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ERDC Countermine Phenomenology Program

3D Laser Scanner Data Collection

Linda Peyman Dove, Sam S. Jackson, Jerrell R. Ballard,
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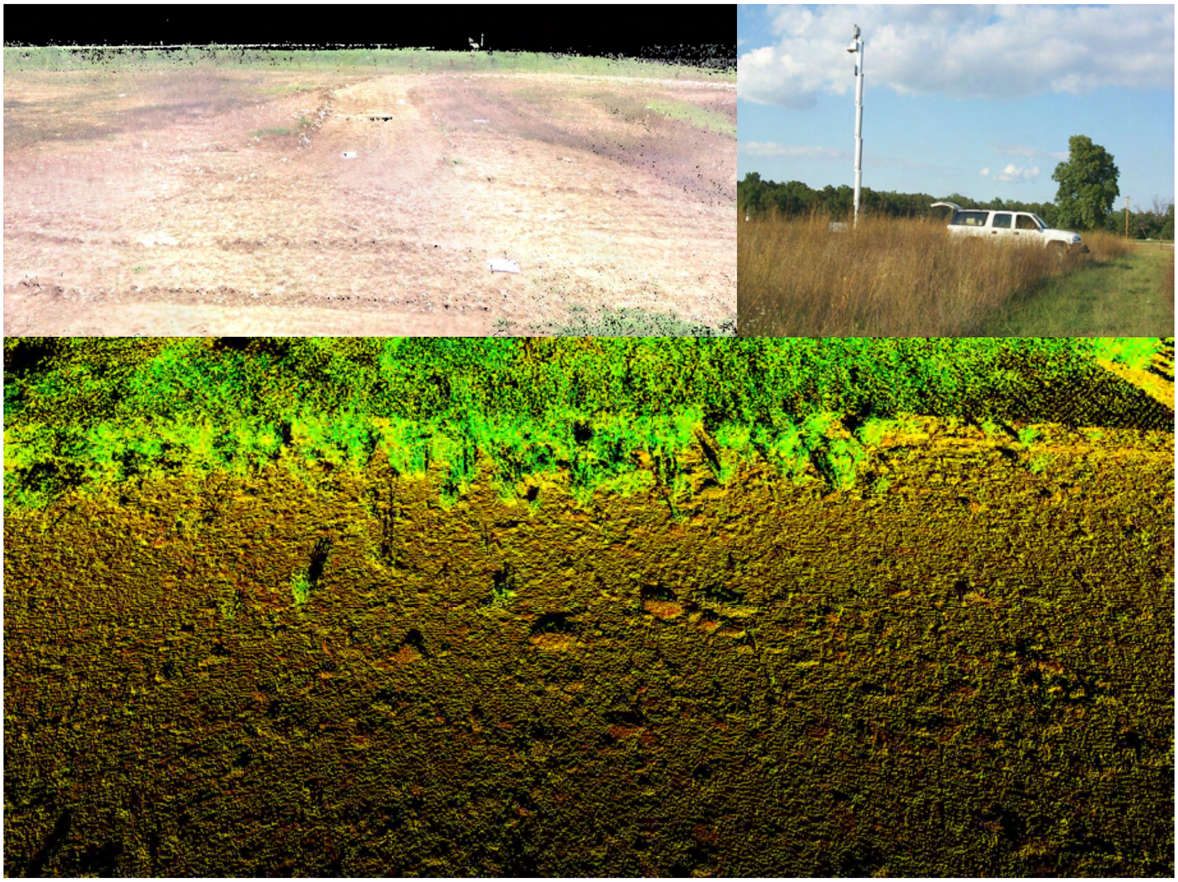
September 2007



Environmental Laboratory

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Final report

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Abstract: The objective of the Countermine Phenomenology Program is to increase the probability of detection and reduce false alarm rates by developing an understanding of the influences of the geo-environmental conditions on relevant mine and improvised explosive device signatures for sensor modalities. This involves the development and demonstration of more robust signal processing algorithms based on geo-environmental impacts.

3D laser scanner data were collected in order to obtain the high-resolution surface geometry necessary to determine subsequent impact on emitted thermal and reflective signatures. 3D laser scanner point clouds were used in the modeling and analysis for the computational testbed. Sites selected for the generation of high-resolution surface geometry consisted of widely varying environments at nine sites in desert and temperate environments.

The primary purpose of this report was to document procedures and measurements of the 3D laser scanner data and secondarily to provide a digital collection of the data so that the data may be used by other Army researchers in future research studies such as the ERDC Near Surface Phenomenology Program and other proposed 6.2 programs. The point cloud data file(s) for each site have been archived and are available for limited distribution.

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Preface

The field data collection and data analysis for the 3D laser scanner data described in this report were performed by personnel from the Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. This work was funded by the ERDC Countermine Phenomenology Program.

Dr. Larry Lynch, Geotechnical and Structures Laboratory (GSL), was the Program Manager for the ERDC Countermine Phenomenology Program. Dr. David A. Horner, GSL, was the Technical Director for the Countermine Phenomenology Program. Dr. Thomas Broach was the U.S. Army Night Vision and Electronic Sensors Directorate (NVESD) technical monitor for the Countermine Program. Jerrell R. Ballard, Jr. was the EL technical monitor for this effort and Principal Investigator for the Desert Road data collection. Thomas E. Berry, EL, was the Principal Investigator for the Desert Site and Temperate Site data collection. Data collection and analysis were performed by Berry, Ballard, and Sam S. Jackson, EL, and M. Elizabeth Lord, Bowhead Information Technology Services, Alexandria, VA.

