) data and EM61 data on a single towed platform. GEO-CENTERS' existing STOLS was used as a host system; the STOLS custom-fabricated aluminum dune buggy with a low magnetic self-signature, Mags, differential Global Positioning System (GPS), sensors, computers, and tractor-trailer for transportation were reused. The new simultaneous electromagnetic and magnetometry system augments STOLS with interleaved sampling electronics that allow EM61 coils to be physically located on the same platform as the Mags without corrupting the Mag data. The electronics monitor the rising edge of the 75-Hz transmit pulse from the EM61, waits 8 ms for the pulse to die down, samples the Mags for 5 ms, then waits for the next transmit pulse and repeats the cycle. Data acquired at McKinley Test Range (Redstone Arsenal, Huntsville) show that Mag data quality, with the EM system switched on, is commeasurate with Mag data quality when the EM system is switched off. Mag, EM61, and GPS data are acquired in a single file.

Along with new interleaved sampling electronics is a new proof-of-concept non-metallic tow platform to host both the EM61 coils and the Mags in a low-noise environment. Constructed almost entirely from fiberglass, the only metallic components on the platform are the axles, the hub, and a small number of aluminum pop rivets. The wheels are composite. Even the tires have had the metal beads removed. Total metallic mass has been reduced by over 99 percent by weight as compared to the original aluminum STOLS tow platform. Certain key structural locations have been reinforced with marine-grade plywood. The proof-of-concept platform was fielded successfully for a prove-out at McKinley Test Range. However, it should be noted that the platform was designed to fit into the existing budget for the ESTCP project, not for commercial surveys; it has no suspension, is speed-limited, and may not survive a fielding over rugged terrain without sustaining structural damage.

Five Geometrics 822A Mags updating and outputting at 75 Hz are deployed at 1/2 meter spacing. The Mags are 3 meters behind the tow vehicle. Three 1/2 meter Geonics EM61 coils (upper and lower) internally updating at 75 Hz and outputting at 10 Hz are deployed in a master/slave onfiguration on the rear of the platform, 2.5 meters behind the Mags, also at 1/2 meter spacing. The center line of the middle three Mags is coincident with the center line of the three EM61 coils. Both the Mags and the lower EM61 coils are mounted on pivots so they can swing up if they encounter an obstacle while moving forward.

Custom, Unix-based data processing software is used to process the file containing the Mag, EM61, and GPS data. The GPS updates are first automatically examined, and any jumps that could not occur at a nominal vehicle speed are flagged, allowing the operator to manually correct them. Sensor heading is calculated using smoothed position updates.

Mag and EM61 data are then processed separately, as they require different corrections. For the Mag data, the reference Mag recording the ambient variations of the Earth's magnetic field is time-correlated, then subtracted off. The data are then directionally divided into passes acquired in uniform directions (that is, north-going, south-going, west-going, and east-going, or whatever set of directions were used for the survey site).

For each major direction, an independent set of sensor offsets are calculated, and are then applied to that set of data to background-level the sensors and remove streaks in the image. A site-wide offset may also be applied if the reference Mag is over geology with a background different than that of the survey site.

EM61 background is not directionally dependent, but EM61 data is background-leveled individually by file to account for drift that may occur file-to-file.

Once the background-leveling corrections have been determined, data is processed as follows. Adjacent 1-Hz GPS updates are used to position the sensor array at the beginning and at the end of each second. From there, each sensor on the array can be positioned at each of its updates. An array is set up by the data processing software at a 10 cm cell spacing, and each sensor update is positioned into the appropriate cell in the array. A nearest-neighbor-inverse-distance-squared interpolation is used to fill in the intersensor spacing regardless of the direction of travel. The interpolated image is then displayed on the screen for analysis

Analysis of the Mag is performed using a nonlinear least squares match to a model of a point dipole with adjustable angles. Outputs from the model are object location, depth, magnetic moment, angle of incidence, and angle of orientation. On the basis of magnetic moment, an estimate is made of object size. For objects that do not resemble point dipoles because they are either too weak or too spatially extended, the object's location can be pinpointed using the mouse. An optional comment field may be added to each target.

Simultaneous viewing and analysis of the simultaneously-collected Mag and EM data is obtained by running two linked copies of the data processing software. Once linked, panning, zooming and scrolling in one set of data automatically pans zooms and scrolls in the other set, and drawing a region of interest in one set of data automatically draws the same region in the other set.

Data output is available in a variety of formats, including raw, corrected (navigation corrected and background-leveled), and interpolated.

PERFORMANCE SUMMARY

The data submitted by GEO-CENTERS consisted of three response stages, one from the pulsed EM sensor, one from a Mag sensor, and one for combined EM/MAG. The combined EM/MAG response stage data resulted from the Mag and EM data being visually fused and using human judgement to determine whether or not there was an object in the grid square. Due to the subjective nature of visually selecting targets, true signal responses do not exist.

Results for the blind grid test broken out by size, depth and nonstandard ordnance are presented 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 individual EM and Mag RESPONSE STAGE results were derived from the list of anomalies above the demonstrator-provided noise level. The combined EM/MAG RESPONSE STAGE results were derived by utilizing the demonstrator's provided classification (e.g. blank grid or ordnance in grid) that was visually selected based on human judgement. Due to combined EM/MAG data set not meeting the requirements to utilize the standard scoring software, the data was hand scored utilizing the same scoring rules specified in the site handbook. 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 the table below have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

BLIND GRID SCORING SUMMARY

				By Size			By Depth, m		
Metric	**Overall**	**Standard**	**Non-Standard**	**Small**	**Medium**	**Large**	**< 0.3**	**0.3 to <1**	**>= 1**
EM RESPONSE STAGE									
P_d	0.80	0.80	0.75	0.80	0.75	0.80	0.90	0.70	0.50
P_d Low 90% Conf	0.71	0.72	0.62	0.71	0.61	0.55	0.82	0.58	0.27
P_{fp}	0.85	-	-	-	-	-	0.85	0.90	1.00
P_{fp} Low 90% Conf	0.80	-	-	-	-	-	0.74	0.79	0.63
P_{ba}	0.50	-	-	-	-	-	-	-	-
MAG RESPONSE STAGE									
P_d	0.85	0.90	0.70	0.75	0.85	1.00	0.80	0.85	0.90
P_d Low 90% Conf	0.77	0.84	0.59	0.66	0.76	0.79	0.71	0.72	0.66
P_{fp}	0.90	-	-	-	-	-	0.90	0.90	1.00
P_{fp} Low 90% Conf	0.85	-	-	-	-	-	0.81	0.82	0.63
P_{ba}	0.70	-	-	-	-	-	-	-	-
COMBINED EM/MAG RESPONSE STAGE									
P_d	0.65	0.75	0.45	0.50	0.70	0.90	0.65	0.70	0.20
P_d Low 90% Conf	-	-	-	-	-	-	-	-	-
P_{fp}	0.75	-	-	-	-	-	0.70	0.75	1.00
P_{fp} Low 90% Conf	-	-	-	-	-	-	-	-	-
P_{ba}	0.10	-	-	-	-	-	-	-	-

Response Stage Noise Level: 2.00
Note: *The response stage noise level was provided by the demonstrator.*

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