APPLICATION NOTE

Airborne Detection of Chemical Powders Using Infrared Hyperspectral Imaging

Abstract

Airborne surveillance is routinely used in applications related to border protection, homeland security, command and control or even maritime surveillance. High Resolution infrared imaging provides to airborne surveillance activities valuable detection capabilities based on target shapes, temperatures and chemical nature. The spectral dimension provided by infrared hyperspectral imaging can add selectivity and efficiency to this task leading to additional tools for the detection and identification of ground targets, based on their unique spectral signature. Integrated into a fully automated gyrostabilized gimbal mounted in front of an helicopter, the Telops Hyper-Cam, an infrared hyperspectral imager, has been used to perform an airborne detection of a benign chemical powder spill (ammonium sulfate). This paper describes how the remote detection of a chemical powder spill was successfully achieved using the Telops airborne hyperspectral imaging system.

Introduction

Persistent surveillance and collection of airborne intelligence, surveillance and reconnaissance information is critical in such applications as border protection, homeland security, command and control or even maritime surveillance. High resolution imagery in visible and infrared bands provides to airborne surveillance activities valuable detection capabilities based on target shapes and temperatures. The spectral resolution provided by infrared hyperspectral imaging can add a spectral dimension to the measurements, leading to additional tools for the detection and identification of targets, based on their unique spectral signature.

The Telops Hyper-Cam sensor is a standoff infrared imaging spectrometer that enables simultaneous spatial, temporal and spectral analysis. It is based on the Fourier-transform technology yielding high spectral and spatial resolution as well as high accuracy radiometric-calibrated data. The spectral information provided on each image opens numerous image processing capabilities for efficient detection and identification of chemical substances. The Hyper-Cam has been recently used in a gyrostabilized gimbal attached at the front of an helicopter as shown in Figure 1. The successful detection and identification of a chemical powder spill (ammonium sulfate or AS) is presented as an illustration of airborne infrared hyperspectral imaging potential for surveillance.

Figure 1: Telops Hyper-Cam mounted into a gimbal (bottom) at the front of on an helicopter (top)

Experimental information

Airborne Hyper-Cam System

The Telops Hyper-Cam is a compact hyperspectral imaging instrument using Fourier Transform Infrared (FTIR) spectroscopy. It provides a unique combination of spatial, spectral and temporal resolution for a complete characterization of the substances being monitored. Its high performance and efficiency as a standoff chemical agent detector has been proven through numerous field campaigns. The Hyper-Cam Long-Wave features a Focal Plane Array (FPA) detector containing 320×256 pixels over a basic 6.4°×5.1° field of view. The spectral resolution is user-selectable between 0.25 and 150 cm^{-1} over the 8.0 to 11.8 µm spectral range. The Hyper-Cam offers a high sensitivity for each pixel of the scene under observation. The Hyper-Cam was designed from the ground up so the control and the data acquisition are specifically optimized.

The Hyper-Cam Long-Wave was adapted and mounted into a gyrostabilized gimbal manufactured by PV Labs. The gimbal head provides compensation for aircraft perturbations from pitch and roll shifts as well as vibrations in order to target a fixed point on the ground based on the GPS coordinates. The Hyper-Cam benefits from the access to a calibration blackbody mounted in the zenith position with corresponding temperature reference.

Hyperspectral images were recorded at altitudes of 300, 1000 and 3000 meters above the test site. The helicopter was stationary and heading toward a wind of 10 km/h during the acquisitions. As a reference point for the reader, one pixel of the Hyper-Cam detector represents an area of 11 × 11 cm on the ground at an altitude of 300 m. During the present flight test, hyperspectral images with dimensions of 128 × 128 pixels were recorded at a spectral resolution of 6 cm^{-1}.

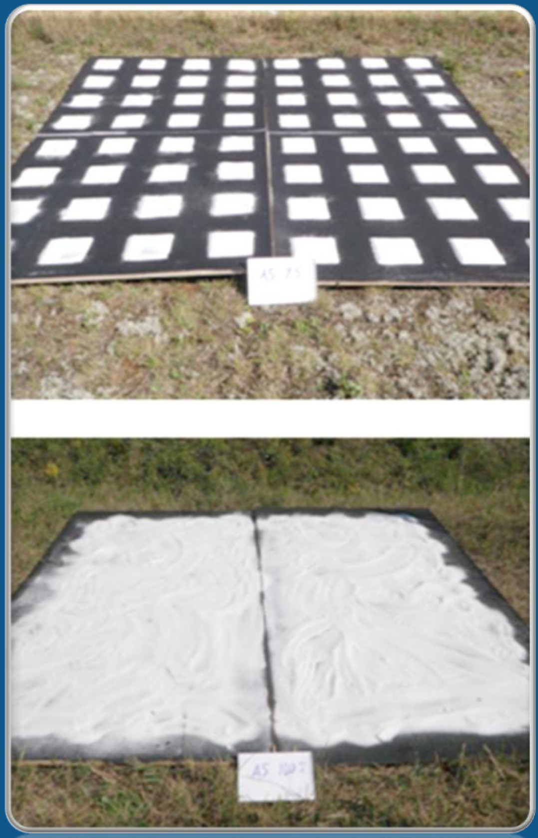

Figure 2: Ground view of ammonium sulfate plates with a 25 % (top) and 100 % (bottom) surface filling factor

