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Paper Session II-C - Warfighter-1: An Air Force Partnership With Industry To Advance Space Imaging Spectroscopy

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Warfighter-1: An Air Force Partnership With Industry To Advance Space Imaging Spectroscopy

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Abstract

The Air Force Research Laboratory Integrated Space Technology Demonstrations (ISTD) Program Office has partnered with Orbital Sciences Corporation (OSC) to complement the commercial satellite's high-resolution panchromatic imaging and Multispectral imaging (MSI) systems with a moderate resolution Hyperspectral imaging (HSI) spectrometer camera. The program is an advanced technology demonstration utilizing a commercially based space capability to provide unique functionality in remote sensing technology. This leveraging of commercial industry to enhance the value of the Warfighter-1 program utilizes the precepts of acquisition reform and is a significant departure from the old-school method of contracting for government managed large demonstration satellites with long development times and technology obsolescence concerns.

The HSI system will be able to detect targets from the spectral signature measured by the hyperspectral camera. The Warfighter-1 program will also demonstrate the utility of the spectral information to theater military commanders and intelligence analysts by transmitting HSI data directly to a mobile ground station that receives and processes the data. After a brief history of the project origins, this paper will present the details of the Warfighter-1 system and expected results from exploitation of HSI data as well as the benefits realized by this collaboration between the Air Force and commercial industry.

Birth of the Project

Information dominance, namely, the ability to optimize surveillance, reconnaissance, and data correlation, provides the near term stimulus for the military space program and has the potential of becoming the deterrence strategy of the future. Gen. Estes, commander of US Space Command, states in a recent speech titled *National Security — the Space Dimension*, "We need to develop a real-time, space-based earth surveillance system to provide the dominant battlefield awareness." [1]

Developing space doctrine must also consider those pragmatic realities to which the services may be driven by economic constraints. Gen Estes continues saying "we need to leverage the advances made by civil and commercial space to help us respond to developing situations and threats faster." By embedding military requirements in civilian/commercial space craft, dual-use sensors can be designed to meet the nonmilitary requirements and, simultaneously, be ready with highly capable on-orbit general purpose sensors for military use.

The mission of the ISTD program is to take a series of Advanced Technology Demonstrations (ATDs) that bring emerging technologies (specifically from the Air Force Research Lab) to bear on Air Force mission area deficiencies as an integrated system and demonstrated in a near operational environment. The ISTD Program Office has the charter to transition technologies into an operational 'warfighter' setting and bring those technologies to demonstrations on a three-year timeframe. In response to the drive for information dominance, Warfighter-1 was

developed to address Air Force Space Command (AFSPC) mission area plan deficiencies [2]. Tactical surveillance was identified as one of the mission areas that would be significantly impacted with the emerging technology of imaging spectrometry or Hyper-Spectral Imaging (HSI). In conjunction with the Air Force's decision to pursue both tactical surveillance and HSI, Gen. DeKok, who was then director of AFSPC/XP, urged the ISTD program office to pursue commercial leveraging.

The primary objectives of the Warfighter-1 program are to evaluate and validate HSI technologies in a space environment, demonstrate user utility of space-based HSI to the military/government users, and demonstrate the ability to leverage commercial space systems.

Acquisition Reform

The procurement of Warfighter-1 was done under the precepts of acquisition reform. In the old way of doing government acquisition, the procuring agency states in the procurement what it wants and how to build it. The new principal is for the governmental agency to state what it wants and for the contractor to state how to build it. While the Warfighter-1 program has been able to attract competition, new issues have surfaced and new ways of doing business are needed in order to take full advantage of "leveraging" a commercial program. Several areas where DOD policy impacts the government's ability to work with commercial industry as a legitimate partner are technical requirements, government licensing for data sales, and control of shared assets. By partnering with a commercial venture, the government has relinquished traditional oversight roles and has exchanged much of their oversight for insight through an Integrated Product Team (IPT) structure into the total program.

Commercial leveraging has the potential to result in enhanced benefits to the government due to synergistic combinations of commercial capabilities and government payload capabilities. To capture these benefits, the government requirements should specify only the absolute minimum requirements. In doing so, the government maximizes the competition with more options to choose from. Additionally, contractors have greater flexibility in proposing enhancements that are a part of the commercial system being leveraged. The value of the enhancements to the government mission are considered during the source selection decision process. The more the government can accept planned commercial system requirements, the more attractive the commercial leverage becomes to both the government and industry. The Warfighter-1 acquisition established just a few minimum requirements to allow the program to take full advantage of the attributes of commercial platforms. Establishing a new dual use capability, at minimal impact to a commercial program, is an attractive incentive to entice industry to enter the competition with an eye toward creating new commercial products.