The study was conducted under the general supervision of Mark Null, Chief, Environmental Systems Branch (ESB), EL; Dr. Dave Tazik, Chief, Ecosystem Evaluation and Engineering Division, EL; Dr. Beth Fleming, Director, EL; and Dr. David Pittman, Director, GSL. Reviews were provided by Mark R. Graves and Scott G. Bourne, ESB.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
kilotons (nuclear equivalent of TNT)	4.184	terajoules
knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

1 Introduction

Background

In FY04, the U.S. Army Engineer Research and Development Center (ERDC), in cooperation with the U.S. Army Night Vision Electronics and Sensors Directorate (NVESD), initiated a research program to address identified technology shortfalls in current and future countermine systems with respect to landmine and minefield detection. Future countermine systems will be required to operate in a wide range of geo-environmental conditions at a higher rate of advance than is currently achievable. One constraint on higher operational rates of countermine systems is the high false alarm rates experienced with the systems.

Objective

The objective of the Countermine Phenomenology Program was to increase the probability of detection and reduce the false alarm rate by (1) developing an understanding of the influences of the geo-environmental conditions on relevant mine and improvised explosive device (IED) signatures for sensor modalities, and (2) developing and demonstrating more robust signal processing algorithms based on geo-environmental impacts. These objectives were accomplished by developing and validating technologies to model, measure, and mitigate the effects of geo-environmental factors that impact the detection capabilities of mine, minefield, and IED detection sensors. The emphasis of the program was on understanding and predicting geo-environmental background and false alarm sources for high priority countermine sensing technologies. The validated technologies were integrated into a computational testbed to provide a scalable numerical laboratory to evaluate existing and emerging sensor technologies in realistic operational environmental conditions, to develop and test candidate signal processing and automated target recognition (ATR) algorithms, and to ultimately evaluate various combinations of sensor modalities in detection and identification of mines and IEDs.

Purpose

The purpose of this report is to document procedures used in the measured three-dimensional (3D) laser scanner field data collection and analysis. 3D laser scanner data were collected in order to obtain the high-resolution surface geometry necessary to determine the subsequent impact on emitted thermal and reflective signatures. The 3D laser scanner data were used in subsequent modeling and analysis for the computational testbed.

The secondary purpose of this report was to provide a digital collection of the data so that they may be used by other Army researchers in future research studies such as the ERDC Near Surface Phenomenology Program and other proposed 6.2 programs.

2 Description of Measured Field Data and Analyses

Background

The 3D laser scanner was used to collect data at nine sites during parts of July and August 2004, and March, June, July, August, October, November, and December 2005. Four of the sites were located in a desert environment while five of the sites were located in a temperate environment. The sites were selected because they represent different environments with diverse backgrounds. The sites include Desert Site A (desert grassy), Desert Site B (desert rocky), Desert Site C (desert rocky), a Desert Road Site, Temperate Site A (temperate dirt), Temperate Site B (temperate grassy), Temperate Site C (temperate dirt), Temperate Site D (temperate tall grassy), and Temperate Site E (temperate short grassy).

Site descriptions

Desert Site A

Desert Site A (Figure 1) represents a desert environment with fine sandy silt soil and a grassy cover. Desert site A was located in a year-round arid climate with soils deposited by an Eolian process. The area was flat and the soil texture did not change with depth; however, the soil density did increase 5 to 10 cm below the surface. Depending on the rainfall amounts, vegetation cover ranged from non-existent to completely grass covered at a height of 0.5 m. Data were collected at this site in June 2005.

Desert Site B

Desert Site B (Figure 2) represents a desert environment with Malpais soils. The Malpais series consists of very deep, well-drained soils that formed in alluvium and colluvium from mixed rock sources. Malpais soils are on alluvial fans and colluvial slopes bordering mountains (U.S. Dept. of Agriculture, April 2007). This site was adjacent to a small wash containing typical desert vegetation. Desert Site B consisted of well-graded gravel on the top 2 cm with a silty sand in the subsurface. Referred to as

Figure 1. Desert Site A.

Figure 2. Desert Site B.

desert pavement, the surface layer of Desert Site B was primarily loosely packed black to dark brown rocks ranging from 1 to 3 cm in diameter. Large boulders were scattered out 5 to 10 m apart. The site was flat and void of vegetation. Data from this site were acquired in June 2005.

Desert Site C

Desert site C consisted of scattered vegetation, primarily spots of short sage and bushes. The soils in the area consisted of sediment carried from nearby mountains. The soil was dark brown gravelly clayey sand. Rocks were rounded and scattered on the surface ranging in sizes from 0.5 to 4 cm in diameter. The soil was extremely dry and coarse. The soils between the surface and subsurface were relatively homogeneous. Nearby washes created slight undulations in the relatively flat area. Nearby washes ranged from 2-3 m in width and 1-2 m in depth. These washes are prone to flooding during rain events. Rainfall in the region was limited. Data from this site were acquired in July 2005.

Desert Road Site

The Desert Road Site (Figure 3) represents a road environment. The desert road site consisted of well drained, light gray, poorly graded gravel. The area had little to no slope. The road was well compacted with a subgrade consisting of the surrounding gravelly silt soils. The surface and subsurface were well compacted, suggesting a limited amount of voids and a short range of moisture contents between saturation and residual moisture content. Fine dust covered the road, due to the dry climate. Extremes in temperature along with winds provided for an extremely dry surface. Data from this site were collected in December 2005.

Figure 3. Desert Road Site.

Temperate Site A

Temperate Site A (Figure 4) is located in a temperate environment, encompassing a bare dirt field. The soils consisted of reddish orange, clayey sand which did not appear to be naturally deposited. The soil was dense and brittle making the collection of undisturbed soil samples difficult. The soil consisted of a clayey sand. Void of vegetation, the soil texture did not change with depth. The area had little to no slope. The data at this site were collected in November 2005.

Figure 4. Temperate Site A.

Temperate Site B

Temperate Site B (Figure 5) is representative of a grassy temperate environment. The soil was deposited by alluvial processes and consisted of cohesive, organic, dark brown clay. The area was on a slight 2-percent slope located near an undulation in the terrain. The site appeared to be well drained. The soil was homogenous to a depth of 1 m. The grass extended to a depth of 0.5 m. The data at this site were acquired in October 2005.

