PROBLEM STATEMENT:
EO/IR reconnaissance is of primary importance to Military Intelligence. A key tool to increasing the information content of reconnaissance imagery is the use of hyperspectral imaging. This technology divides the image data, pixel by pixel, into very narrow wavelength (color) bands. This high-resolution spectral data is effective in identifying previously hidden features in the image, and can distinguish camouflage paint from tree canopy, tag recently disturbed earth, identify compounds in chemical plumes, and provide data beyond the spatial resolution of the imaging system (sub-pixel resolution).

The efficacy of hyperspectral imaging has been demonstrated by several successfully fielded systems including SEBASS, AVIRIS and HYDICE. However, a significant drawback to these systems is the massive amount of extraneous data captured in each field. Some systems such as COMPASS collect over 1 gigabyte of data every 40 seconds. Real-time processing of this amount of data represents a significant bottleneck in performing time critical targeting.

To satisfy current and future requirements, data collection and analysis must be significantly faster in order to deliver the right information to the right warfighter at the right time. Furthermore, surveillance devices need to be distributed, not concentrated in single instruments, so that any warfighter can access fresh target data anywhere in the battlespace. This means they must be robust, reliable and affordable.

Under Air Force contract No. F19628-03-C-0079, BD&E developed a unique, patent-pending staring hyperspectral technology called the HyperPixel Array™ (HPA™). This optical processor-based hyperspectral system greatly reduces digital computational requirements, leading to a faster and more sensitive instrument.
BD&E has been awarded 4 separate contracts to further develop this technology for various military applications: in the LWIR for space-based imaging, in the MWIR region for high-energy events, such as RPG launches, in the SWIR for characterization of missile intercepts and miniaturized for use in Exo-atmospheric Kill Vehicles.

**Hyperspectral Imaging at the Speed of Light**

This massively parallel system collects the full three-dimensional hyperspectral data cube without scanning. Incident photons from a surveillance image are detected *en masse* by a two-staged optical processor. This device manipulates the data set prior to any electronic detection or software processing, operating on the data set *at the speed of light*. No computer algorithm can process faster.

The data cube is divided into orthogonal constituents of wavelength and two spatial locations as depicted in Figure 1. The processing system uses a staring array of HyperPixels™. Each HyperPixel™ is a separate spectrographic channel capable of resolving hundreds of spectral bins. Since it is a staring system, its sensitivity can be made arbitrarily high by staring longer. Since it does not scan, there is no temporal distortion of the spatial information.

*Figure 1. This is a graphical representation of the data cube and the acquisition parameters of existing systems. If we consider the data cube as a three-dimensional body, existing scanning systems measure only one slice through the data cube at any given instant. Wavelength scanning systems measure a slice of the cube at a fixed wavelength, slit scanning systems measure at a fixed position in one spatial dimension. The HPA system is unique in that a parallel optical processor measures the entire data cube simultaneously, and continuously distributes the entire cube onto a detector array.*
Military Applications

Hyperspectral imagery is poised to become a key element in the military’s arsenal of tools for surveillance and reconnaissance, force protection and chemical defense. Additionally it is receiving increased attention in the homeland defense arena, both as a first responder’s tool and in sample analysis.

The HyperPixel Array™ imager is rugged, compact and modular enough to be mounted on a variety of platforms, including satellites, UAVs, Future Combat System (FCS) vehicles, Aerial Common Sensor aircrafts, portable vehicles and hand-carried or robotic instruments. Thus, this innovation will offer benefits across a variety of DoD platforms.

The HyperPixel Array™ can support Distributed Ground Centric Sensor (DGCS) surveillance of the battlespace environment. It is ideally suited for use in low-cost micro UAVs, where it can vastly benefit emerging military needs. It can be easily optimized for surveillance of transient signals and rapidly occurring events such as explosions, rocket launches, low contrast aircraft, cruise missiles, and artillery fire. Its high-discrimination capability will be able to classify explosions, identify missile type from a launch signature or dynamically assess bomb damage. It will also be able to identify critical mobile targets in heavy foliage, smoke or dim light and will be able to accurately differentiate between targets and decoys. It will play a vital role in battlespace awareness and space control missions. Specific applications for MASINT missions include COBRA BRASS, FORTE and MTI. Other related interest areas include Common Imagery Ground/Surface Systems (CIGSS), Signals Intelligence (SIGINT), Joint Airborne SIGINT Architecture (JASA), Imagery Intelligence (IMINT), and Measurements and Signatures Intelligence (MASINT).

Advantages

The HyperPixel Array™ offers a unique solution to the hyperspectral surveillance problem. It reduces the volume of hyperspectral data collected, and maximizes the signal to noise. This design offers the following advantages:

1. The HPA™ will reduce the data volume to rates that can be analyzed and distributed in real time.
2. Based on a staring array, the HPA™ will permit longer integration times resulting in higher signal-to-noise ratios. This will allow the system to operate in lower light and higher clutter regimes than other systems.
3. Because it is a framing system it has no motion artifacts and can be used from unstable platforms, or handheld.
4. Because it a staring device it can run at high rates, ideal for transient signals (explosions) and rapidly occurring events.
5. It is significantly smaller and more robust than current technology, allowing for use on satellites, UAVs, robots, or handheld.
6. Its low cost will allow for many distributed systems over a single battlespace. Multiple systems will provide for redundancy, insuring that
data will get to the warfighter regardless of individual instrument loss or failure, and provide knowledge at the point of decision-making.

The hyperspectral instruments currently developed or in development at Bodkin Design & Engineering are as follows:

<table>
<thead>
<tr>
<th>Model</th>
<th>Band</th>
<th>Data Cube</th>
<th>Resolution</th>
<th>IFOV</th>
<th>HFOV</th>
<th>VFOV</th>
<th>Frame Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNIR-20B</td>
<td>0.42-0.67</td>
<td>90 X 75</td>
<td>20</td>
<td>11.25</td>
<td>Various Foreoptics Available</td>
<td>30</td>
<td></td>
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<tr>
<td>VNIR-90</td>
<td>0.50-0.91</td>
<td>55 X 44</td>
<td>90</td>
<td>4.56</td>
<td>Various Foreoptics Available</td>
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<tr>
<td>MWIR-60</td>
<td>3-5</td>
<td>23 X 17</td>
<td>60</td>
<td>34</td>
<td></td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

ABOUT THE COMPANY

Bodkin Design & Engineering, founded in 1992, provides electro-optical and mechanical design services to address military and commercial needs. The company’s products are manufactured and marketed through a combination of in-house efforts and strategic relationships. The company holds many patents and has extensive experience building electro-optic sensors. Previous instrumentation development includes miniature UAV cameras, air-droppable sensors, and spectrometers. The company is currently developing hyperspectral imagers for the Missile Defense Agency and Air Force. Under a previous Navy-funded SBIR contract, the company developed the world’s first uncooled microbolometer-based miniature camera for the Pointer UAV. The resulting technology is now part of BAE System’s product line.