TESTING OF SURFACE UNEXPLODED ORDNANCE DETECTION VIA AN ACTIVE/PASSIVE MULTISPECTRAL LINE SCANNER SYSTEM

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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 at the terrain surface. The system was originally designed for remote minefield detection. This adaptation will help aid in the cleanup of Department of Defense (DoD) sites with unexploded ordnance (UXO) contamination. Existing technologies for detection and remediation of UXO are expensive, dangerous to personnel, labor intensive, and technologically inefficient. The use of airborne remote detection minimizes the risk to personnel during the environmental assessment and analysis of the site. 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 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 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, which indicate the presence of surface UXO contamination. The results presented are from the test flights performed at Fort Rucker, Alabama on UXO material sent from Jefferson Proving Ground, Indiana and Yuma Proving Ground, Arizona. The test flights are funded by the Environmental Security Technology Certification Program (ESTCP) and managed through the Army Environmental Center (AEC). The system shows promise for a secondary use for surface UXO detection.

INTRODUCTION

There is increasing need for dual-use or multi-use technology due to current and anticipated DoD budget reductions. Through funding from ESTCP, REMIDS is now being evaluated for a secondary use of surface UXO detection. The initial test flights have been performed at Ft. Rucker, Alabama using the UXO material sent from Jefferson Proving Ground, Indiana and Yuma Proving Ground, Arizona. Test flights will be performed at Jefferson Proving Ground, Indiana and Yuma Proving Ground, Arizona later during the fiscal year. The U.S. Army Aviation Technical Test Center (ATTC), Ft. Rucker, Alabama, provided aircraft support. The Waterways Experiment Station (WES) personnel operated the airborne scanner and processed the data collected from the test flights.

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 x 1.9 in. Typical coverage for a single pass during one 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 gives a nominal surface scan resolution of 3.0 x 3.0 in. Typical coverage for a single pass during one 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 x 6.0 in. Typical coverage for a single pass during one hour of flight is 3600 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.

SITE PREPARATION

Staging Area

The calibration site and the test site were setup at the Highfalls staging area of Ft. Rucker, Alabama. The vegetation coverage was grass and broad leaf weeds with an average height of 2.0 cm. The soil particle size characteristics are given in Figure 2. The soil plasticity is none and the soil moisture content ranged from 7.0% to 10.2% during the test flights.

Calibration Site

The layout of the calibration site is shown in Figure 3. The calibration site consisted of water containers, roofing material, UXO material, reflectance standards, resolution targets, and black and white panels. The roofing material, reflectance standards, and resolution targets were used to calibrate the active laser sensors. The water containers, and black and white panels were used to calibrate the passive infrared sensor. The UXO material was used to define the classification of the UXO material in the test site. Temperatures of the water containers, black and white panels, and UXO materials were collected during the day of the test flights. The weather data (temperature, relative humidity, wind direction, and precipitation) were also collected throughout the test flight day.

Test Site

The survey of the test site is shown in Figure 4. The test site contained UXO material and other man-made material. The UXO material consisted of whole and fragments of 155mm, 152mm, 106mm, and 105mm projectiles; 81mm and 60mm mortars; and 40mm grenades. The man-made materials consisted of aluminum cans, electrical cable, a 55-gal drum, glass and plastic containers, and expended small arms casings. The test site also contained roofing material from previous construction at the Highfalls staging area. The non-UXO materials were placed in the test site as representatives of items that may cause false positives. A false positive is the classification of a non-ordnance item as an ordnance item.

DATA COLLECTION

The samples 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 x 1.9 in. This resolution allowed for detection of smaller UXO material. The resolution is the same for both the active and passive channels.

The test flights were flown on 09 March 1996, 11 March 1996, and 12 March 1996. The flight paths were flown with headings of 0, 90, 135, 180, 270, and 315 degrees over the calibration and test sites. This allowed for different orientations of the ordnance material with respect to the scanner for shape filter testing.