The Warfighter-1 program will accelerate the entry/availability of hyperspectral imagery into the commercial remote sensing market. A large part of the market as viewed from U.S. industry will consist of overseas sales. Many of the potential contractors for Warfighter-1 were clear that unless this new data could be sold overseas, they would have a difficult time in recovering their investment in flying a hyperspectral sensor. However, contractors received no assurances prior to the contract award from the Department of Commerce that they would be able to sell the data commercially. This situation is particularly troublesome for new ventures attempting to get into the commercial remote sensing business. Industry bidding decisions were difficult due to the inability to confirm that foreign data sales would be permitted. Presently, the Department of Commerce is considering a license for OSC to sell and/or export HSI data or imagery products to foreign countries

One of the biggest issues that face the Warfighter-1 program is how much time and to what extent can the government control the payload and/or spacecraft. Potential contractors were very concerned about turning control of their commercial spacecraft over to the govern-

ment for long periods of time. Also, there was a serious concern with business opportunity cost (commercial and government data cannot be collected simultaneously) associated with the operation of the spacecraft by the government. To resolve this situation, the Warfighter-1 program defined a specific number of hyperspectral data sets be delivered (500 to be exact), instead of specifying the number of hours or days the government would control the spacecraft. Contractors then had the flexibility to determine how much time and control would be allowed to the government to provide the mission unique HSI data sets based on their unique commercial system design and customer base.

Hyperspectral Imaging

Figure 1: Spectral imaging spectral resolution example for Multi-Spectral (MSI), Hyper-Spectral (HSI) and Ultra-Spectral (USI) Imaging systems. [Multispectral Users Guide, 5]

LandSat, SPOT and myriad other satellites have had as part of their primary payload a 2-10 band multispectral imaging camera. With a small number of spectral bands, major surface reflectance features can be identified and classified with a multispectral system. However, subtle spectral features necessary for discrimination of plant species or identification of well-camouflaged targets requires a hyperspectral (nominally hundreds of spectral bands) or an ultraspectral (nominally thousands of spectral bands) imaging camera to discriminate. Figure 1 shows an example of the three spectral resolution classes in spectral imaging. Because of the complexity associated with building either a Hyperspectral or Ultraspectral imaging system, no spaceborne HSI or USI system has been built and successfully put into orbit and functioned.

Imaging spectrometry or HSI has emerged from the field of geoscience remote sensing where the spectroscopic reflectance signature of minerals measured in a laboratory was taken to the field first by the JPL Airborne Visible and Infra Red Imaging Spectrometer (AVIRIS) [3]. More recently, a DOD airborne sensor, Hyperspectral Digital Imagery Collection Experiment (HYDICE) has been flown over military targets to determine the applicability of HSI data to meeting various military needs [4]

As an example of the added information gained by an HSI system over an MSI system, Figure 2 gives the spectral reflectance signature of a leaf for both an HSI and MSI system. Although some useful information can be gleaned from the MSI spectral signature about the state of the leaf, however the HSI spectral signature clearly provides much greater information on otherwise undetectable higher fidelity features as to the exact condition of the leaf.