Figure 5. Temperate Site B.

Temperate Site C

Temperate Site C is representative of a site void of vegetation with a primarily rocky surface. The site is relatively flat, with the exception of a drainage ditch oriented north and south across the central, eastern half of the field. The site consists mainly of large boulders and smaller rocks with sparse patches of grass vegetation. The data at this site were acquired in August 2004, March 2005, and August 2005.

Temperate Site D

Temperate Site D (Figure 6) is representative of a tall grassy temperate environment. The grassy site has about a 5- to 10-percent grade with a northwest-facing slope. It is comprised mostly of thick grass with varying density and distribution over the field. The soil consisted of a lean clay with scattered rocks. The data at this site were acquired in July 2004.

Figure 6. Temperate Site D.

Temperate Site E

Temperate Site E is representative of a short grassy temperate environment. The soils in this area consisted of a lean clay. The data at this site were acquired in August 2004, and March and August 2005.

3D laser scanner data collection

Leica 3D laser scanner

A Leica HDS3000 3D laser scanner manufactured by Leica Geosystems HDS, Inc. (formerly Cyra Technologies) was used to provide a high-definition survey for the sites. The SmartScan Technology™ of this unit provides a maximum 360° horizontal field of view and a maximum 270° vertical field of view. The scanner emits rapid pulses of green (523 nm) laser light that sweeps across the landscape and sends back numerous measurements with precise x, y, and z coordinates, each having an associated RGB color and intensity value. The scanner enables point clouds to be captured that correspond to true point positions where the laser pulse hits the object. The point cloud represents the shape and position of the objects scanned relative to the position of the scanner (Cyra Technologies 2004). Table 1 summarizes the scanner specifications.

Table 1. Specifications for the Leica HDS3000 3D laser scanner.

Field of view	360° H x 270° V
Positional accuracy	6 mm at 50 m
Wavelength	523 nm
Spot size	< 6 mm at 50 m
Pulse rate	1000 points/sec effective to 100 m
Max point cloud density	1.2 mm

The operating software used in conjunction with the laser scanner during data acquisition was Cyclone version 5.0. The Cyclone software provides the capability to visually interpret and process the data and then integrate the collected information into useful geospatial formats.

3D laser scanner data collection area and setup

Table A1 provides details of the 3D laser scanner data collected at each site. For all Desert Sites and Temperate Sites A and B, data were collected in a 10-m by 15-m area at a scan density of 5 mm by 5 mm. Data at Temperate Site C were collected in a 45-m by 45-m area at a scan density of 1.5 cm by 1.5 cm, in a 40-m by 320-m area at a scan density of 2 cm by 2 cm, and in 10-m by 15-m areas at a scan density of 5 mm by 5 mm. For Temperate Site D, data were collected in an area 40 m by 160 m at a scan density of 5 cm by 5 cm. For Temperate Site E, data were collected in a 45-m by 45-m area at a scan density of 1.5 cm by 1.5 cm and in 10-m by 15-m areas at a scan density of 5 mm by 5 mm.

For Desert Sites A and B, the Desert Road Site, and Temperate Sites A and B, the 3D laser scanner data were collected in the same areas where thermal imagery was collected for the Countermine Phenomenology Program (Peyman Dove et al., in preparation).

Various features (undisturbed soil, disturbed soil, target(s), and vegetation) were located at each site. A disturbed soil feature is an area disturbed deep enough to bury the desired target. The soil is flipped over when placed back in the hole. Small metal, large metal, and large plastic targets were used.

The 3D laser scans were conducted for each site before and after the targets were placed or areas were disturbed. These are called preliminary and post scans, respectively. (Both preliminary and post scans were not conducted at all sites. Please see Table A1 for details on whether preliminary and post scan data are available for a particular site and timeframe.)

To obtain an unobstructed viewing angle from the 3D scanner locations, the scanner was positioned on a trailer-mounted boom system. (A boom system was not used at the desert sites since they were flat and the boom system did not appear necessary. However, it was later found that the bare earth could not be seen through the grass at Desert Site A. If the boom system had been used, the bare earth probably would have been visible.) For Temperate Sites C, D, and E, the boom system was made of aluminum with a chain-driven lift (Figure 7). The 3D laser scanner was raised to approximately 7.6 m above the ground, which resulted in 30- to 50-degree measurement angles. Temperate Sites C, D, and E represented the first time the 3D laser scanner was used by the ERDC for the Countermine Phenomenology Program. Experience obtained from these sites provided knowledge for improvements to the system. For example, it was found that the aluminum used to construct the boom system expanded in the heat; therefore, the boom system was altered to a plywood scaffolding system (Figure 8) at Temperate Sites A and B.

Figure 7. Trailer-mounted setup of Leica 3D laser scanner at Temperate Site D.

Figure 8. Trailer-mounted setup of Leica 3D laser scanner plywood scaffolding boom system.

3D laser scanner target acquisition and site scans

Once the 3D scanner was set up at the appropriate location, a high-resolution picture image of the viewing area was captured using the 3D scanner's built-in camera (Figure 9). This allowed the surveyor to preview the area to be scanned.

Target acquisition

Cyra registration targets (Figure 10) were used with the Leica laser scanner to serve as tie points to register the scanner data into a single point cloud representing each site. Flat Cyra registration targets were initially used but hemisphere Cyra registration targets were subsequently used and found to be preferable. The SmartScan Technology allowed the scanner to automatically identify the Cyra registration targets without operator intervention. Once the scanner identified the Cyra registration target, a geometric center of the target was computed automatically (Leica Geosystems 2007).

