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Hyperspectral Imagery Collection Upon Pikes Peak (HICUPP)

AFTER INITIATIVE REPORT

Kenney Battlelab Initiative

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This initiative put a HSI sensor atop Pike's Peak to perform a low cost, high volume collection of off nadir HSI data from Peterson AFB, Schriever AFB, Buckley ANGB, Ft. Carson and the Colorado Springs area. We wanted to know if a HSI collector could gather spectrally significant information. Specifically, collect high aspect and long distance HSI data with spectral resolution useful to the warfighter.

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EXECUTIVE OVERVIEW

Hyperspectral Imagery Collection Upon Pike's Peak (HICUPP)

Hyperspectral Imagery (HSI) collectors have shown great potential as surveillance and reconnaissance tools of the future. To date, only aircraft and unmanned aerial vehicles (UAV's) had been used as platforms for HSI sensors. Additionally, the HSI data collected from these platforms had been "on nadir" i.e. looking nearly straight down at the target. Soon, we expect to have some limited space capability (Warfighter 1) to perform HSI collections. This initiative put a HSI sensor atop Pike's Peak to perform a low cost, high volume collection of off nadir HSI data from Peterson AFB, Schriever AFB, Buckley ANGB, Ft.Carson and the Colorado Springs area. We wanted to know if a HSI collector could gather spectrally significant information. Specifically, collect high aspect and long distance HSI data with spectral resolution useful to the warfighter.

The SB conducted two collections from atop Pike's Peak, 24 Jun through 9 Jul 98 and 28 September through 9 Oct of 98. The SB was responsible for target scheduling, HSI data collection, and conducted all coordination efforts between Pike's Peak and Schriever AFB. During the demonstration, MEDECO (Medical and Environmental Corporation) was responsible for the HSI sensor control system – twin digital array scanned interfometers. HQ SWC/AE performed HSI data analysis on over 100 collected datacubes. The SB accomplished the following initiative objectives:

Objective 1: HICCUP successfully collected off nadir data under atmospheric and geometric conditions similar to space. During the demonstration period, the system produced over 100 HSI datacubes of selected targets.

Objective 2: The HICUPP data provided a better understanding of U.S. forces vulnerabilities to space-based spectral collections and exploitations. The datacubes from HICUPP will contribute to the limited spectral library for future space systems such as Warfighter 1.

Objective 3: Effective detailed data analysis of the datacubes proved the value of subpixel analysis. This technique allowed us to overcome poor spatial resolution (pixel size) and identify objects by their spectral signature.

The Space Battlelab conducted the HICUPP demonstration to provide other government agencies fielding future spaceborne HSI satellites and UAV systems, with a better understanding of off nadir capabilities. HICUPP confirmed the use of off nadir collection techniques to allow greater utility of future HSI systems. By collecting off nadir, HSI satellite systems will have improved utility by not being limited to collecting directly over a target. Based on successful analysis results, HICUPP has shown spectral data collected at extreme angles has a high potential to provide significant target identification and assessment.

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1. DEMONSTRATION MISSION STATEMENT

A. Purpose

The purpose of the HICUPP initiative was to prove the value of collecting useful off nadir/long slant range HSI data. This purpose was accomplished by placing a HSI sensor atop Pike's Peak to perform a low cost, high volume collection of off nadir HSI data from Peterson AFB, Schriever AFB, Buckley ANGB, Ft.Carson and the Colorado Springs area. Off nadir collection techniques permit satellite systems to dramatically increase the coverage of a target area. Off nadir collection techniques will also drastically reduce the revisit time required by a satellite. For example, the Landsat Multi-Spectral Imaging system (which collects only on-nadir) revisits a target area every 384 hours (16 days), whereas collecting just 30 degrees off nadir reduces the revisit time to every 36 hours (1 and ½ days). This allows for an operational improvement of almost a factor of 11. The success of collecting off nadir data will be shared with the space and the airborne spectral communities to benefit the development of any future HSI systems.

