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Technical Note

# Detection of single graves by airborne hyperspectral imaging

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ABSTRACT

Airborne hyperspectral imaging (HSI) was assessed as a potential tool to locate single grave sites. While airborne HSI has shown to be useful to locate mass graves, it is expected the location of single graves would be an order of magnitude more difficult due to the smaller size and reduced mass of the targets. Two clearings were evaluated (through a blind test) as potential sites for containing at least one set of buried remains. At no time prior to submitting the locations of the potential burial sites from the HSI were the actual locations of the sites released or shared with anyone from the analysis team.

The two HSI sensors onboard the aircraft span the range of 408–2524 nm. A range of indicators that exploit the narrow spectral and spatial resolutions of the two complimentary HSI sensors onboard the aircraft were calculated. Based on the co-occurrence of anomalous pixels within the expected range of the indicators three potential areas conforming to our underlying assumptions of the expected spectral responses (and spatial area) were determined. After submission of the predicted burial locations it was revealed that two of the targets were located within GPS error (10 m) of the true burial locations. Furthermore, due to the history of the TPOF site for burial work, investigation of the third target is being considered in the near future. The results clearly demonstrate promise for hyperspectral imaging to aid in the detection of buried remains, however further work is required before these results can justifiably be used in routine scenarios.



## 1. Introduction

In studies where airborne detection of clandestine mass graves has shown promise [1,2], the use of hyperspectral imaging (HSI) systems and data analysis has been the key technology. Although sparse in number, these studies illustrate that with sufficient grave material, HSI has the ability to provide a location of potential mass grave sites. However, there has been no work, that the authors are aware of, that uses airborne HSI for detection of single grave sites. A preliminary look at in situ hyperspectral data collected over single graves had shown inconclusive results [1]. Fundamentally, with a single grave there is a much smaller amount of remains when compared to the mass grave studies; thus the probability of detection is lower. As the HSI detection scenario for the mass graves is already challenging, using the same technology for detection of single graves is expected to be an order of magnitude more difficult.

Originally developed for the Earth Sciences [3], HSI has gained popularity within the forensic community for a variety of applications such as trace evidence analysis [4], blood stain ageing [5], chemical identification [6], document analysis [7], and artwork analysis [8], among others. Conceptually, the process of HSI measurement is simple: incoming electromagnetic energy impinges upon a pixel of the detector and generates a voltage which is measured and transformed into a Digital Number (DN). DN's are the basis of the usable HSI data and are converted to Spectral Radiance Units (SRU's) via laboratory-based spectral calibration coefficients determined prior to data collection [9]. Higher order spectral processing is undertaken after the data is converted to SRU units.

For imagery collected from an aircraft or spaceborne platform the spectral HSI results are then georectified to allow for proper mapping of each image onto the surface of the Earth. In the process of georecitfication, the Inertial Navigation System/Global Positioning System (INS/GPS) data collected simultaneously with the imagery allows for distortion corrections due to aircraft motion.

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However, georectification changes the spectra [10] in each pixel, therefore we have applied the spectral filtering on the un-georectified data, and then applied the spatial filter to the geocorrected data to avoid this problem. The resulting data generally also requires orthorectification; a process often contained within the overall georectification process that takes into account use of a digital elevation model of the topography [11] for proper placement of image pixels.

The purpose of this project was to perform a blind-test of the potential for airborne HSI technology to locate known buried remains of pig carcasses that are used as human analogues. The Royal Canadian Mounted Police (RCMP) supplied two defined areas within the Technical and Protective Operations Facility (TPOF) site in Ottawa, Ontario, Canada, where one area contained no buried remains and the other contained the remains of at least one buried pig. The goal was to collect airborne HSI data and predict the coordinates for the estimated location(s) of the remains and compare those results with the known coordinates. The location(s) of the true remains were only known to the RCMP and at no time during this project were these locations or the age(s) of the burial(s) revealed to the project personnel.

## 2. Materials and methods

### 2.1. Site

The TPOF site is located within the semi-urban outskirts of Ottawa, Canada. The site itself consists of mixed-wood forest and clearings. Based on intelligence from the RCMP, the site was reduced from the entire TPOF area to two regions of interest (white boxes in Fig. 1) each of which was nominally 85 m × 35 m and were both within clearings. Arboreal vegetation in the clearings consists predominantly of boreal forest broadleaf and coniferous trees with a mixed herbaceous understory. The soil at the two areas of interest is primarily composed of fine sand with clay horizons expressed at a variety of depths.