The GPS data collected during the test flights was 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.

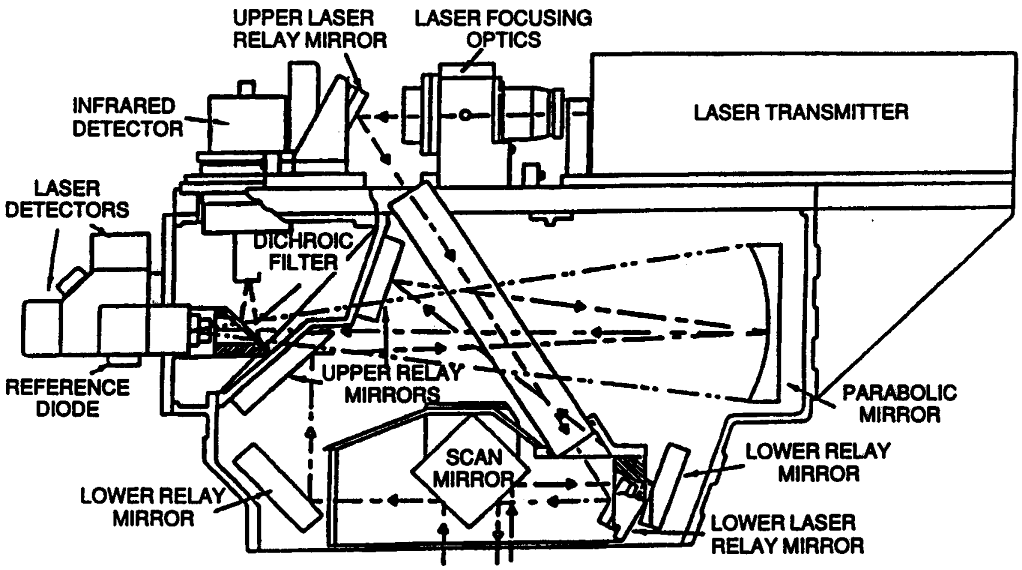

Figure 1. Scanner Physical and Optical Layout

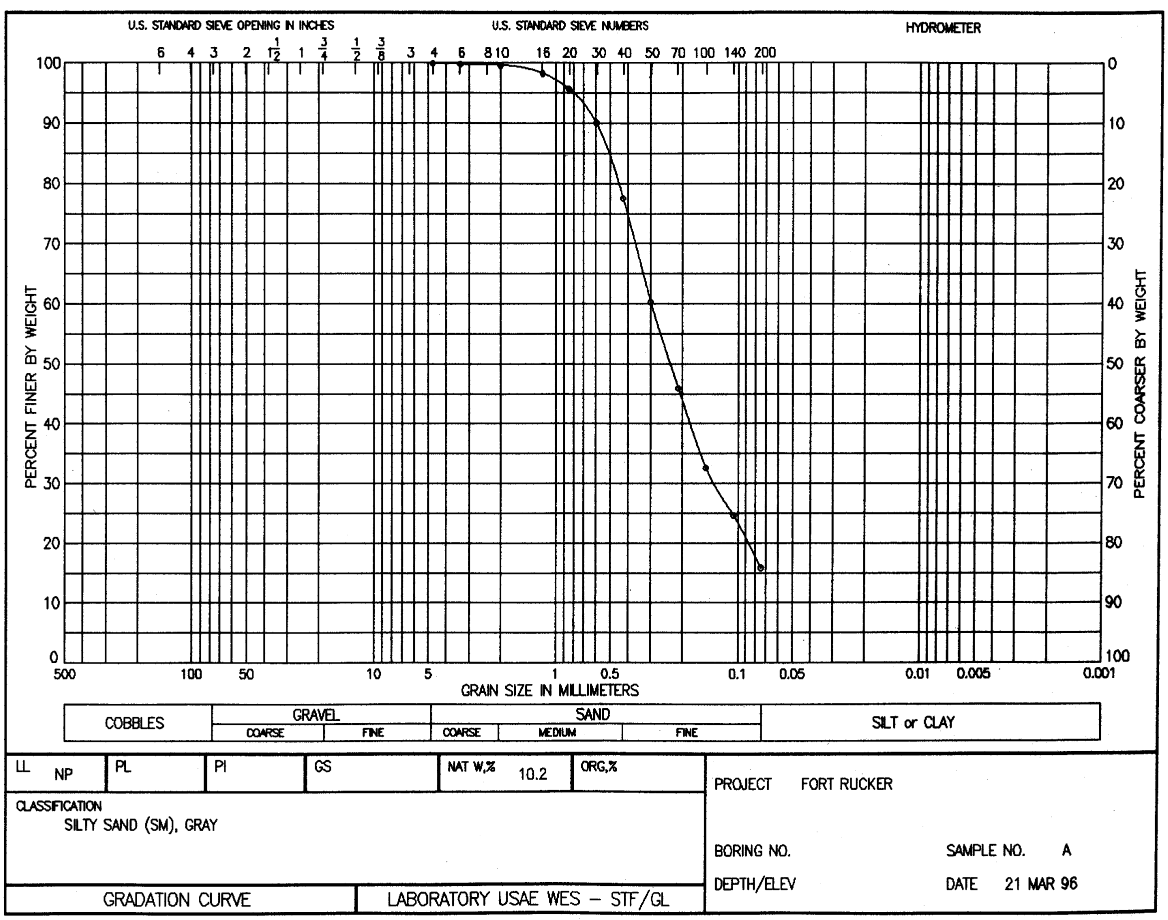

Figure 2. Fort Rucker Soil Sample

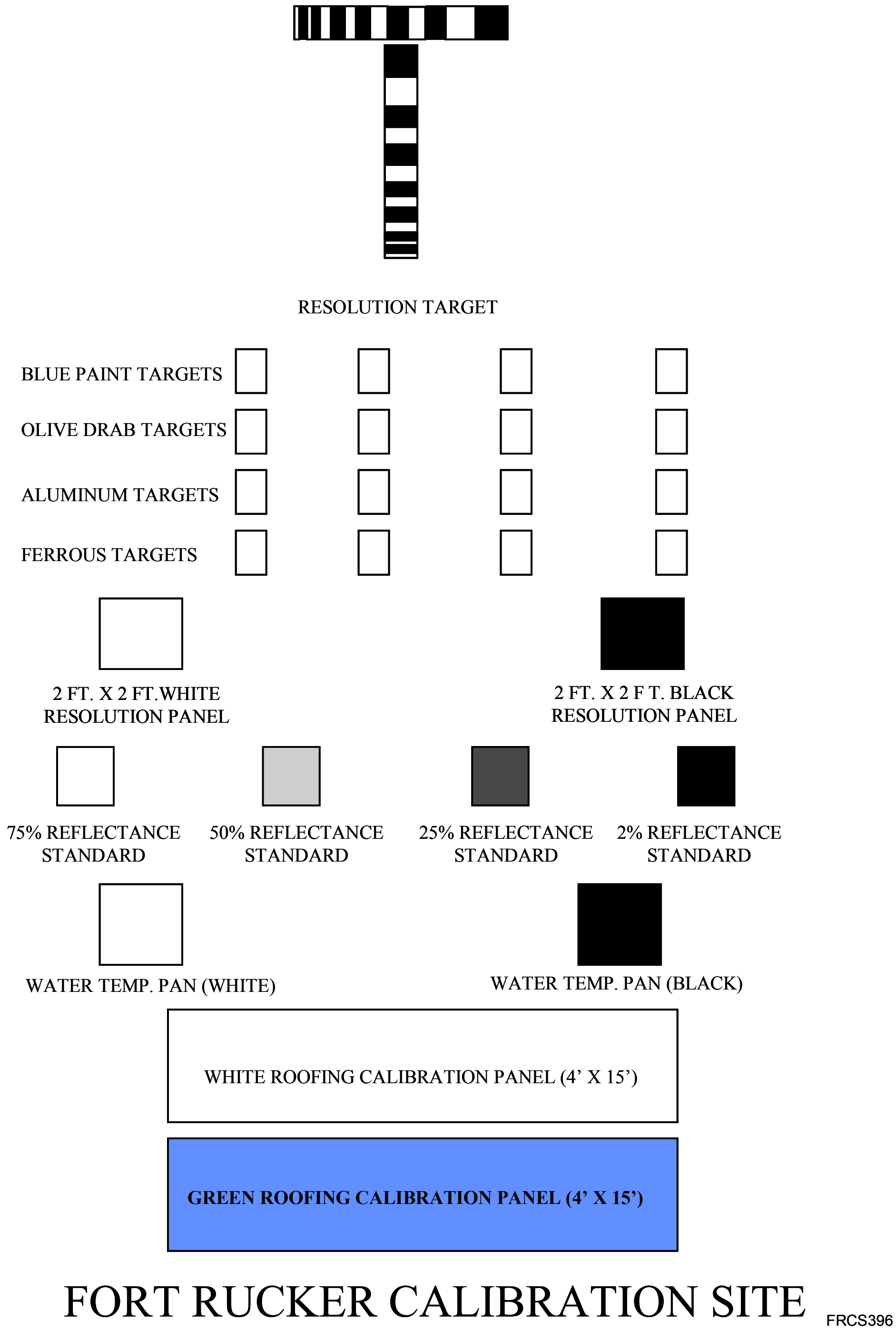

Figure 3. Calibration Site Layout

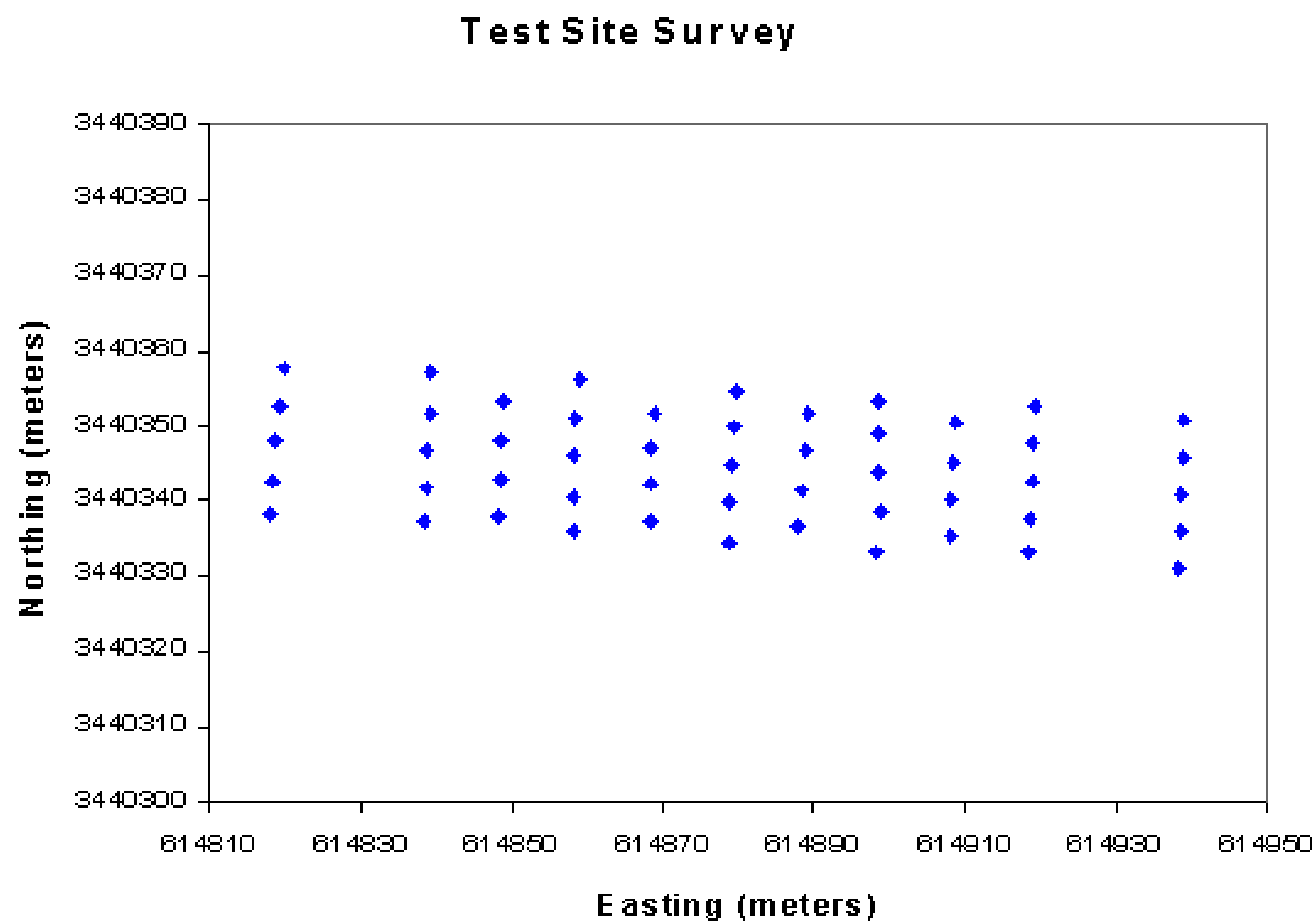

Figure 4. Survey of Test Site

RESULTS

Imagery

A picture of ordnance materials used in the test site with images of the three channels collected is presented in Figure 5. The right-most image is the polarization image. The middle image is the reflectance image. The left image is the thermal image. The images were taken from the 10:55 am test