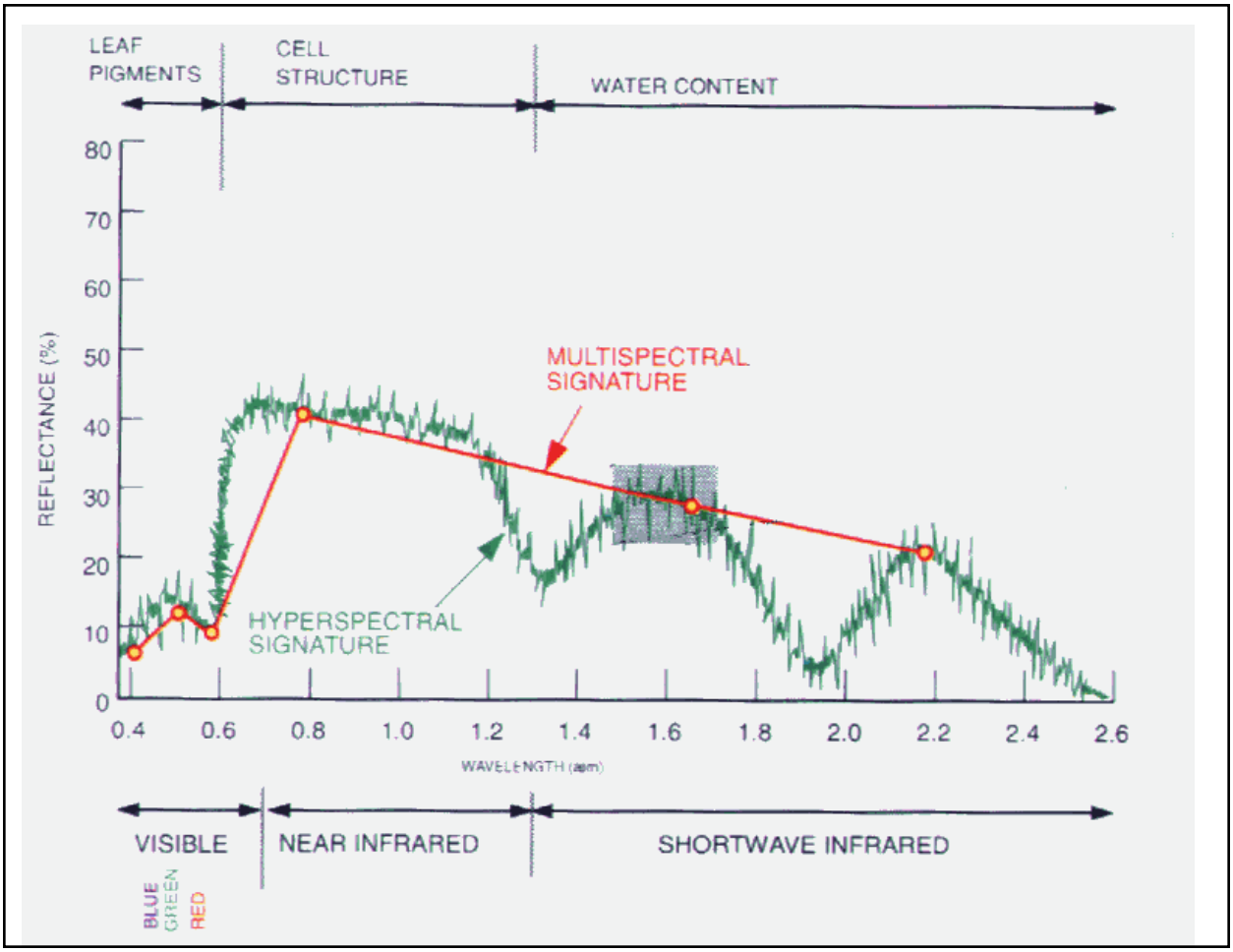

Figure 2: Spectral reflectance signature of a leaf for both an HSI and MSI system. [5]

Warfighter-1 System Description

The Warfighter-1 system has two missions. The commercial mission is to generate, process, and distribute panchromatic, 4-band MSI, and 280-band HSI data on a commercial basis. The Warfighter-1 mission is to generate, process, and analyze HIS data in order to validate technology and demonstrate the military utility of hyperspectral sensing from space.

The Warfighter- OrbView (WF-OV) system consists of a space vehicle and a ground segment. The space vehicle consists of the spacecraft and its imaging payload as shown in Figure 3. The spacecraft additionally interfaces with the launch vehicle and the Global Positioning System constellation of satellites. The ground system consists of the OrbView Operations Center (OOC), the Warfighter-1 Mission Data Center (MDC), and the Warfighter-1 Mobile Ground System (WMGS). The ground system interfaces with ORBIMAGE (the commercial sales company for OSC) customers, Warfighter-1 users, and ORBIMAGE distributors. The OOC manages and controls the space vehicle in support of both the Warfighter-1 and commercial missions. It also performs commercial data processing and data archive functions and supports customer interfaces both domestically and internationally via local distributors. The MDC is responsible for Warfighter-1 image exploitation and verification data processing and archive and supports Warfighter-1 user interfaces. Through direct connectivity with the OOC, the MDC provides Warfighter-1 users with capabilities for payload tasking uplink, imagery and

ancillary data downlink, and data analysis in support of imagery exploitation. The Warfighter-1 Mobile Ground System is responsible for providing real-time, in-field satellite command uplink, hyperspectral imagery downlink, data processing, exploitation, and analysis capabilities in order to support Warfighter-1 exercises and utility demonstrations.

