The Magazine of the National Intelligence Community

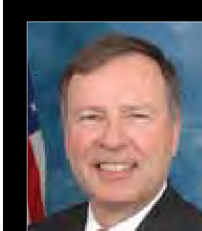
# Geospatial Intelligence Forum

## HUMINT Builder

## Lt. Gen. Michael T. Flynn

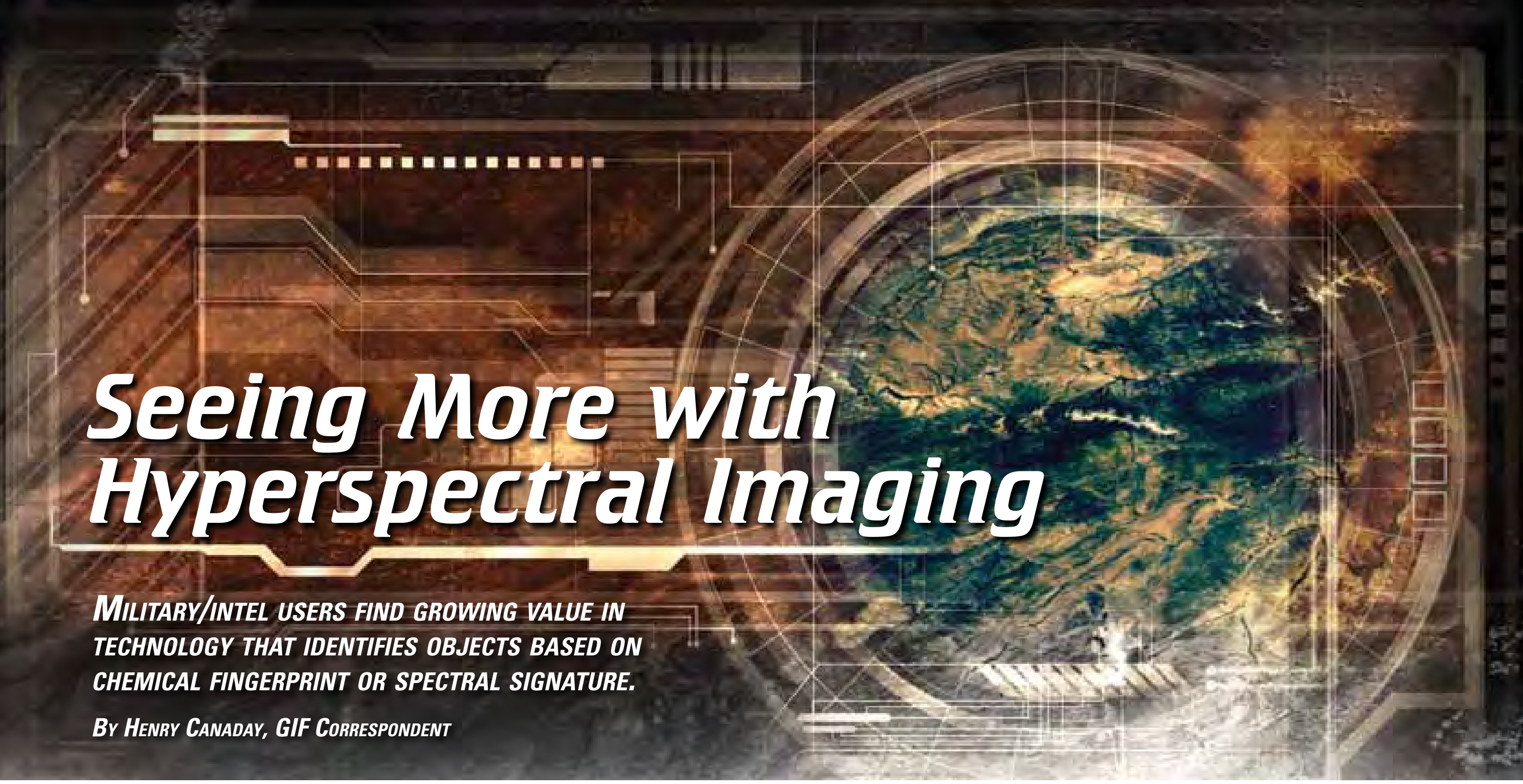
### Director Defense Intelligence Agency

GIF
www.GIF-kmi.com
Defense ★ Intelligence
Homeland Security
March 2013
Volume 11, Issue 2



