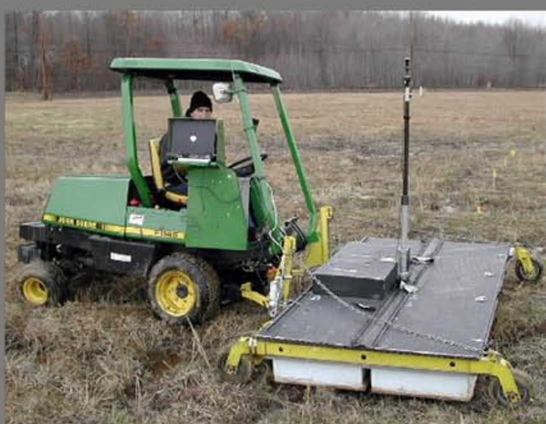
TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

WITTEN CART IMAGING SYSTEM

BLIND GRID SCORING RECORD NO. 45



The CART Imaging System was demonstrated by Witten Technologies, Inc. at Aberdeen Proving Ground, Maryland.

The CART Imaging System

is a syntheticapertur radar system that was demonstrated as a vehicular mounted platform by Witten Technologies, Inc. at the Aberdeen 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

The CART Imaging System is a new synthetic-aperture radar system designed for 3D underground imaging. The radar in the standard 200 MHz CART is down-looking, ultra-wideband impulse radar, with a pulse spectrum from about 50 to 400 MHz. (A prototype 400 MHz CART is available with pulse spectrum from about 150 to 650 MHz.)

The CART uses nine transmitters and eight receivers in two parallel rows to create an equivalent 16-channel (bi-static) ground-penetrating radar (GPR) array. Spacing between channels in the normal array is about 5 inches, so the ground swath covered by the array is about 6.25 feet wide (1.9 m). The physical antennas are bowties (linear dipoles) aligned along the direction of motion. The system can fire and collect all 16 channels once every 4 inches (measured along the direction of motion), while moving at speeds up to 1500 ft/hr (475 rn/hr).

To record positions, the CART uses a surveying instrument called a laser theodolite (also called a Geodimeter or total station). Positioning is accurate to a fraction of an inch over a range of several thousand feet, provided there is line of sight between a reflecting prism mounted on the radar unit and a base station. The positioning system allows the radar to move in arbitrary patterns over the ground to collect data on an irregular grid. Special algorithms re-grid the data and perform synthetic-aperture focusing in the two horizontal (cross-range) directions to create a 3D synthetic-aperture radar (SAR) image.

The first step in data acquisition was to establish a position for the base station of the survey Geodimeter. The position must have good lines of sight over the area surveyed. The parameters for the radar acquisition were then set:

- Time sampling: typically, 0.1 to 0.5 nanoseconds
- Total recording time: typically, 40 to 120 nanoseconds
- Inline sampling interval (along the direction of motion): typically, 2 to 4 inches
- Position tracking interval: typically, every 4 to 6 feet

Radar data acquisition then proceeds as the vehicle with the CART system drives over the site in an arbitrary pattern and the Geodimeter system records its position at the specified intervals. Data collection of a single profile is usually stopped after the vehicle proceeds a given distance, usually about 100 to 300 feet; and a new profile is started. This process repeats itself until the whole area is covered. In certain applications, where the polarization of the radar antennas could be important, the area will be covered a second time with the vehicle proceeding along profiles that are approximately perpendicular to the initial ones.

To provide a reference grid for the underground images, surface features, such as curb lines, manhole covers and trees, are surveyed when the radar data are collected and superimposed on the image. The final images, usually presented as horizontal slices through the ground at different depths, are provided electronically in various formats: images (.jpg), movies (.mov, .avi), or computeraided design (CAD) (.dwg, .dng).

Radar data are first processed to clean up the raw traces. This involves:

- Aligning data to a common zero-time reference
- Filtering to compensate for variations in antenna responses
- Filtering to remove unwanted signal reverberations within the CART

Special algorithms merge the positioning data (in a local coordinate system) and the radargrams, which are interpolated onto a uniform grid for synthetic-aperture focusing. Coherency analysis determines the best velocity for focusing energy in the subsurface. Focused (migrated) images are then produced in horizontal planes going down from the surface, usually in 1-inch depth increments. Features are extracted from the images by software that is guided by a human interpreter. Standard routines are used to look for coherent events (linear features or areas of high intensity) in the image. Radar images can be superimposed or correlated with other image data or maps to aid the interpretation.

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 or discriminating 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 positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in the table 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	0.70	0.70	0.70	0.55	0.75	1.00	0.60	0.95	0.40
P_d Low 90% Conf	0.63	0.60	0.59	0.46	0.61	0.79	0.49	0.83	0.19
P_{fp}	0.75	-	-	-	-	-	0.70	0.80	1.00
P_{fp} Low 90% Conf	0.69	-	-	-	-	-	0.58	0.71	0.63
P_{ba}	0.35	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.55	0.50	0.60	0.40	0.70	0.80	0.40	0.90	0.10
P_d Low 90% Conf	0.48	0.42	0.48	0.30	0.55	0.55	0.30	0.78	0.01
P_{fp}	0.60	-	-	-	-	-	0.55	0.62	0.60
P_{fp} Low 90% Conf	0.52	-	-	-	-	-	0.47	0.51	0.25
P_{ba}	0.15	-	-	-	-	-	-	-	-

Response Stage Noise Level: 13.00
Recommended Discrimination Stage Threshold: 53.00

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