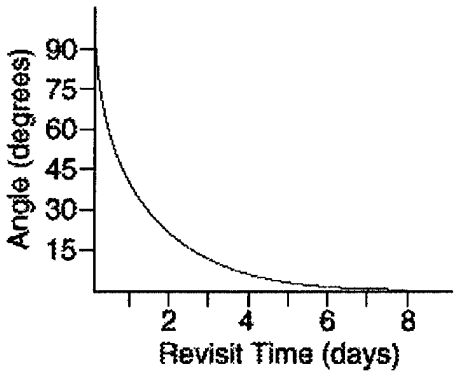

Figure 1. Off nadir angle vice revisit time.

B. Problem

HSI technology is an emerging field offering enormous opportunity in the areas of bomb damage assessment, target identification and analysis, crop studies, foliage analysis and support to counter-narcotic operations. HSI sensors have shown great potential as surveillance and reconnaissance tools of the future. Soon we will have a space capability (e.g. Warfighter 1) to perform HSI collections. It is suspected hyperspectral information from Warfighter 1 and systems like it will have substantial military utility, but there is little real-world, measured information to prove this suspicion.

Similarly, there is little information to provide insight into the challenges of collecting space-based HSI data. Previous efforts to demonstrate the military utility of HSI have concentrated on low risk/high payoffs like camouflage identification, taggant detection and the detection of small (sub-meter) calibration targets. The experimental collects supporting these efforts and demonstrations have typically been performed in clear weather, near-nadir angles with good atmospheric conditions by low flying aircraft (e.g. 2,000 – 20,000 feet above ground level). While these experiments were useful for studying the potential operational use of HSI sensors under optimal conditions, there has been little assessment of the HSI technology from a space platform. The space environment represents substantial challenges for a HSI collection: the atmosphere is more extensive, the spatial size of pixels is likely to be larger, and the collection angle is more likely to be oblique.

C. Objectives

HICUPP was an approved Space Battlelab Initiative examining long slant range data acquisition and off nadir collection to approximate future hyperspectral collection and exploitation from space. This was accomplished by placing a HSI sensor on the top of Pike's Peak to perform a low cost, high volume collection of HSI data. The collections from Peterson AFB, Schriever AFB, Buckley ANGB, Ft.Carson and the Colorado Springs area will assist in the validation of future space-based HSI collection strategies. The following objectives were met:

1. Successfully collected off nadir data under atmospheric and geometric conditions similar to space. During the demonstration period, the system produced over 100 datacubes of selected targets.

2. The HICUPP data provided a better understanding of U.S. forces vulnerabilities to space-based spectral collections and exploitations. The datacubes from HICUPP will contribute to the limited spectral library for future space systems such as Warfighter 1.

3. Effective detailed data analysis of the datacubes proved the value of subpixel analysis. This technique allowed us to overcome poor spatial resolution (pixel size) and identify objects by their spectral signature.

The Space Battlelab designed these ojectives to measure the potential of a HSI platform in space. In a series of collections, we took advantage of the long slant range extended from the top of Pike's Peak to multiple sites in the Colorado Springs-Pueblo-Denver-Mount Evans area. Placing a sensor atop Pike's Peak provided extreme off nadir angles to the targets collected. The amount of atmosphere encountered from Pike's Peak to the targets also simulated a space to earth collection.

D. Length of Time

1. Submittal of Battlelab Initiative to Approval

HQ SWC/AE submitted the HICUPP concept to the Space Battlelab on 19 Sep 97. The Space Battlelab presented the concept to the Battlelab Planning Cell (BPC) on 23 Oct 97. The Space Battlelab General Officer Advisory Group (GOAG) approved the HICUPP concept for detailed planning on 6 Feb 98 and approved HICUPP for execution on 3 Apr 98. The Space Battlelab allocated HICUPP $126.5K in FY 98 for execution.