**View From the Hill**
**Rep. Doug Lamborn (R-Colo.)**

**Tactical Cloud Computing ★ Human Terrain Tools**
**Hyperspectral Imaging ★ Operationalizing Integration**



# Seeing More with Hyperspectral Imaging

**Military/Intel users find growing value in technology that identifies objects based on chemical fingerprint or spectral signature.**

*By Henry Canaday, GIF Correspondent*

The recent selection of a hyperspectral imaging (HSI) sensor for the Senior Year Electro-Optical Reconnaissance Sensor platform, used on the Air Force U-2 Dragon Lady for very high-altitude reconnaissance missions, has underscored the growing importance of that type of sensing technology.

The announcement late last year that UTC Aerospace Systems would use an HSI sensor from Headwall Photonics represented a major public advance for the technology. But even before then, HSI capabilities and uses were steadily expanding.

HSI sensors are basically imaging devices like cameras that have been coupled with radiometers and spectrometers. They collect solar reflected energy in the ultraviolet (UV), visible, near-infrared (IR) and shortwave infrared (SWIR) portions of the electromagnetic spectrum, or emitted energy in the mid-wave infrared (MWIR) and long-wave infrared (LWIR) portions of this spectrum.

David Bannon

Because HSI can identify objects based on the target's chemical fingerprint or spectral signature rather than rely solely on visual appearance, it can see much more than the human eye. For example, HSI can identify the chemical signature of camouflage, which looks like the surrounding environment to human eyes, by using algorithms. These algorithms match data from HSI images with a digital library of chemical signatures.

But highly useful capabilities come with major challenges. HSI generates massive amounts of data for interpretation, so users must be able to select only the data of interest. Also, very fast and effective algorithms for image interpretation are needed, and the signature of each relevant chemical must be in the digital library. Moreover, for many practical uses, all of this must be done very quickly and with modestly sized equipment.

## Aberration Correction

Industry has been pushing hard to meet all these challenges, plus some others also necessary for the full exploitation of HSI capabilities.

Headwall Photonics has built up a leadership position in HSI over the past decade, according to Chief Executive Officer David Bannon. Innovative engineering allows Headwall to make sensors that yield aberration-corrected images and that have no moving parts.

"These are specially designed for harsh environments, airborne, on the ground or handheld," Bannon said. The company manufactures the diffractive optics that go into HSI and offers a broad range, from UV to visible light to near IR, SWIR and LWIR.

Aberration correction yields high performance. "Hyperspectral sensors are designed with image slits, and the larger the image slit the wider the field of view," Bannon explained. "With aberration correction designed into the sensor, we enable the use of a very tall image slit and can sweep a wide swath of ground."

This means Headwall sensors perform well across the whole field of view of the sensor, both in the middle and at the edges of the flight path. "We are able to sweep a very wide swath of ground with very high spectral and spatial resolution," Bannon said. "Having a high-efficiency optical subsystem allows the sensor to achieve very high signal-to-noise performance."

Bannon said this performance advantage is the reason Headwall was selected for key defense projects such as the U-2 Dragon, real-time HSI on the MQ-1 Predator and real-time target detection on small unmanned aerial systems. Headwall technology works across the board, for space-qualified satellite sensors, airborne, mast-mounted and handheld HSI.

Bannon sees several major trends in military HSI at present. The first is real-time target detection at the tactical level. "It used to take too much time to process, analyze and distribute. That time has been much reduced."

The second is development of products across spectral ranges, from UV all the way up to LWIR. Headwall has implemented a strategy for coupling sensors as a common-sensor module that provides for visible and near infrared, SWIR and LWIR capabilities to utilize all spectral features of the target set.

The third trend is reduction in the size of bundled systems, not just for HSI sensors but for GPS inertial navigation, processors and storage as well. "So as the size of the UAS decreases, from Global Hawk to Scan Eagle to handheld, we have developed an HSI system suited for each," Bannon said.

The last and related trend has been development of ground-based HSI sensors, suitable for use by reconnaissance troops, that can identify very small targets at a distance of a mile.

In general, "we want to make HSI useful and actionable, so you don't have to be a Ph.D. optical scientist to operate it," Bannon said. "You just push a button, algorithms are processed and you see the target on the screen."

At the other end of the size spectrum, Headwall makes large HSI systems on satellites and won the development contract for the high-performance sensor system on the U-2. One important goal here is affordability.

