

Real-time Spectral Band Optimization for Unmanned Aerial Systems (UAS) Hyperspectral Camera

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PROBLEM STATEMENT

Unmanned Aerial Systems (UAS) are often engaged in gathering Intelligence, Surveillance and Reconnaissance (ISR) information to detect and identify potential threats. Hyperspectral imaging and other effective new sensors are now in use, but they can produce raw ISR data at rates that can easily overwhelm the available transmitter bandwidth on most UAS platforms. The controllers of a UAS mission require this raw information quickly so that it can be processed to reveal the presence and identity of potential threats, allowing the controllers to take action against them while a UAS remains in flight. Current on-board data processing systems are unable to manage the vast amount of information generated by advanced sensors in a timely manner. An on-board system for processing and disseminating the data in real-time is needed.

DSPCon is developing the Optimized Hyperspectral Camera System (OHCS) to meet the demanding data requirements of airborne hyperspectral camera technology.

WHO CAN BENEFIT?

The most important beneficiary of DSPCon's new OHCS technology is the warfighter. With an OHCS-based system aboard the UAS providing real-time information concerning threats in the littoral environment, the warfighter is able

to determine an immediate and appropriate response, potentially saving lives and property.

Department of Defense (DoD) programs that can benefit from DSPCon's OHCS technology are those that have an ISR component, particularly where Image Intelligence (IMINT) is required. While the focus of this SBIR is for the OHCS to be deployed on an aerial platform, namely the Silver Fox, the new system can provide benefits to both manned and unmanned ground vehicles, as well as seaborne vessels. The low weight, small size, low power consumption and high-speed processing capability of the OHCS makes it attractive for integration with new systems, as well as for upgrading legacy systems. Aircraft programs of this type include both manned and unmanned aerial systems patrolling over land or water environments. Ground-based systems include unmanned robotic vehicles that acquire image intelligence to identify both human and explosive threats.

Commercial beneficiaries of this technology include agriculture, where spectral signatures can reveal the condition of crops. While real-time operation is not critical in these applications, the low weight, small size and low power consumption of the OHCS allows a small inexpensive UAS or manned vehicle to host the system.

BASELINE TECHNOLOGY

Hyperspectral imaging is a method of obtaining the spectral content of each pixel in an image. This technology divides image data pixel-by-pixel into many narrow, contiguous wavelength (color) bands, resulting in a three-dimensional image, known as a *datacube*, which offers both geographical position and spectral content; therefore, it contains significantly more data than a standard image.

The baseline hyperspectral technology used in the platform is known as a "pushbroom" type of hyperspectral camera, where the scene below the UAS is captured in a pattern perpendicular to the direction of flight. The term pushbroom describes the method in which a line image (that is, a single row of spatial pixels) is imaged and spectrally resolved at a rate commensurate with the speed of the UAS platform, and ensuring that the area below the aircraft is imaged without any gaps.

The great strength of the current approach is that the hyperspectral technology is airborne and able to completely cover the patrol area with a large number of both *spatial* resolution cells and *spectral* resolution cells. This allows small objects to be imaged, and their unique spectral signatures to be captured, allowing them to be distinguished from other objects and background.

A significant issue with current implementations of this technology is that hyperspectral images are collected too quickly for transmission to the ground. A hyperspectral camera collects datacubes at a rate of 125 Hz, while the data

transmitter aboard the UAS can transmit images to the ground control station at a rate of only 30 Hz. The images need to be stored aboard the aircraft and must be downloaded and processed post-mission to extract actionable information on threats. This creates a significant lag between when a threat is “seen” and recorded by the camera aboard the UAS, and the time that the threat can be identified.

Additionally since missions can last five hours or more, downloading and transporting data to a processing station after recovery of the aircraft adds additional time and manpower to the effort. Eliminating these costs to the warfighter warrants the development of the on-board processing system developed by DSPCon.

TECHNOLOGY DESCRIPTION

Seeing the Navy’s need for aerial systems that deliver actionable data to the controllers of a UAS mission while it remains in flight, DSPCon Inc. proposed an innovative system that can identify targets in real-time, by coupling a hyperspectral sensor with a high-speed processor embedded on the UAS platform. DSPCon’s system combines a number of technologies: (a) images from hyperspectral cameras, (b) on-board data acquisition, processing and analysis, and (c) communication to warfighters.

DSPCon’s algorithms extract critical target information from the raw data collected from the sensors, which are processed on-board the UAS. Compressed images of the targets, generated by the algorithm processing, are coupled with metadata that represents the aircraft’s ground position, and orientation data obtained from the UAS GPS receiver and autopilot system. This data contains the most critical target information. The compressed images are designed to be easily carried within the bandwidth capabilities of the platform’s transmitter.

DSPCon offers an integrated real-time processing system that is capable of evaluating the unique spectral properties of both artificial and living targets to help determine what they are, and where they are, even when visible light is not sufficient to identify them. The OHCS offers the military forces of the United States and its allies an opportunity to exploit hyperspectral sensor capabilities through DSPCon’s low-cost, programmable data analysis and recording platform. The OHCS reduces risks to military personnel, and can operate 24 hours a day.

The OHCS technology platform offers the Navy a system that is small, lightweight, and efficient, conforming to the required size, weight and power (SWaP) consumption requirements. The system also compresses the raw hyperspectral images into an efficient data-stream that is sent to the team controlling the flight. This data-stream is processed and compressed by the OHCS aboard the UAS during the flight, and delivered over the air-to-ground datalink to allow flight controllers to evaluate the information, and to take action while the aircraft remains airborne.

