PHENOMENOLOGY OF INERT PROJECTILES IN THE THERMAL IR

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1. INTRODUCTION

Unexploded ordnance poses a hazard to civilian and military personnel alike as they can be difficult to locate and remove. Not only are they found in combat zones but also in current and former training zones. These training zones can be far removed from combat zones and around civilian populations. Removal of the UXO is a priority. However, prior to the removal process the UXO must be located. Due to the large areas of training zones, ground field surveys can pose a financial and logistical burden, not to mention the hazard to personnel walking through a UXO site.

Detecting UXO is best accomplished by utilizing a variety of sensor types [1-3]. Past efforts have focused on using ground penetrating radar (GPR) to determine the location and depth of UXO [4]. However, this is a ground field survey and may be impractical over large areas. Other studies have used airborne wideband synthetic aperture radar (SAR) to aid in the search for and identification of UXO [5]. These airborne studies have the advantage of covering large areas and being more mobile than their ground based counterparts. Another study investigated the application of using thermal infrared (IR) imaging in for UXO detection [6]. The author gives a brief history of thermal IR as it pertains to bomb detection then expands on the ideas and methods used to apply it to UXO and UXO fragment detection. The author states that much care must be given to the timing of image acquisition as the thermal properties of the target and ground will change throughout the day.

The Canadian Department of National Defense (DND) UXO Legacy Sites program was initiated in 2005 with the purpose of *"The programmed and prioritized reduction of UXO risk at legacy sites through education, property controls, UXO assessment surveys, and UXO clearance operation"*. In support of this program, the Spectral and Geospatial Exploitation Section of Defence Research and Development Canada conducted an experiment in which inert projectiles, projectile fragments and common false alarms (pop cans, wood, glass, rocks) were imaged using off the shelf thermal cameras in the LWIR and MWIR. The targets and false alarms were imaged at different orientations and ground conditions (buried, partially buried, unburied) using a soil and vegetation background over a 24 hour period. Determining the optimal wavelength and period of time to

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image the targets is the goal of this study. Supplementary goals include investigating the effects of projectile size, projectile paint or rust cover, and false alarm composition as it pertains to thermal detection. The hypothesis is that the time period, or band, with the greatest difference in contrast between the inert projectiles and background or inert projectiles and false alarms would be the best time to detect UXO. This paper presents some of the results obtained thus far.

