SURFACE UNEXPLODED ORDNANCE DETECTION VIA AN ACTIVE/PASSIVE MULTISPECTRAL LINE SCANNER SYSTEM AT YUMA PROVING GROUND, ARIZONA

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ABSTRACT

This paper describes the use of a helicopter-mounted multispectral line scanner system as a tool for detecting unexploded ordnance (UXO) at the terrain surface. The system, called the REmote MInefield Detection System (REMIDS), consists of an active/passive multispectral line scanner, real-time processing and display equipment, and navigational equipment. The system is evaluated at Yuma Proving Ground (YPG), Arizona, in a blind demonstration. The evaluation test grid at YPG used in the demonstration is a 500- by 1,000-m area covered with hundreds of inert items on the surface. The items consist of mines, grenades, rockets, mortars, projectiles, bombs, and scrap. The performance of the system with respect to the detection of the different classes of items will be presented. The adaptation of this minefield detection system will help aid in the cleanup of Department of Defense (DoD) sites with UXO contamination. The use of airborne remote detection minimizes the risk to personnel during the environmental assessment and analysis of the site. The system collects three channels of optically aligned image data consisting of two active laser channels, one polarized reflectance and the other total reflectance, and one passive thermal infrared channel. The real-time processing and display system is based on parallel processor technology. The system can be flown at various altitudes and forward speeds to characterize sites for the presence of surface UXO. The system also incorporates onboard recording and the insertion of differential Global Positioning System (GPS) coordinates. GPS coordinate information will allow contaminated areas to be added into a Geographical Information System (GIS). The detection is based on the remote identification of surface anomalies and materials that indicate the presence of surface UXO contamination. The demonstration is funded by the Environmental Security Technology Certification Program (ESTCP) and managed through the Army Environmental Center (AEC). The system shows promise in the secondary use of surface UXO detection.

INTRODUCTION

An increasing need for dual-use or multiuse technology exists because of current and anticipated DoD budget reductions. Through funding from ESTCP, REMIDS is now being evaluated for the secondary use of surface UXO detection. The demonstration is a blind demonstration performed at YPG. The U.S. Army Aviation Technical Test Center (ATTC), Fort Rucker, Alabama, provided aircraft support. The Waterways Experiment Station (WES) personnel operated the airborne scanner and processed the data collected for the demonstration.

BACKGROUND

The airborne data collection system consists of an active/passive line scanner, real-time processing and display equipment, and navigational equipment and is described in detail elsewhere (Ballard 1992). The scanner collects three channels of optically aligned image data consisting of two active laser channels (one polarized reflectance and the other total reflectance) and one passive thermal infrared channel. The real-time processing and display system is based on a massively parallel processor. The system has a scan rate of 350 scans per second with 710 data pixels per scan. The system can be flown at different altitudes. Low-altitude (130 ft.) flights are flown with a forward speed of 30 knots to characterize the site for the presence of surface UXO. This allows for the surface scan resolution to be nominally 1.9 by 1.9 in. Typical coverage for a single pass during 1 hour of flight is 300 acres. Medium-altitude (200 ft.) flights are flown at a forward speed of 52 knots. This altitude and forward speed give a nominal surface scan resolution of 3.0 by 3.0 in. Typical coverage for a single pass during 1 hour of flight is 900 acres. High-altitude (400 ft.) flights are flown at a forward speed of 104 knots. This altitude and forward speed gives a nominal surface scan resolution of 6.0 by 6.0 in. Typical coverage for a single pass during 1 hour of flight is 3,600 acres. The detection is based on the remote identification of surface anomalies and materials that indicate the presence of surface UXO contamination. A cut-away diagram of the scanner is shown in Figure 1.

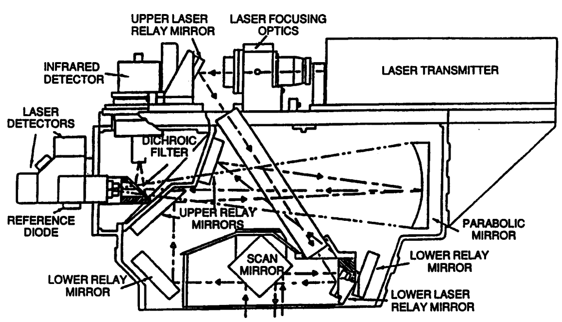

Figure 1. Scanner Physical and Optical Layout

SITE INFORMATION

Yuma Proving Ground

YPG has an interest in UXO characterization and remediation because of the large number of UXO contamination within their test ranges. YPG has set up test grids for the evaluation of systems used in UXO detection. The test grid with surface items was used in this demonstration. A calibration site was set up next to the test grid. The calibration site is based on earlier REMIDS calibration sites. The materials used and their function are described in the calibration site section. The vegetation coverage in the test grid is very sparse and consists mainly of dried bushes and trees with no foliage on them. The height of the bushes ranges from 0.5- to 1.5-m. The tree height ranges from 1.0- to 2.5-m.