flight. The air temperature at this time was 10 degrees C and the soil temperature was 14 degrees C. Pictures of the items in the imagery are shown to the left of the imagery if Figure 5.

Data Fusion

The three channels were fused together as shown in the decision space graph given in Figure 6. The 3D histogram represents the background and UXO material data points. The polarization, reflectance, and thermal parameters are represented in the axes. The solid spheroid represents the threshold detection space for aluminum.

Global Positioning System

The RMS error between the test site survey points and the test flight target points was less than 3.0 meters for test flights flown with wind velocities less than 10 knots. The RMS error for test flights flown with wind speeds greater than 20 knots was less than 4.0 meters. The lack of yaw and pitch compensation was the main factor for the increase RMS error.

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. Thus, work is needed in algorithm development to minimize false alarms and to target only those anomalies that are surface UXO related. REMIDS technology is currently being enhanced by Raytheon Corporation as part of the Airborne Standoff Minefield Detection Program. Their effort will produce a downsized higher resolution active/passive system capable of operating from an unmanned aircraft. Any algorithm development for other uses of REMIDS would aid in the quick adaptation of the Raytheon system when its development stage is completed.

The use of an inertial navigation system, to track the helicopter orientation, would aid in the reduction of GPS errors due to yaw and pitch.

The need for accurate flight path control has also been shown. The elimination of overlapping flight paths and uncovered areas would greatly increase the efficiency and reliability of manned and/or unmanned airborne platforms.

REFERENCES

Ballard, John H., R. M. Castellane, B. H. Miles, K. G. Wesolowicz. (1992) "The Remote Minefield Detection System (REMIDS) II Major Components and Operation." Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Trimble Navigation, Ltd. (1992) "System Operating Manuals." Sunnyvale, CA: Trimble Navigation.