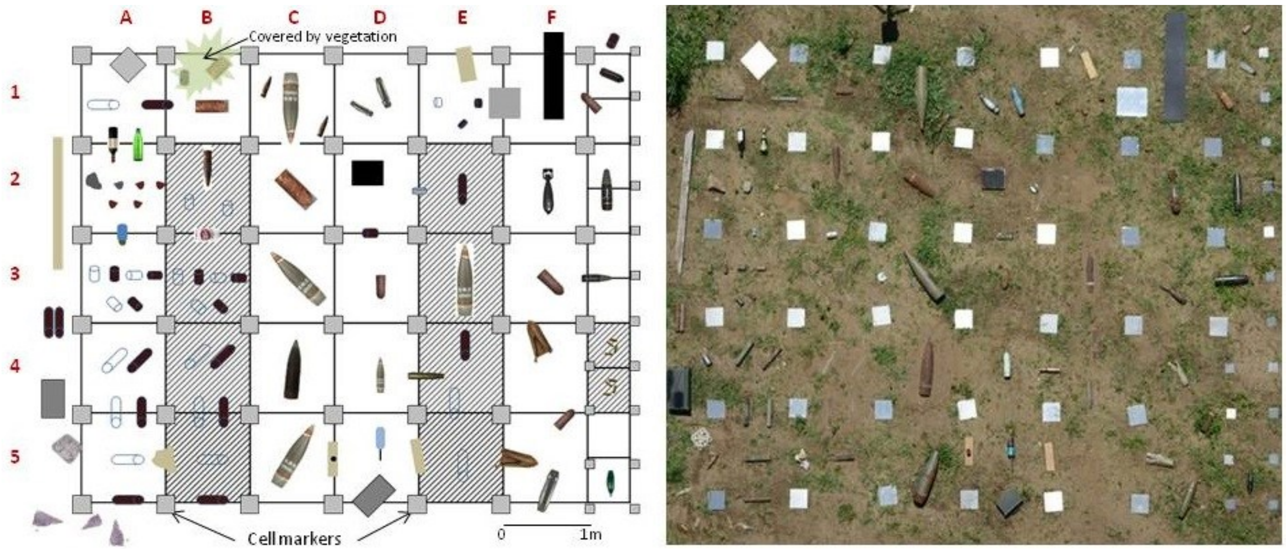
2. METHODS

Study Site and experimental setup

The study was conducted in a sandy soil and grass background representative of the background found in the firing ranges at the Canadian Forces Base (CFB) Valcartier. Two FLIR SC6000 thermal cameras, a mid-wave infrared (MWIR) and a long-wave infrared (LWIR) covering the 3-5 and the 8.2-9.6 micron band ranges were used to record data during a 32-hour period between 13:30 on July 8 and 21:30 on July 9, 2013. The cameras were calibrated using a blackbody radiator and reference panel at ambient temperature (21°C) inside a laboratory environment. The optics was focused on the ground from an elevation of 30 m. The nominal temporal resolution was 15 minutes and the spectral resolution approximately 0.8 cm.

Weather during July 8 was sunny with cloudy periods in the evening and light rain early in the night. Weather for the remainder of the experiment was dominated by clouds. The temperature ranged from 13°C to 25°C.

Figure 1 describes the 5 m x 6.5 m grid that was set up on the ground to position the targets. The cells within the grid measured 1 by 1 m with the cell corners marked out by 20 x 20 cm aluminum plates used for registering the multi-temporal images. The grid was oriented in a North-South direction to minimize the shadow of the boom lift and was given a labelling scheme of *row-column* to help locate the targets. A total of 30 inert projectiles and 56 false alarms were used within the grid boundaries. The targets orientation and land-cover varied within the grid with some being oriented at 90°, 45° and 0° to the camera and lying on the surface, partially buried or buried at <5 mm in the soil. The inert projectiles ranged in size from small bullets to large 155-mm artillery shells (bullets not address in this paper). The covering on the projectiles ranged from painted to rusted. The false alarms were made up of wood, glass and plastic drinking bottles, various metal objects, rubber matting, and aluminum pop cans.



(a) **(b)**

Figure 1. Experimental setup: (a) Sketch and (b) visible image of the targets layout within the sampling grid.

Image Processing

Images were rectified to a base image and a temporal data cube created for both wavelengths. A subset of the images was created to ensure that all bands had the same spatial extent. Regions of Interest (ROI) were created for the inert projectiles, false alarms, and backgrounds in order to compare the values of the targets across time. A moving average of 5 was applied to both the images in order to stabilize the variance within them. The difference between projectiles and backgrounds were then calculated on the smoothed spectra.

3. RESULTS

Targets buried, half buried, on surface: Figure 2 shows the percent grey level difference between the targets and the average background. The buried and half buried targets have more thermal contrast with the average background than do the projectiles laying at the surface in both the LWIR and MWIR, the thermal contrast being more pronounced in the MWIR. It is in the evening after the sunset and until 21h30 that the contrast is maximal for the buried and half buried targets. They remain warmer than the background. Targets lying on the surface exhibit their more pronounced contrast in the MWIR near 6:00 where they appear colder than the background.