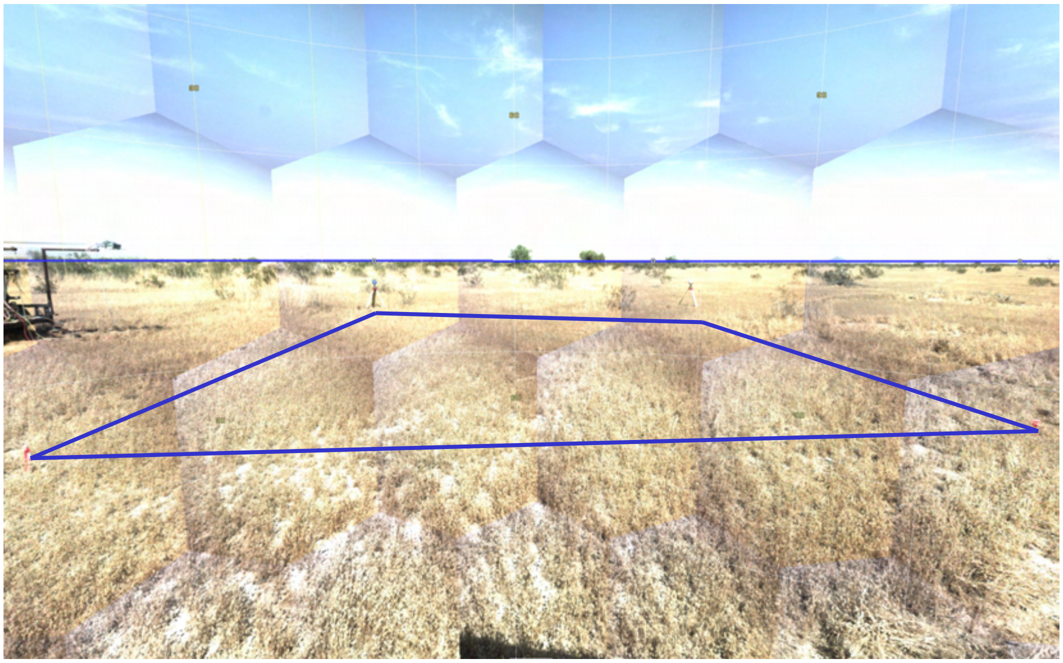

Figure 9. High-resolution picture image at Desert Site A captured using the scanner's built-in camera. (The desired 10-m x 15-m area of acquisition is outlined in blue. This line was added for clarity and was not a feature of the scanner's built-in camera.)

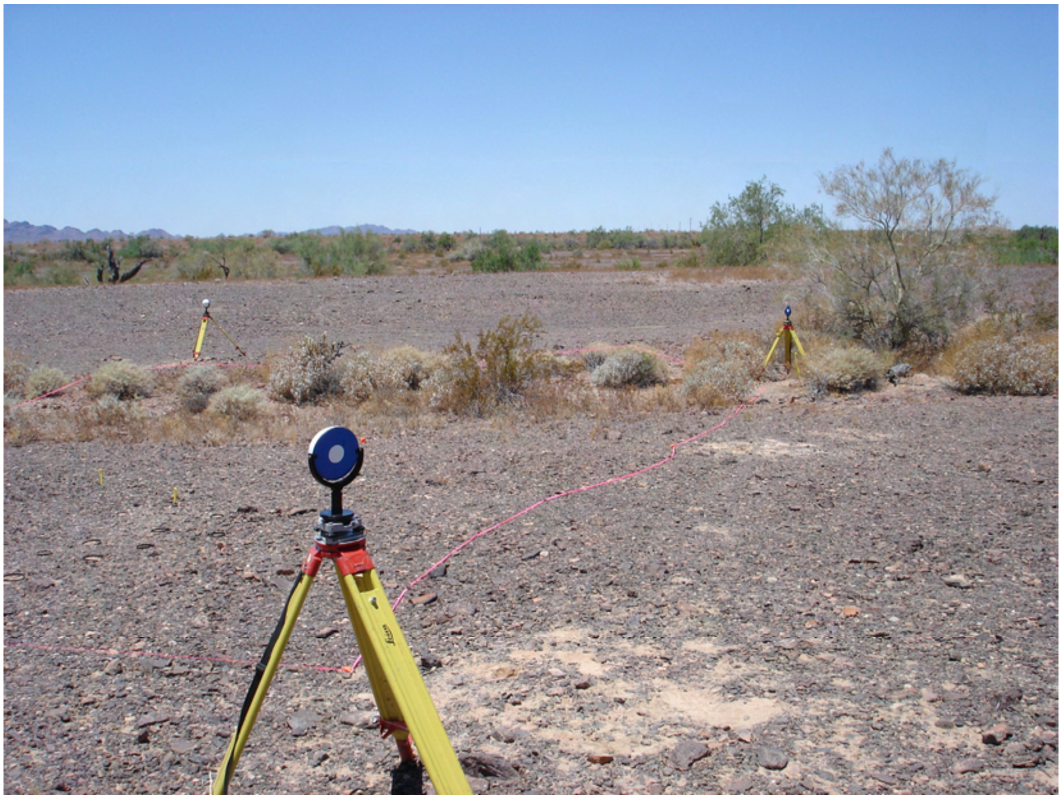

Figure 10. Cyra hemisphere registration target.

A minimum of three Cyra registration targets were placed at each scanner setup in order to have sufficient tie points to register all of the scanner locations into a single point cloud representing each site. Each Cyra Registration target was positioned at opposite extents of the site and served as common targets for additional scanner setups. Each tie point was labeled with a unique registration identification.

All corresponding Cyra registration targets within the effective scan range (< 100 m) were probed with the scanner prior to acquisition to determine the approximate distance to the target. To obtain a tie point with minimal deviation from the center of the target, the target had to be scanned with a sufficient density of postings in the object's center. Once a point was manually selected that was close to the target's center, the scanner performed a coarse scan to locate the center circle and then proceeded with a fine scan (~1.2 mm spacing) to locate the exact center. A vertex was placed at the perceived center of the Cyra registration target, representing the tie point (Figure 11).