Calibration Site

The layout of the calibration site is shown in Figure 2. The calibration site consists of the water containers, roofing material, UXO material, man-made materials, reflectance standards, resolution targets, and black and white panels. The roofing material, reflectance standards, and resolution targets are used to calibrate the active laser sensors. The water containers and black and white panels are used to calibrate the passive infrared sensor. The UXO material is used to define the classification of the UXO material in the test grid. The UXO materials consist of whole projectiles and fragments of 155-, 152-, 106-, and 105-mm projectiles; 81- and 60-mm mortars; and 40-mm grenades. The non-UXO man-made materials are placed in the calibration site as representatives of items that may cause false alarms (false alarms being the classification of an item as ordnance when it is not). The man-made materials consist of aluminum cans, electrical cable, glass and plastic containers, and expended small arm casings. Temperatures of the water containers, black and white panels, and UXO materials are collected during the days of the data collection flights for the demonstration. The weather conditions of temperature, relative humidity, wind direction, and precipitation are also collected throughout the data collection flight days. The background of the calibration site is the same as that of the test grid. The soil of the test grid is either a sandy silt soil from the Indian Wash area or a desert pavement.

Test Grid

The size of test grid is 500 by 1000 m. The test grid is made up of 800, 25- by 25-m cells. The cells are arranged in 40 rows of 20 cells each. It is covered with hundreds of inert items on the surface. The items consist of mines, grenades, rockets, mortars, projectiles, bombs, and scrap.

DATA COLLECTION

The data collected by the system are three digital channels. The three channels are polarization, reflectance, and thermal. The system was flown at an altitude of 130 ft. with a forward speed of 30 knots to collect the samples. This allowed for the surface scan resolution to be nominally 1.9 by 1.9 in. This resolution allowed for detection of smaller UXO material. The resolution is the same for both the active and passive channels.

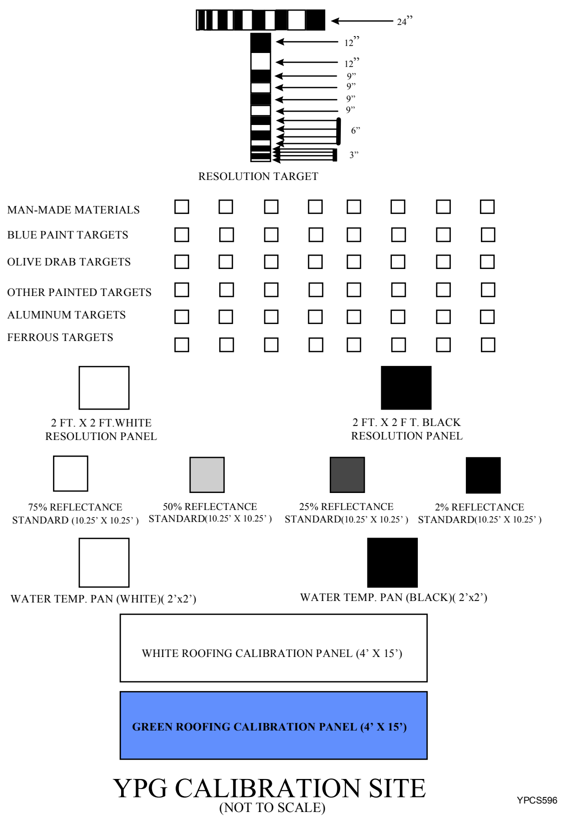

Figure 2. Calibration Site Layout

The data collection flights for the demonstration were flown on 24 June 1996 through 27 June 1996. All of the data collection flights were aligned with the boundaries of the cells. None of the flights were flown over the cell centers. Four of the data collection flights were flown along the 20 columns of the cells; the other two data collection flights were flown along the rows of the cells.

The GPS data collected during the data collection flights were real-time corrected differential GPS. The GPS equipment (Trimble 1992) used for the survey is independent of the scanner system. The synchronization of the information between the GPS system and the scanner system was integrated together via time stamps.