Results & Discussion

In-Flight Hyper-Cam Performances

In-flight performance tests were carried out on the gyrostabilized Hyper-Cam mount and the results were found to be similar to factory measurements in similar conditions. Small translational shifts, on the order of 1 to 2 pixels per acquisition, were measured for each recording. Therefore, vibrations and movements induced by the helicopter were well compensated and good images could be recorded during the test flight.

Chemical Powder Detection

The area containing chemical powder spills (ammonium sulfate) at different surface fill factors is shown in Figure 2. Lime (calcium hydroxide) was also used as a chemical spill on the test site in order to make sure of the identification potential of the Hyper-Cam. Airborne hyperspectral images of the test site were then recorded at flight altitudes ranging from 300 to 3000 meters. A visible image of the test site taken from the airborne imaging platform is shown in Figure 3.

The detection of ammonium sulfate was carried out on the basis of its unique infrared spectral signature as displayed in Figure 4. In this figure, each spectrum corresponds to a single pixel from an hyperspectral image recorded at an altitude of 300 m. The broad feature located at 1100 cm^{-1} corresponds to the ammonium sulfate while the other features, common to both spectra, refer to atmospheric water vapor. Detection results obtained at the various altitudes are shown in Figure 5 (see next page).

The positive detection of ammonium sulfate corresponds to the colored overlay pattern over the infrared broadband image in black and white. The broadband image of each scene was obtained from the integrated infrared signal over the complete spectral range available. The experiment shows successful detection and identification of the ammonium sulfate powder spills from the 300 m altitude for all fill factors (grids of 12.5%, 25% and 100% respectively). The imaging quality of the Hyper-Cam-LW sensor allows for the clear distinction of the different fill-factor grid patterns, without any false alarm. The 1000 m and 3000 m altitude measurements provide successful detection and identification on the 100 % fill-factor grid only. The lower fill factor of other grids (12.5 % and 25 %) did not allow resolving the ammonium sulfate spectral features from the surrounding area. Simulated lime, i.e. calcium hydroxide spills were positioned next to the ammonium sulfate spill as seen in the top image of Figure 5(see next page). The selectivity provided by infrared hyperspectral imaging is demonstrated in this figure as detection is exclusively located on ammonium sulfate. This kind of selectivity results from a detection scheme based on the unique infrared spectral signature of the target of interest.

Figure 3: Visible image of the test site recorded at an altitude of 300 meters

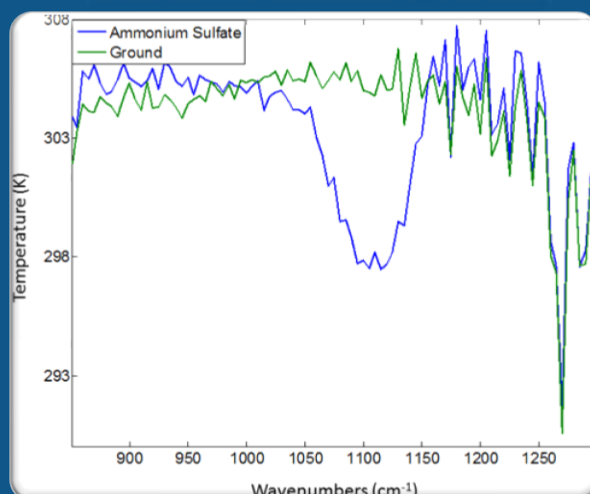

Figure 4: Single pixel spectrum of an area covered with ammonium sulfate (blue curve) and the surrounding ground (green curve) recorded with the gyrostabilzed Hyper-Cam mount at an altitude of 300 meters

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Conclusion

The gyrostabilized Telops Hyper-Cam imaging sensor has proven to be a reliable and powerful system for providing rich and high quality hyperspectral images from fixed altitude. The detection and identification has been successful in selectively determining the location of generic chemical powder spills. Hyperspectral imaging offers an advantageous approach for airborne surveillance of solid targets.

Figure 5: Selective airborne detection of ammonium sulfate at an altitude of 300 (top), 1000 (center) and 3000 (bottom) meters

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