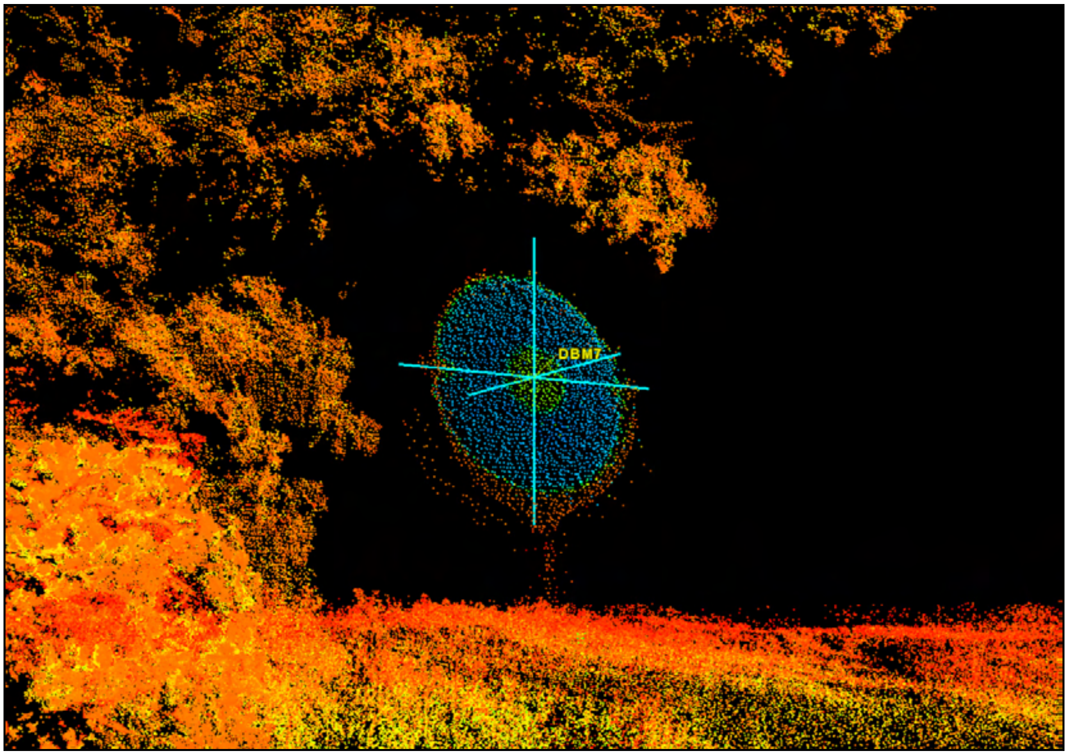

Figure 11. Tie point generated from precise Cyra registration target acquisition. Posting color represents multi-hue intensity of each laser return. High intensity appears blue and low intensity appears red.

Site scans

The site was scanned after the Cyra registration targets were located. Typically, several scan setups were needed to obtain data for each site. Approximately a 10-percent edge overlap at each scanner setup extent was used. Scan resolution at the 10-m by 15-m and 45-m by 45-m sites ranged from 5 mm to 1.5 cm and for the larger sites (Temperate Sites C and D) the scan resolution was 2 cm and 5 cm, respectively. Figure 12 depicts a small portion of the scan at Temperate Site C and depicts the point cloud representation of the large metal targets at the site.

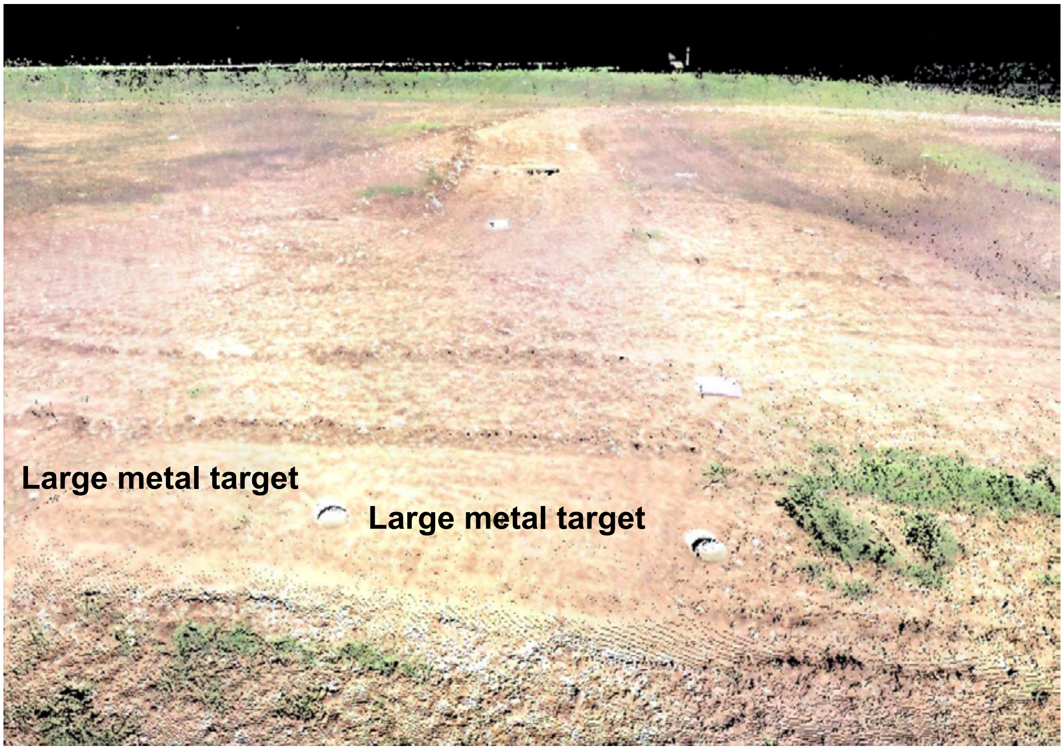

Figure 12. Graphical depiction of scanned Temperate Site C showing surface metal targets. True-color laser postings are spaced every 2 cm.