Bannon estimated that the Air Force's Airborne Cueing and Exploitation System-Hyperspectral (ACES-HY) on the Predator costs $5-7 million. "The defense community only needs a few of those and can only afford a few," he said.

Headwall HSI, by contrast, costs from $150,000 to $500,000 and offers compelling and comparable performance. "There is a substantial level of innovation being offered by small technology manufacturers such as Headwall and, in an era of constrained military spending, I believe the geospatial community will have to consider nontraditional suppliers."

## Material Identification

As an independent, not-for-profit, 501(c3) corporation, Riverside Research plays a unique role, according to Michael Nelson, the company's intelligence operations director. "Our unique role allows us to provide cradle-to-grave support across HSI acquisition, integration into platforms, system engineering of flight and ground stations, algorithm development, mission planning and analysis."

Riverside currently supports all four services as well as the National Geospatial-Intelligence Agency.

The company assists on integrating HSI onto platforms, ensuring systems perform "in the real world," Nelson said. "There are many good sensors that never achieve operational status."

The company both develops its own algorithms and validates other firms' algorithms. It helps analyze images and advise on HSI analytic software.

Riverside worked with the Air Force on ACES-HY for the Predator. Although originally designed for the Predator, ACES-HY can be put on other platforms, Nelson noted. Riverside also worked with the Air Force to integrate the SPIRITT sensor onto the U-2 and with NGA to convert Air Force HSI systems to NGA platforms.

Michael Nelson

HSI's big advantage is the ability to do what Nelson calls non-literal material identification. "Instead of using visual cues, such as identifying a tank because you see it in the image, HSI data, in conjunction with specialized, spectral-based algorithms, can identify materials not visible to the human eye," Nelson said.

The technique can cover wide areas and has potential to identify camouflaged targets, explosive materials before they are weaponized and trace aerosol signatures.

"I think the technology is gaining momentum due to its success," Nelson said. "The next big hurdle is the integration of LWIR sensors into ISR platforms. There are technical challenges in LWIR, but it has important capabilities like gas detection."

The research director believes in a layered approach to ISR. "HSI is best utilized as one layer of an integrated, multi-sensor analytic package. Adding the capability to cue other sensors, such as radar or electro-optical, can provide a powerful analytic tool by taking advantage of the synergy gained from fused data," he explained.

Riverside is investigating the challenges of processing massive volumes of complex data, which is a major issue for all ISR capabilities, including HSI. "We are trying to come up with ways to efficiently apply commercial big-data solutions to HSI processing in real time," Nelson said.

The company has partnered with several other firms to integrate hardware and software best suited to the problem. Nelson argues that future intelligence products must include rapid analysis of HSI data in cloud-based environments, followed with fusion of those results with other data sources, optical and non-optical, for optimal performance.

## Analytic Software

Exelis Visual Information Solutions (VIS) develops software for visualizing and analyzing remotely sensed data, explained Beau Legeer, vice president of products management. It offers ENVI software to analyze HSI data.

"What we saw last year was the continued airborne use of HSI to work on problems that were beyond the scope of traditional panchromatic and multi-spectral sensors," Legeer said. "There were both a continuation of old HSI programs and some new programs in the field."

However, there has apparently been no solution yet to one big HSI challenge, that of denied airspace. "HSI is still limited to places we can fly over," Nelson acknowledged.

Exelis has seen HSI become more available to tactical users, and ENVI has been put to the service of the tactical edge. In the past, Legeer said, HSI was mostly used retrospectively and forensically. "Now we are able to get the data quickly and run the work flows to identify materials of interest, and it often queues further action. In the past HSI investigated after the fact, post mortem. Now we can do this closer to the tactical edge."

This is possible partly because software has evolved to support HSI users who do not have much training or experience. "Scientists used to be the only ones who could use the data," Legeer said. "Now we have workflows put together by scientists that can produce a material identification and give you confidence estimates for the identification. The analyst just walks through a guided process and gets the material and confidence estimate. This is making HSI easier to use."

These workflows are the software steps that substitute for the steps once taken by HSI experts based on their experience and expertise. The steps are necessary because HSI data must be corrected and validated before it is compared with chemical signatures of materials.

"In layman's terms, you are separating the noise from the signal," Legeer explained. "That way, you get fewer false positives; now that is automated."