2. From Approval to Completion

HICUPP began on 4 Apr 98 and was completed on 8 Mar 99.

a. 4 Apr 98 - 23 Jun 98 (site survey, demo, coordination, etc)
b. 24 Jun 98 - 9 Jul 98 (initial data collection)
c. 10 Jul 98 - 27 Sep 98 (data analysis and preparation of 2nd collection)
d. 28 Sep 98 - 9 Oct 98 (final data collection)
e. 10 Oct 98 - 24 Jan 99 (detailed data analysis)
f. 25 Jan 99 - 8 Mar 99 (HQ SWC/AE Analysis Report for HICUPP)

2. COURSE OF ACTION

A. Overview

Major Norm Williams of the Space Battlelab worked with both Major Zoe Hale of HQ SWC/AE and Dr. William Hayden Smith (MEDECO) to conduct the demonstration. The Space Battlelab conducted the demonstration atop Pike's Peak at Colorado Springs, CO. During the demonstration, the SB was responsible for logistical coordination to include target scheduling, transportation, and HSI data collection. MEDECO was responsible for the digital array scanned interfometers (DASI) HSI sensor control system while HQ SWC/AE performed HSI data collection of targets and data analysis on over 100 collected datacubes.

B. System and Demonstration Description

1. Equipment

A variety of different types of equipment was used to support this data collection. The DASI sensor consisted of a visible/ near infra-red and short wave sensor mounted on a sensor bar. As the target image was collected, the data from the DASI sensor was transferred to a computer. This data was copied to a Jaz drive and then processed in HQ SWC/AE for data analysis. A sighting scope and magnetic compass were mounted on the sensor bar to ensure accurate target acquisition.

2. Targets

The SB surveyed potential target sites in the local area prior to the data collection. These included both military and civilian facilities, as well as agricultural features. The local area was surveyed and Global Positioning System (GPS) coordinates were taken for potential targets. This helped to accurately identify and locate the targets from the top of Pikes Peak during the data collection. Agricultural areas were identified to assess the ability to detect disturbed soil and different types of vegetation. Areas producing bright illumination (large local shopping center and ballparks) at night were chosen for the night collect. During the night collect, imaging roads and using change detection techniques during the data analysis identified mobile targets. Targets with a large surface area and perpendicular (buildings and ray domes) to the sensor were chosen to ensure positive identification during subpixel analysis. Almost all targets collected from Pike's Peak required subpixel analysis due to the extreme oblique angles involved in the demonstration.

3. Change of Seasons.

The Space Battlelab chose the two data collection periods to take advantage of changes to vegetation occurring during different seasons of the year. The two collection periods also provided different seasonal atmospheric conditions. During the first data collection period, (24 Jun through 9 Jul 98) the relative humidity was high and the vegetation was verdant. The relative humidity was noticeably lower and the vegetation had changed to its fall colors during the second collection (28 Sep though 9 Oct 98) period. These seasonal differences were detected during the data analysis.

4. Analysis

Preprocessing and detailed data analysis was accomplished by HQ SWC/AE in the Analytical Support Facility. Preprocessing of datacubes allowed for integration of different processing systems during detailed analysis and took into account various system effects. Minor faults such as a bird flying in front of the sensor were corrected and wind oscillations were removed from the data.

Several Commercial Off-The-Shelf (COTS) and Government Off-The-Shelf (GOTS) products were used by HQ SWC/AE to complete the detailed data analysis. The primary COTS data analysis tools used included ENVI (The Environment for Visualizing Images) to gain greater geometric accuracy in the image by correcting for sensor position, topography and other sensor effects. ENVI was used because it provides a sophisticated set of hyperspectral and multispectral analysis tools with the capability to do sub-pixel analysis. Erdas' IMAGINE™ Professional provided a set of tools that allowed for in-depth map

building and analysis. One of the GOTS tools MODTRAN (MODerate resolution TRANsmittance code), is an atmospheric optical model and was used to predict correct atmospheric effects.

The HICUPP collection produced over 100 HSI datacubes and proved HSI sensors can collect useful off nadir information. The large number of datacubes collected will help HQ SWC/AE refine sub-pixel analysis and other hyperspectral processing techniques. The complete HICUPP detailed data analysis is contained in the HQ SWC/AE classified document Technical Report 99-08, Analysis Report for the Hyperspectral Information Collection Upon Pikes Peak (HICUPP) Initiative (Secret).

3. RESULTS

The HICUPP demonstration was extremely successful in meeting the objectives established during the initial stages of the initiative.