3D laser scanner data processing

A 3D, continuous point cloud of each site was generated by coregistering each scanner setup location's point cloud and referencing it to a common coordinate system.

3D laser data registration

Registration is a method that aligns many individual point clouds into a single georeferenced point cloud to represent the entire site. The registration process uses mathematical algorithms that compute the optimal alignment transformations for each point cloud in the registration so that the point clouds are aligned as closely as possible in the resulting point cloud (Cyra Technologies 2004). Cyra registration targets placed at the extent of each setup site served as tie points in the registration process. The tie points that were common to adjacent point clouds were fitted together to establish an accurate relationship between each of the point clouds. The software used an algorithm that locates tie points that are geometrically consistent, to find the optimal solution.

After registering the point clouds together for each site, the single point cloud was then georegistered to the Universal Transverse Mercator (UTM) projection using the North American Datum 1983 (NAD83). Surveyed coordinates of specific Cyra registration targets used in the registration process were collected to millimeter accuracies with a Real Time Kinematic (RTK) Global Positioning System (GPS). Each Cyra registration target's position was identified to a minimum of 10 mm horizontal accuracy. A minimum of three surveyed Cyra registration targets with known coordinates was used for each site and corresponded to all relative point clouds. (GPS coordinates were not available for Temperate Sites C and E, except for the Temperate Site C data collected in August 2004. Thus, for almost all of Temperate Sites C and E, the point clouds are provided in local coordinates.)

Surface analysis

After the georegistered point clouds were generated for each site, surface analysis techniques were used to develop products such as digital contour maps and terrain models. These products provide 3D visualization of the background phenomenology and enable analysts to measure topographic variations within the site.

The vegetation and background data were manually extracted from the point clouds in order to develop a file representing bare ground. For Temperate Sites C and D, manual extraction as well as the "region grow" algorithm in the Cyclone software were used to extract the vegetation and background data to generate a point file of the bare ground.

The "region grow" algorithm uses a subset of individual laser data points (5 to 9) that are representative of relatively flat, bare ground from a centralized area within a site's point cloud. The surface-smoothing algorithm segments the point cloud to form a horizontally expanded, planar point cloud indicative of the terrain geometry. The algorithm operates based on fit calculation parameters that are user-specified and continues until all assumed non-ground data points are effectively isolated from the remaining ground points. The primary surface parameters involved in this process include (1) region thickness thresholding, which defines the range of data points to be surfaced as ground, (2) surface angle tolerance to account for areas of high relief, and (3) gap distance, which defines the maximum distance allowed between portions of the same smooth surface. Since some points were not properly identified using the region grow algorithm, they were manually edited until satisfactory results were obtained (Jackson and Bishop 2005).

After all assumed vegetation was removed and the ground surface points were identified, the points representing bare ground were used to create a Triangulated Irregular Network (TIN) using Environmental Systems Research Institute (ESRI) ArcGIS 9.1 software (ESRI 2007). An elevation contour map was produced from the TIN, with the contour interval specified by the software operator. An example of a contour map for Temperate Site C is shown in Figure 13. A regularly spaced sample grid was then generated from the original TIN layer to provide a digital terrain model.

For Temperate Site D, an additional analysis procedure was used due to the dense vegetation at the site. A vegetation height map was produced to better quantify the background component of the site (Figure 14). Laser data points representative of the site were exported from the Cyclone software as an x, y, and z comma-separated text file. This text file was then imported into a custom application written specifically for this vegetation height extraction.[1] The application was designed to distinguish and isolate assumed ground hits and maximum vegetation height hits. The application extracts laser data from the lowest 10 percentile using each hit's elevation (z) value and then averaging those within a cell size of 1 m^2. This is the assumed ground. Likewise, laser data from the top 10 percentile were extracted by z value, averaged, and then output as a single point representing the average maximum vegetation height for that 1-m^2 cell.

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[1] Personal communication 2004, R. E. Melton, Jr., Computer Engineer, JAYA Corporation, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