Another advance is the quality of data received by ground stations. Data used to come down from sensors raw and uncalibrated. "Now we have very good onboard processors so that data is calibrated and corrected when it comes down," Legeer said.

Exelis acquired one developer of these improved onboard systems in order to provide a more end-to-end solution for users in the future.

Better data from the sensors means the first-level workflow has already been done. "Certain targets of interest have been identified when the data gets to the ground," Legeer noted. "So we can focus on validations and look for other materials."

The fact that ground station software no longer has to do calibration, he added, represents a major advance.

Exelis VIS workflows are very flexible, so when HSI scientists come up with better interpretation methods, these can be inserted into the software easily. Another advantage of ENVI is that it can test new techniques, so that these do not have to be rewritten for a different production system after testing.

HSI will continue to be important in the future, Legeer said, noting that the technology will be helpful in monitoring the situation in Afghanistan as international forces are reduced.

## Processing Performance

Another innovation comes from SpecTIR, which recently made operational its SpecTIR Hyperspectral Automated Processing and Exploitation System (SHAPES), a highly rugged, end-to-end, ground-based hyperspectral remote-sensing capability in a trailer. Along with offering unique horizontal-scanning capabilities, SHAPES is a first because "there is no man in the loop," explained Sean Anklam, chief innovation officer.

SHAPES's sensor can complete a scan in 30 seconds, and then SHAPES takes 20 to 40 seconds to process, exploit and generate a report from scanned data. Processing includes radiometric calibration, atmospheric compensation and target detection. "In comparison, two years ago that process took upwards of eight hours to complete," Anklam pointed out.

SHAPES thus dramatically increases performance in acquisition, processing and exploitation. In tactical scenarios, this speed is crucial. "Any hyperspectral system capable of running autonomously while producing near real-time results adds tremendous value to military operations," Anklam said.

Terrestrial HSI is not limited to vehicles or trailers. SpecTIR recently acquired a core-logging hyperspectral system, Sisu Rock, from its Finnish partner, Specim Limited. Sisu Rock can rapidly scan and produce mineral maps of rock cores extracted from drilling operations. It can also produce high-resolution hyperspectral images and maps of trace minerals from drill cores in less than 15 seconds, greatly improving drill-core analysis.

Specim has also created an indoor HSI system, Sisu Chema, a tabletop station that produces hyperspectral images by scanning trace chemical samples as small as 30 microns. Sisu Chema could be used in pharmaceuticals, law enforcement and military intelligence.

Airborne HSI has seen consistent reductions in size and power consumption and improvement in spatial, spectral and radiometric resolution, Anklam observed.

ProSpecTIR VS sensors are now used worldwide. They scan visible, near-infrared and SWIR portions of the spectrum at half-meter ground-sample distances.

"We've also put considerable care into developing state-of-the-art radiometric calibration, wavelength mapping and geoprocessing for these sensors that ensure unparalleled accuracy, traceability and repeatability of data," Anklam noted. "Sensors come in plug-and-play packages weighing less than 100 pounds and occupying a few square feet of space."

SpecTIR has been improving HSI logistics and deployment options as well. It can rapidly deploy a sensor, computer and operator via its aircraft network to nearly any place on the globe. Sensors and computers can be quickly disassembled, shipped in ruggedized containers and integrated into almost any aircraft. The company can easily adjust integration rates and fore optics of sensors for different speeds and altitudes of HSI operation.

Better logistics and ruggedized sensors have allowed SpecTIR to deploy in a variety of climates, from the Canadian Arctic to the Australian outback and jungles in Brazil and central Africa.

SpecTIR routinely integrates HSI with complementary sensors such as high-resolution cameras and light detection and ranging (LiDAR) systems. HSI provides data on chemical composition, while LiDAR yields data on height, size, location and volume. Data fusion then creates extraordinary, robust intelligence products, Anklam said.

The innovation officer predicts that the next generation of HSI will be small enough to be integrated into many types of UASs. Specim has developed a very small and inexpensive LWIR sensor, Aisa OWL. Cooled by the Stirling thermodynamic cycle, OWL does not require the space and expense of liquid-helium and liquid-nitrogen cryogenic systems.

"New focal-plane array and optical materials are being developed that will allow for imaging of expanded portions of the electromagnetic spectrum, while reducing development costs," Anklam said. ★

For more information, contact *GIF* Editor Harrison Donnelly
at harrisond@kmimediagroup.com or search our online archives
for related stories at www.gif-kmi.com.