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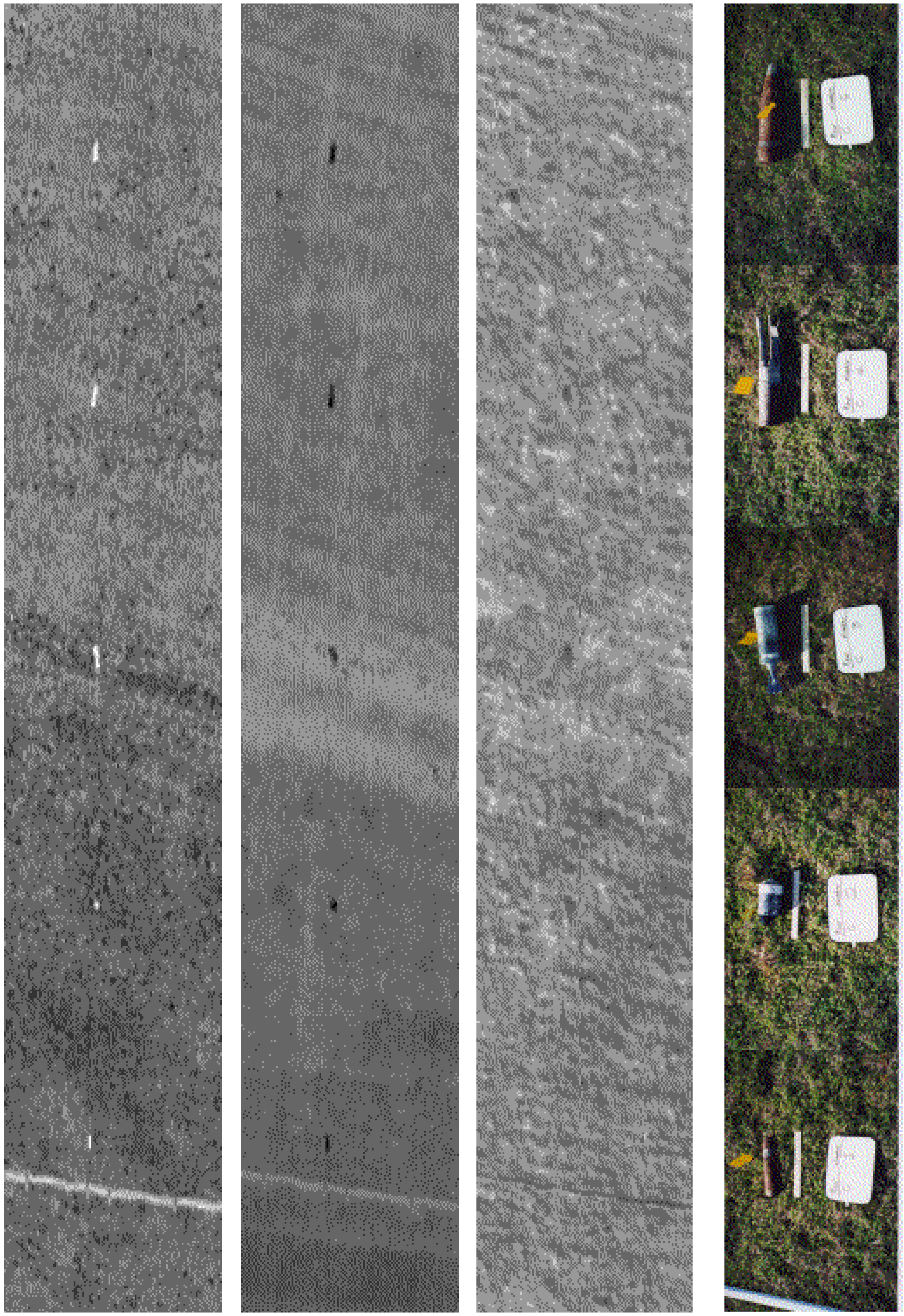
Permission was granted by the Chief of Engineers to publish this information.