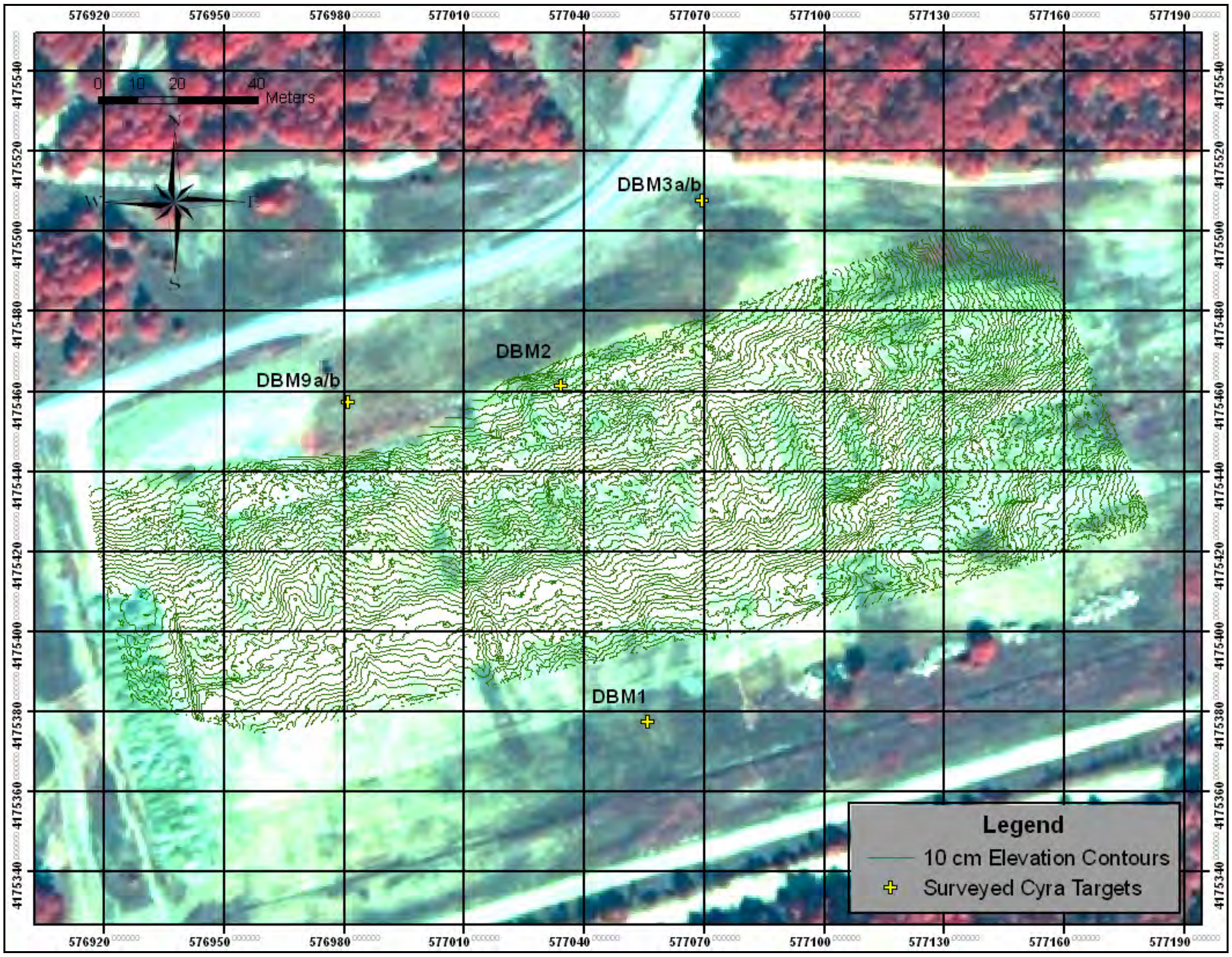

Figure 13. Ground elevation contour map (10-cm interval) detailing the micro topography representative of the Dirt Site.

The output, x and y values for the center of each cell and an average elevation value, were uploaded into an ESRI point shapefile. Vegetation height was calculated by subtracting the assumed ground elevation points from the assumed vegetation elevation points. These new elevation point values were the representative vegetation height value for each 1-m cell center, which were used to generate a grid of the site (Jackson and Bishop 2005).

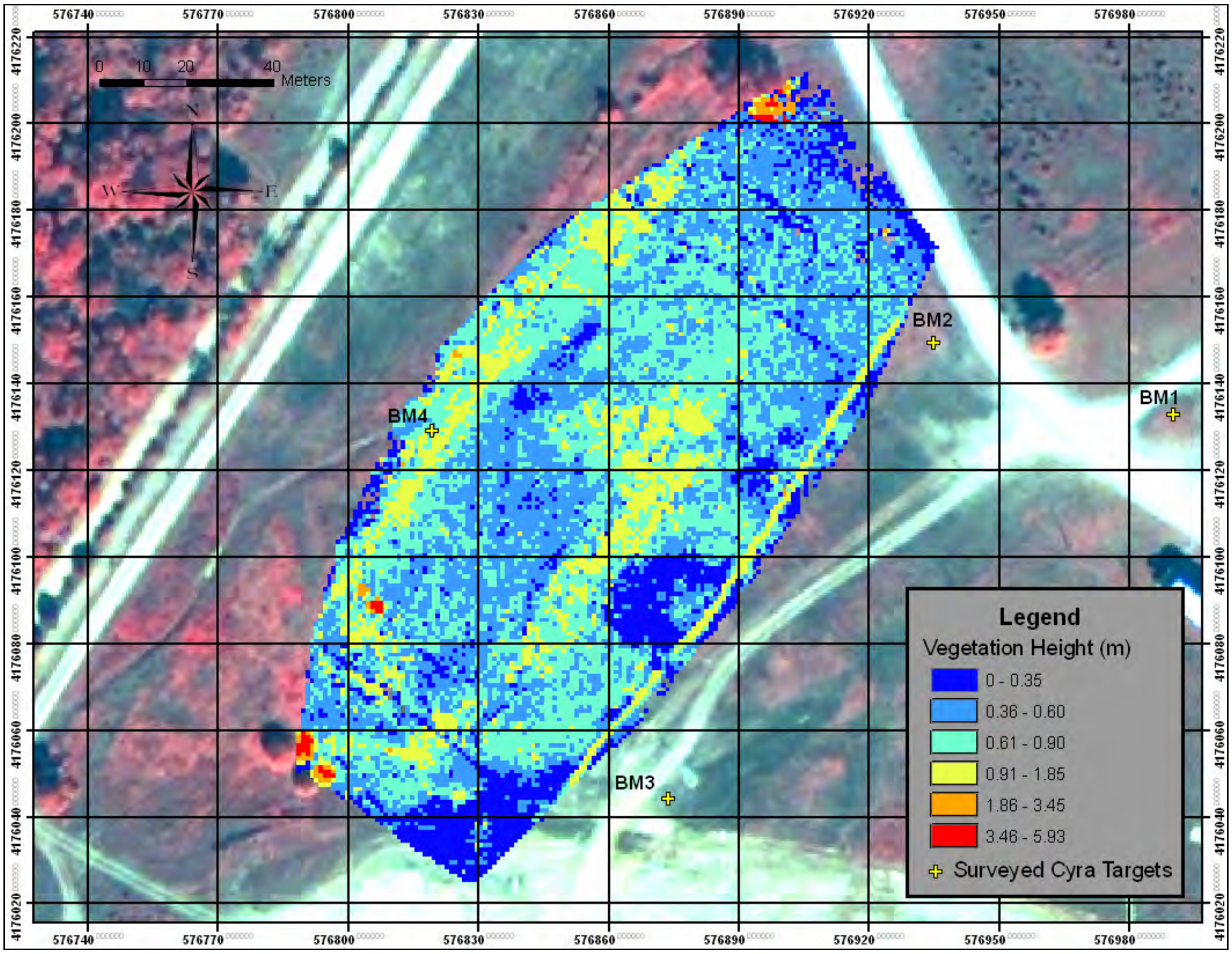

Figure 14. Vertical view of Temperate Site D depicting vegetation height in meters. The image portrays a chromatic sequence with lower vegetation heights appearing blue and higher vegetation heights appearing red.