The quick transfer of this critical data enables Navy forces to respond rapidly to potential threats. DSPCon’s OHCS offers controllers an immediate view of indispensable data that will alert them to threats and targets of interest.

An integrated high-speed data-recording function, part of DSPCon’s embedded system on the UAS, also allows Navy personnel to perform more detailed post-mission analysis of the uncompressed hyperspectral imagery collected during a mission, enabling even greater strategic advantages for U.S. and allied forces.

DSPCon Technology Innovations

During the development of the OHCS system, DSPCon introduced two key classes of innovation, and coupled them with Commercial-Off-The-Shelf (COTS) components currently used on UAS platforms.

Hardware design - The first class of innovation is a compact and lightweight hardware design that offers high-speed processing with low power requirements. It includes an interface to a hyperspectral camera, a high-speed processor, and solid-state memory that can acquire, process, and store the camera’s data during flight, and in near real-time.

Software algorithms - The second class of innovation includes complex algorithms designed to identify the critical subsets of spectral bands (from among the multitude of spectral bands in a hyperspectral datacube) that adequately describe particular targets of interest. These innovations enable near real-time identification of targets by (a) recognizing unusual spectral signatures (relative to the background) in the camera’s field-of-view, or (b) identifying targets in the field-of-view that match a known spectral signature.

<u>Feature</u>	<u>Advantage</u>	<u>Benefit</u>
Records Hyperspectral data	Offers an additional component for target identification	Helps eliminate wasteful investigation of false targets and reduces collateral damage
Programmable	Flexible use in multiple applications and varied targets	User can develop new algorithms depending on need
Critical mid-flight processing	Summarizes and reports on critical data in near real-time	Control team can see results and make decisions during mission
Compresses data	Allows low-bandwidth air-to-ground communication	Input into critical decisions can be made and confirmed during a single mission
Archives raw data	Offers detailed post-flight analysis of all recorded data	Allows the development of more strategic information

COTS Architecture	Reduced costs in procurement and maintenance	Inexpensive system; easily replaced if damaged
Compatible with Silver Fox (small tactical UAS)		
<ul style="list-style-type: none"> • Small size 	Cannot be easily detected	Reduces visibility to hostile parties
<ul style="list-style-type: none"> • Weight < 5 lbs. (including camera) 	Can be easily mounted on unmanned aerial systems	Reduces risk to defense personnel
<ul style="list-style-type: none"> • Power < 20W (including camera) 	Conserves power for longer flights	Reduces the number of flights and allows more efficient use of UAS

CURRENT STATE OF DEVELOPMENT

DSPCon is close to completing the software architecture that manages the data flow in the OHCS system and interfaces with the COTS hyperspectral camera, and the on-board navigation and video transmission hardware. The framework will also be able to host the third-party developed algorithms for spectral unmixing that extracts key information on the targets of interest in the hyperspectral image data. Completing this will place the development of the OHCS at TRL 2 (see Milestones table below).

DSPCon will conduct further testing of the system at DSPCon headquarters with a scaled down field test. Plans include mounting an OHCS camera above a moving scene with scaled down parameters to simulate flight at normal UAS cruising speed and altitude. DSPCon is in the process of executing a laboratory test of the performance of the software architecture and the latest development of the spectral unmixing algorithms on a laboratory test bed. At the end of the Phase II program, DSPCon expects that the new technology will be at TRL 5.

Milestone	TRL	Risk	Measure of Success	TRL Date
Integration and test of software algorithms	2	Low	Successful laboratory test of algorithm on benchtop prototype	4Q/2010
Complete electrical design of OHCS modules	3	Moderate	Generation of final schematic	4Q/2010
Validate design of chassis mount	4	Moderate	Successful validation integrated OHCS chassis and system components	1Q/2011
Embedded system software design	4	Moderate	Successful lab demonstration	2Q/2011
Complete full system test	5	High	Consistent detection of test target	3Q/2011

REFERENCES

The contact information for the Program Manager for this SBIR program:

Program Manager, Avionics (NAWCAD), Phone: (301)342-2098

WHEN THE TECHNOLOGY WILL BE READY FOR USE

At the end of Phase II, the OHCS will be ready to transition to flight testing on a Silver Fox UAS platform. Following completion of testing on the Silver Fox, the technology will be ready for implementation on other manned and unmanned aircraft platforms.

Milestone	TRL	Date
Flight certification and review for OHCS on Silver Fox UAV platform	6	2Q/2012
OHCS test in operational environment on Silver Fox UAV	7	4Q/2012
Final modifications and adjustments for full launch	9	3Q/2013

ABOUT THE COMPANY



New Jersey-based DSPCon is a leading systems integrator and full-service solution provider of high bandwidth, high-performance data acquisition, analysis and archiving systems for governmental agencies and commercial enterprises in the military, defense, aerospace, avionics, machinery, manufacturing and telecommunications industries.

DSPCon systems empower organizations to streamline test and development cycles and improve operational and production efficiencies by slashing the time between data acquisition and processed analytical results. Mission-critical applications include acoustic, vibration, shock and rotating machinery analysis; sonar and radar processing; digital data recording and jet engine testing. The company is certified to ISO9001:2008 quality standards.

DSPCon solutions are powering the mission-critical data management needs of leading, world-class companies such as Pratt & Whitney, Rolls Royce, Honeywell and General Dynamics, helping them transform application data into actionable intelligence to achieve faster test and production times, lower failure rates and maximize asset utilization.

Visit the company's website at www.dspcon.com.