The first objective was to prove we could collect useful off nadir data. We were very successful in doing this as more than 100 off nadir HSI datacube collections. This effort proved that a small field of view sensor could collect accurate HSI data. This data could then be analyzed to locate a target, classify and identify it by its spectral signature. Data from off nadir angles in excess of 75 degrees was successfully processed, and targets were located and identified in the datacube.

In the second objective we showed U.S. Forces could be vulnerable to space based spectral collections. Our present techniques of using camouflage, concealment and deception of military targets are vulnerable to HSI collections. The large number of datacubes collected during the HICUPP demonstration will make a significant contribution to the almost nonexistent off nadir spectral library. Building the spectral library is important to future space systems such as Warfighter 1.

In the third objective, we demonstrated the value of doing sub-pixel analysis and showed that a small amount of spectral data provides a tremendous amount of useful information. We learned we can sacrifice some spatial resolution and make up for this loss by collecting quality spectral data. During HICUPP, we had marginal spatial resolution yet were able to collect useful data at more than 60 miles away at more than 85 degrees off nadir. The target at that distance only filled 1/8 of the pixel but during the sub-pixel analysis of the datacube the target was easily identified.

The results of the HICUPP demonstration exceeded our expectations and proved off nadir collections can be accomplished successfully. Our Armed Forces need to be aware they are vulnerable to space-based spectral collections and seek ways to reduce their vulnerability. The addition of the off nadir data HICUPP provided to the spectral library will help decrease the amount of time it takes to process future off nadir data.

4. RECOMMENDATIONS

This report and the detailed data analysis can be used by designers of future satellite and UAV systems to inform them of the successes HICUPP had using off nadir collection techniques. It's important to stress the need to incorporate off nadir techniques in the planning and designing of these future HSI systems.

The off nadir aspect and great distances from the sensor to the different targets covered in HICUPP are extremely unique and will be made available upon request. The lessons learned during the detailed data analysis will aide in future processing techniques. This improvement will result in quicker processing times and increased reliability during the identification phase. The spectral processing experts need to continue to find ways to accomplish detailed data analysis in a more timely manner. This will allow HSI sensors to be placed in tactical platforms i.e. UAV's so near real time HSI information can be passed to the appropriate battlefield commanders.

The Space Battlelab has passed the HICUPP data analysis to the Army Space and Missile Defense Battlelab. This is in support of their tactical HSI work and a possible demonstration involving a HSI equipped UAV. The SB has also contacted the Air Force UAV Battlelab and discussed the feasibility of placing a HSI sensor on a UAV and doing a collaborative battlelab initiative. This initiative involves collecting HSI data and processing it in less than 90 minutes. This initiative will be one of the first true tactical applications of HSI capabilities.

Although HSI is an emerging technology, there is tremendous military utility that can be taken advantage of if applied properly. The spectral community needs to be aware of this potential and leap at the opportunity to exploit these techniques and apply it to future HSI sensors in space and on UAV's. Our forces need to realize that we too are vulnerable to HSI collections. By educating and training our military on new tactics we could negate the value of HSI collections done by our adversaries. This technology has true value added and must be used by future space and UAV assets as soon as possible.

5. CONCLUSION

The Space Battlelab conducted the HICUPP demonstration with a relatively small budget yet proved useful HSI data can be collected at extreme off nadir angles. All of the objectives that were established prior to the demonstration were accomplished in an outstanding manner. One of the main purposes of the HICUPP demonstration was to provide national agencies, Air Force Space Command and other DoD agencies with a better understanding of off nadir capabilities. The Space Battlelab is promoting off nadir collection techniques so future HSI satellites and UAV's can take advantage of increased collection opportunities. All of this will be accomplished without requiring the sensor to be directly over the target. HICUPP confirmed that using off nadir collection techniques will allow greater flexibility of optimizing future HSI systems. By collecting

off nadir, HSI satellite systems and UAV's will have improved utility by not being required to fly directly over a target. Based on successful analysis results, HICUPP has shown spectral data collected at extreme angles has a high potential to provide significant improvement in target collection techniques.

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