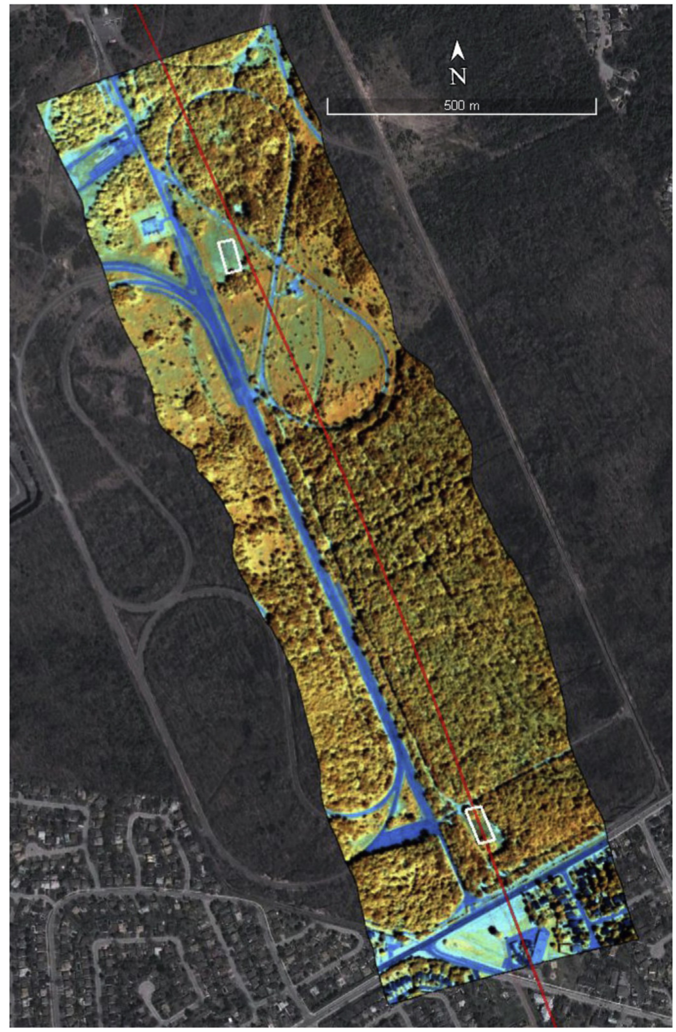


**Fig. 1.** Three band composite overlay of one of the SASI flight lines in Google Earth. The red line represents the flight path of the aircraft. The white rectangles represent the two areas of interest; the Northern and Southern sites.

### 2.2. Airborne HSI collection

In areas of basic research where the spectral bands of interest are not well known (as is the case in this work) a hyperspectral imager is far more useful than a multispectral imager due entirely to the fact that a hyperspectral imager gathers much more information with which to evaluate. When the spectral bands of interest are well known, then a multispectral instrument "tuned" to the bands of interest can be used and is a much more efficient method of imaging at that point.

The National Research Council of Canada's Twin Otter was outfitted with two HyperSpectral Imaging (HSI) systems each recording a different but complementary portion of the reflective electromagnetic spectrum from 408 nm to 2524 nm.

The Compact Airborne Spectrographic Imager (CASI) measured the reflective EM spectrum from 408 nm to 905 nm. It is a pushbroom style HSI system with 512 spatial pixels across the flight line covering a Field of View (FOV) of 33.4°. Each spatial pixel has up to 288 spectral channels. However, the full 512 pixels can only be achieved in the 'multispectral mode' resulting in a coarse spectral sampling interval that was considered unacceptable for this project. In 'spectral mode', the full 288 spectral channels can be acquired in only a limited number of spatial pixels. The reduction in spatial information allows more spectral pixels to be acquired. The number of spatial pixels across the flight line determines the minimum sensor integration time (the time allowed for the reflected light to be collected), or the maximum frame rate. The greater the number of spatial pixels the greater will be the time required to read the data out. This leads to larger along-track (i.e. in the direction of flight) pixels because the aircraft is in constant motion as the data is being acquired. As the imaging data requires georectification, the CASI system had its own dedicated GPS/INS system (Novatel) independently collecting the GPS/INS data.

The second HSI sensor on board, the Shortwave Airborne Spectrographic Imagery (SASI) is also a push-broom style HSI system that measures the reflective EM spectrum from 883 nm to 2524 nm thus allowing for an overlap region with the CASI data for comparison. The SASI operates in a single configuration acquiring 640 spatial pixels across the flight line covering a FOV of 37.8°. Each spatial pixel has 160 contiguous spectral channels providing a spectral sampling and resolution of approximately 10 nm. Although the SASI integration time is adjustable between 0.5 and 16.7 ms (in order to optimize the measured signal levels) its frame rate is fixed at 60 Hz. Consequently, the along-track spatial resolution is dependent upon the aircraft ground speed and altitude above ground level and only minimally influenced by the applied integration time. The SASI is equipped with its own dedicated GPS/INS system (C-MIGITS III) which collects data used for georectification.

At a flight altitude of 643 m (AGL) the CASI cross track resolution was 0.75 m for each pixel. Given the narrow width of the