WF-OV imagery tasking originates with customers or Warfighter-1 users who have a need for imagery that is not already available in existing WF-OV archives. International customers obtain commercial services via distributors with defined zones of image collection and sales authority. ORBIMAGE acts as a distributor for domestic customers and for the Warfighter-1 data via interfaces between the OOC and the Warfighter-1 MDC. During user utility demonstrations, the WMGS interfaces directly with the OOC to provide imagery tasking orders and to receive the resulting command loads in real time for uplink to the spacecraft. Distributors and users are assigned imaging windows on each orbit of the spacecraft according to visibility of each distributor's territory and the operational constraints of the spacecraft. Each distributor is responsible for specifying tasking during each assigned imaging window that addresses customer needs and priorities while meeting spacecraft constraints such as attitude agility, imaging rate, and downlink capacity. Each distributor is provided with tasking software containing spacecraft constraint information in order to support this interactive tasking selection process. Each commercial distributor also maintains a ground station for acquiring imagery collected for that distributor. The OOC maintains high-latitude and CONUS ground stations as primary downlink sites for ORBIMAGE and Warfighter-1 data. During Warfighter-1 user utility demonstrations, the WMGS has the priority tasking and downlink.

Table 1: Hyperspectral Bands

Band	Wavelength Range (mm)	Bands	Band Spacing (nm)
Visible	0.45—0.905	40	11.375
NIR	0.86—1.74	80	11.375
SWIR	1.58—2.49	80	11.375
MWIR	3.0—5.0	80	25

The imaging satellite will be launched into a sun synchronous, 470 km circular orbit by a Pegasus XL or Taurus launch vehicle. The payload will acquire combinations of 1 meter panchromatic (0.45 - 0.9 mm) imagery, 4 bands of 4 meter GSD multispectral imagery in the 0.45-0.9 mm spectral band, and 8 m GSD hyperspectral imagery in 280 bands from 0.45 to 5 mm. The OOC uplinks tasking to the spacecraft for imaging on the current or subsequent orbits. The wide band imagery data is either downlinked directly to distributor-owned data downlink and processing centers or stored in on-board solid state memory and downlinked to one of two commercial ground terminals for dissemination to the customer. The majority of downlinked data is also stored in an archive for subsequent processing and distribution to customers.

The hyperspectral sensor will have 280 hyperspectral channels evenly spaced in each band as outlined in Table 1. The Full Width Half Maximum (FWHM) bandwidth for each band shall be less than or equal to 1.2 times the specified band spacing.

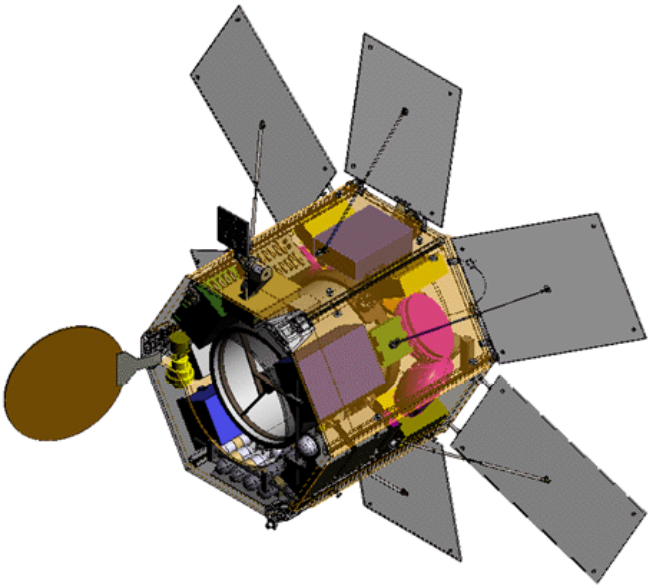

Figure 3: Diagram of the completed Warfighter-1 Satellite

Conclusions

The Air Force Research Laboratory ISTD Program Office has partnered with Orbital Sciences Corporation to complement the commercial satellite's high-resolution panchromatic and MSI cameras with a moderate resolution HSI camera. The program is an advanced technology demonstration utilizing a commercially based space capability to provide unique functionality in a remote sensing technology. This leveraging of commercial industry to enhance the OrbView satellite utilizes the precepts of acquisition reform.

Information dominance has the potential of becoming the deterrence strategy of the future. The HSI system will be able to detect targets from the spectral signature measured by the hyperspectral camera. The Warfighter-1 program will also demonstrate the utility of the spectral information to the theater military commanders and intelligence analysts by transmitting HSI data directly to the WMGS.

References

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