3 Summary

The objective of the Countermine Phenomenology Program was to increase the probability of detection and reduce the false alarm rate by developing an understanding of the influences of the geo-environmental conditions on relevant mine and improvised explosive device (IED) signatures for sensor modalities. Also, the objective involved the development and demonstration of more robust signal processing algorithms based on geo-environmental impacts. The Countermine Phenomenology Program was divided into three major categories: measured field data and analysis, modeling, and computational testbed development.

Within the measured field data and analysis category of the Countermine Phenomenology Program, 3D laser scanner data were collected in order to obtain the high-resolution surface geometry necessary to determine the subsequent impact on emitted thermal and reflective signatures. The 3D laser scanner point clouds were used in the modeling and analysis for the computational testbed. Sites selected for the laser characterization consisted of widely varying environments at nine sites in desert and temperate environments. Four of the study sites were located in a desert environment while five of the sites were located in a temperate environment.

The point cloud data file(s) for each site have been archived and are available for limited distribution. Appendix A provides information on the name of the file, scan density, size of the area where data were collected, date of collection, and the UTM zone where the data are located or whether the data are provided in local coordinates.

References

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Appendix A: 3D Laser Scanner Data Dictionary

The 3D laser scanner point cloud data files for each site have been archived in a .txt file format on a compact disk. The point clouds are named according to the site, date of collection, and whether it was a preliminary or post scan (e.g., Temperate_Site_A_Nov05_prescan). (A preliminary scan was not done at all sites and therefore there is not a preliminary scan file for all sites. Also, for all scans conducted in March 2005 at Temperate Sites C and E, no targets were placed and sites were not disturbed; therefore, these scans are considered preliminary scans with no follow-on post scans). For the scans conducted at Temperate Sites C and E in March and August 2005, no GPS coordinates were collected and thus the data are in local coordinates.

Table A1 provides the name of the file, scan density, size of the area where data were collected, date of collection, and the UTM zone where the data are located or whether the data are provided in local coordinates. Distribution of these data is authorized to U.S. Government agencies only. Requests for the data should be made to the Environmental Systems Branch, Ecosystem Evaluation and Engineering Division in the Environmental Laboratory at the U.S. Army Engineer Research and Development Center (CEERD-EE-C).

Table A1. 3D laser scanner data point files.

File Name	Scan Density	Size of Area	Date of Collection	UTM Zone
Desert_Site_A_Jun05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Jun 05	12
Desert_Site_A_Jun05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Jun 05	12
Desert_Site_B_Jun05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Jun 05	11
Desert_Site_B_Jun05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Jun 05	11
Desert_Site_C_Jul05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Jul 05	11
Desert_Site_C_Jul05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Jul 05	11
Desert_Road_Site_Dec05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Dec 05	11
Desert_Road_Site_Dec05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Dec 05	11
Temperate_Site_A_Nov05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Nov 05	18
Temperate_Site_A_Nov05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Nov 05	18
Temperate_Site_B_Oct05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Oct 05	18
Temperate_Site_B_Oct05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Oct 05	18
Temperate_Site_C_Aug04_postscan.txt	2 cm x 2 cm	40 m x 320 m	Aug 04	15
Temperate_Site_C_Mar05_prescan.txt	1.5 cm x 1.5 cm	45 m x 45 m	Mar 05	Local
Temperate_Site_C_Mar05_prescan.txt (Note that there are three 10-m x 15-m areas within this scan that are at a 5-mm x 5-mm scan density.)	1.5 cm x 1.5 cm	45 m x 45 m	Mar 05	Local
Temperate_Site_C2_Aug05_prescan.txt	5 mm x 5 mm	10 m x 15 m	Aug 05	Local
Temperate_Site_C2_Aug05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Aug 05	Local
Temperate_Site_D_Jul04_postscan.txt	5 cm x 5 cm	40 m x 160 m	Jul 04	15
Temperate_Site_E_Mar05_prescan.txt	1.5 cm x 1.5 cm	45 m x 45 m	Mar 05	Local
Temperate_Site_E_Mar05_prescan.txt (Note that there are three 10-m x 15-m areas within this scan that are at a 5-mm x 5-mm scan density.)	1.5 cm x 1.5 cm	45 m x 45 m	Mar-05	Local
Temperate_Site_E2_Aug05_postscan.txt	5 mm x 5 mm	10 m x 15 m	Aug 05	Local

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14. ABSTRACT

The objective of the Countermine Phenomenology Program is to increase the probability of detection and reduce false alarm rates by developing an understanding of the influences of the geo-environmental conditions on relevant mine and improvised explosive device signatures for sensor modalities. This involves the development and demonstration of more robust signal processing algorithms based on geo-environmental impacts.

3D laser scanner data were collected in order to obtain the high-resolution surface geometry necessary to determine subsequent impact on emitted thermal and reflective signatures. 3D laser scanner point clouds were used in the modeling and analysis for the computational testbed. Sites selected for the generation of high-resolution surface geometry consisted of widely varying environments at nine sites in desert and temperate environments.

The primary purpose of this report was to document procedures and measurements of the 3D laser scanner data and secondarily to provide a digital collection of the data so that the data may be used by other Army researchers in future research studies such as the ERDC Near Surface Phenomenology Program and other proposed 6.2 programs. The point cloud data file(s) for each site have been archived and are available for limited distribution.

15. SUBJECT TERMS

Countermine Phenomenology Program	Point clouds
ERDC Near Surface Phenomenology Program	3D laser scanner data

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