RESULTS

Data Analysis

One goal of this demonstration was to evaluate the data at the site for detection of surface UXO. This could not be done because of problems with the quality of the data collected. The main problem was the single scan line drop out of the synchronized data stream record on the flight tapes. This problem causes the real-time playback system to lose synchronization. When synchronization is lost, at least 64 scan lines of data cannot be processed for surface UXO. Two other problems that were encountered caused problems with the calculation of the shapes of the objects detected. The first is a random four pixel shift in the scan line. The second is a 17-Hz shifting of the image data. The final imagery problem is a 17-Hz intensity banding of the image. However, data for 120 of the 800 cells in the test grid were evaluated at YPG on 02 July 1996 before the demonstration was completed. Eight man-days were expended in the processing of these 120 cells to obtain the surface UXO detections. These man-days included the discovery and identification of the problems with the imagery.

The probability of detection for each ordnance class is as follows:

Item	# Item Det.	# Items Present	Pd
Dielectric Mines	4	4	100
Painted Mines	2	6	33
500 lb. Bombs	3	3	100
155-mm Proj.	3	3	100
81-mm Mortars	15	15	100
Alum. Plates	5	5	100
M75 Grenades	0	15	0
M42 Grenades	0	13	0

The grenades were not detected because of the high false alarm rates that were generated when looking for single pixel targets. The four painted mines that were not detected fell into holiday areas for this data collection set. The holiday areas are discussed in greater detail at the end of this section. The classification of the above detected items was done by the operator after he had reviewed the imagery from the three channels. No misclassifications were made.

False alarms of the survey are as follows:

Item	False Alarms
81-mm Mortars	5

All of the false alarms barely made the spectral classification. Because of the 17-Hz shifting in the imagery, the shape of these false alarms were classified as mortars. After image correction, none of these false alarms were classified as mortars. The area covered in this survey is 0.075 square km. This gives a false alarm rate of 67 false alarms per square km.

The single scanline drop out, the random four pixel shift, and the 17-Hz shifting of the data were corrected in the data before the images were processed again for surface UXO. The 17-Hz banding problem was not corrected.

The algorithm used in the attempt to correct the 17-Hz banding was being affected by the features in the imagery; therefore, this correction algorithm was disabled during the correction of the collected data. Imagery before correction is shown in Figure 3. The corrected imagery is given in Figure 4.

The corrected imagery is stored on CD. The digital array processor code had to be ported to workstations since the single scan line drop out problem could not be corrected on the flight tapes. This ported code is used to process the corrected data. The corrected imagery is evaluated for surface UXO via workstations instead of through the real-time playback system. The findings were evaluated at Yuma Proving Ground during the week of 24 March

Figure 3. Image Before Correction

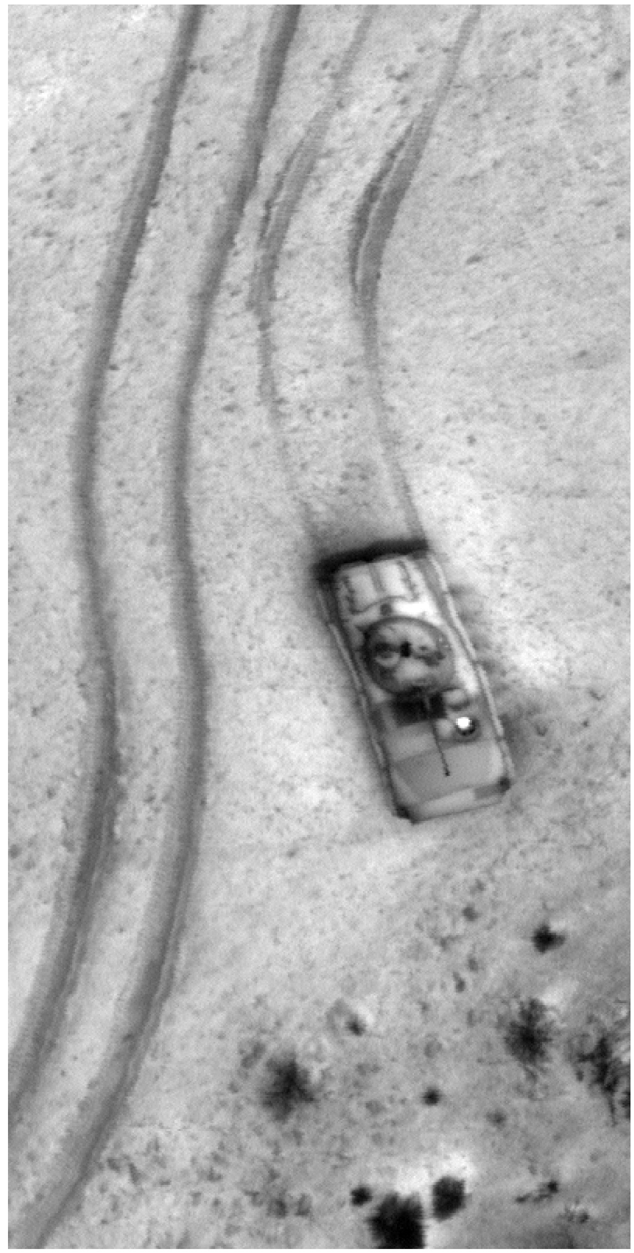

Figure 4. Image After Correction

1997. Five man-days were expended in the processing of the corrected data to generate the surface UXO detections of the 800 cells in the test grid.