Polarization Reflectance Thermal Pictures

Figure 5. Imagery

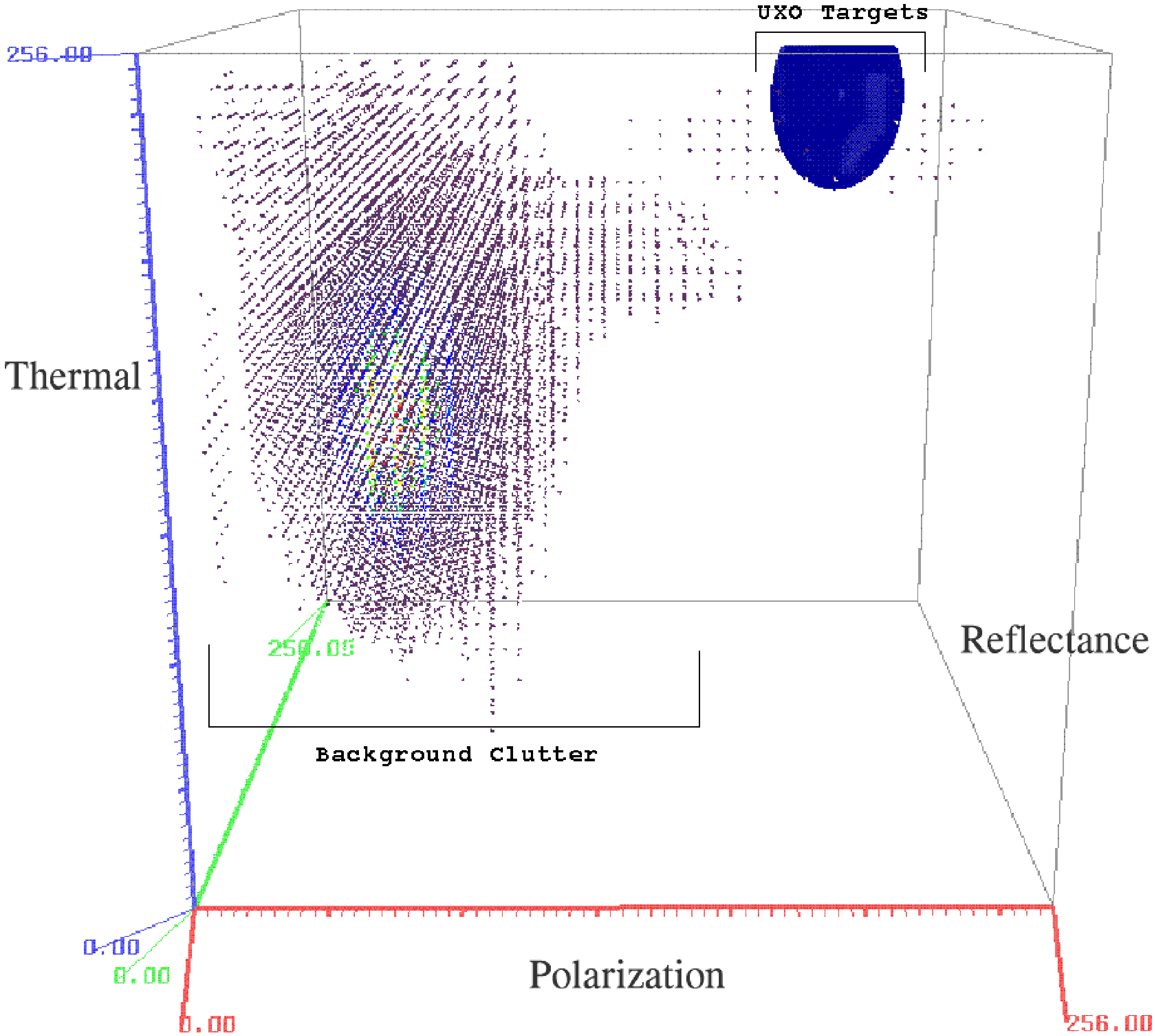


Figure 6. Decision Space Graph