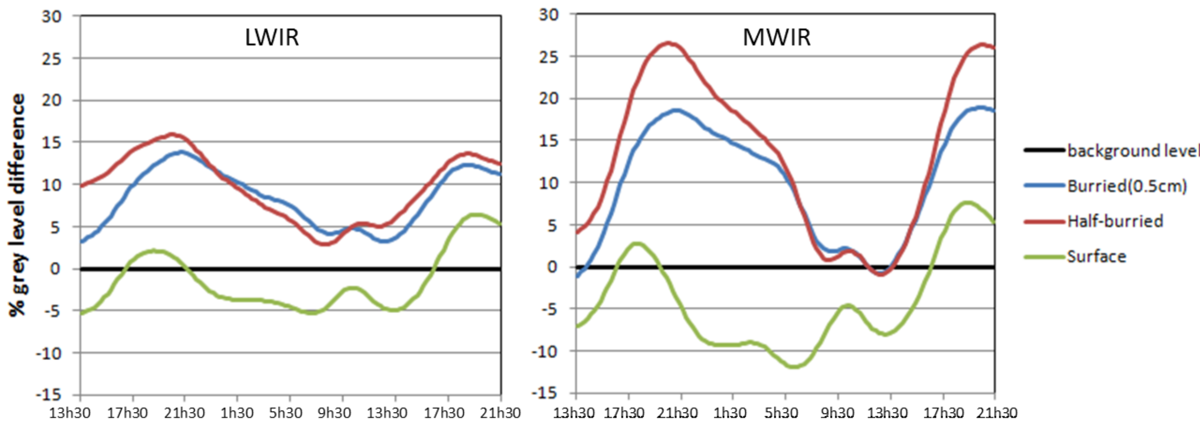


Figure 2. Temporal thermal difference between the average background and the inert projectiles (buried, half buried, on surface).

Large and small targets: Figure 3 shows the temporal signatures of large and small projectiles. In both LWIR and MWIR the large projectiles show more thermal contrast with the background than the small projectiles. The contrasts are higher after sunset and are more pronounced in the MWIR. In the LWIR, the small projectiles are not detected during the first evening (black arrow). Weather records indicate that there was a light rain early that evening which could have contributed to reduce the thermal contrast around that time.

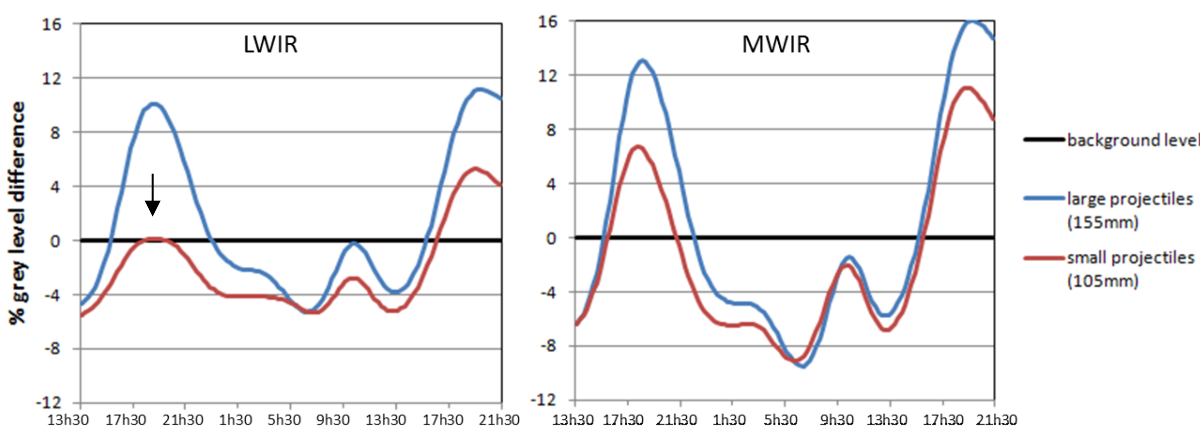


Figure 3. Temporal thermal difference between the average background and large and small projectiles.

4. CONCLUSION AND FUTUR WORK

The analysis results obtained thus far clearly indicate that the preferred time to detect UXO is after sunset. Buried and half buried projectiles can be detected and the size of the projectiles matters. Further studies are on the way to investigate the differences between the false alarms and the projectiles, the type of coating (paint, rust), the local background/target contrast (compared to the average global background contrast used in this study), and the relation to the recorded weather data (not used but recorded for this study). Moreover, a second set of similar acquisition took place 1.5 months later on the same experimental site in which the target remained unchanged in their seasonally evolved background and illumination conditions.

5. REFERENCES

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