The probability of detection for each ordnance class is as follows:

Item	# Item Det.	# Items Present	Pd
Dielectric Mines	39	46	85
Painted Mines	37	51	73
2.75-in. Rockets	38	50	76
Scrap	47	68	69
500-lb. Bombs	8	8	100
155-mm Proj.	29	30	97
105-mm Proj.	23	24	96
81-mm Mortars	82	92	89
Gator Mines	9	28	32
Alum. Plates	10	10	100
Armor Plates	2	2	100
M75 Grenades	0	35	0
40-mm Grenades	0	86	0
M42 Grenades	0	40	0
Strbck and Fins	2	3	67
Valmeira Mines	0	5	0

False alarms of the survey are as follows:

Item	False Alarms
Dielectric Mines	1
Scrap	6
Gator Mines	12

The area covered in this survey is 0.5 square km. This gives a false alarm rate of 38 false alarms per square km. The false alarms were not evenly distributed throughout the test grid. The false alarms were concentrated around the wash areas. These areas contained desert varnish rocks that caused most of the false alarms because the desert varnish return was similar to the oxidized iron surface return.

The classification of the detected items was done by reviewing the system report of the detected items. The report indicates whether the item had any aluminum, iron, painted, and/or plastic surfaces. The report also gives the area of the item, its maximum length, an estimated width of the item, and the location in the image. The operator typically made the classification on the reported information. If the operator had a question about an item, he could review the imagery associated with the item. There were no misclassifications in this survey.

The smaller scrap pieces, grenades, and Valmeira mines were not detected because of the high false alarm rates that were generated when looking for single pixel targets. The lack of 100% coverage of test grid for any one of the data collection flights is observed. As mentioned earlier, the test grid is a 1000- by 500-m area made up of 800, 25- by 25-m cells. Data were collected over the test grid in the following two formats. The first format is 21, 1,000-m passes, and the second format is 41, 500-m passes. The passes are aligned with respect to the cell boundaries. There is only a 2-m overlap between adjacent passes. This caused numerous holiday areas in the coverage of the test grid for any one data collection flight. A holiday area is an area the system did not fly over so that data could be collected.

The strongback (Strbck) gator mine cover and the new snake eye fin (Fins) assembly are both large items and were easy to detect. However, the old snake eye fin assembly was not detectable with the four return classes of aluminum, iron, paint, and plastic. The snake eye fin assembly is made of painted brass. The new snake eye fin assembly was reported as having a painted and iron surface. The old snake eye fin assembly was mainly oxidized brass with some paint. Most of the surface was not associated with a return class. Smaller areas on the assembly were detected but were not large enough to have at least four good data points. Unlike iron, the oxidation process of brass greatly changes the polarization and reflectance characteristics.

The scrap detected items mainly consisted of aluminum items. The scrap is made up of fragments of 2.75 rocket motor bodies (aluminum on one side and white paint on the other) and shrapnel (iron). The undetected scrap items were either in holiday areas or too small to yield four good data points.

The gator mines were missed because of their size. Only those that had four or more good data points were detected. The false alarms were high in this class. This is because the shape of the small objects is more difficult to discern. Also, the painted surface return and the iron surface return are both similar to the background return for this area. The background return in polarization is very high (>30%) in areas where there is desert varnish type rocks. Most of the false alarms in this class were rocks with shapes resembling those of the mines.

Global Positioning System

The RMS error between the surveyed items in the test grid and the data collection flight detected items was less than 2.0 m for items within 5 degrees of nadir. The RMS error for the detected items that were greater than 5 degrees from nadir was less than 5.0 m.

CONCLUSIONS

REMIDS has demonstrated the ability to detect surface UXO materials. This system has also shown the ability to detect a wide range of man-made objects. The susceptibility to small-sized background material, desert varnish, with spectral characteristics common to at least one return class is shown. Thus, work is continuing in algorithm development to minimize false alarms and to target only those anomalies that are surface UXO related.

The need for accurate flight path control has also been shown. The elimination of overlapping flight paths and holiday areas would greatly increase the efficiency and reliability, respectively, for the system.

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