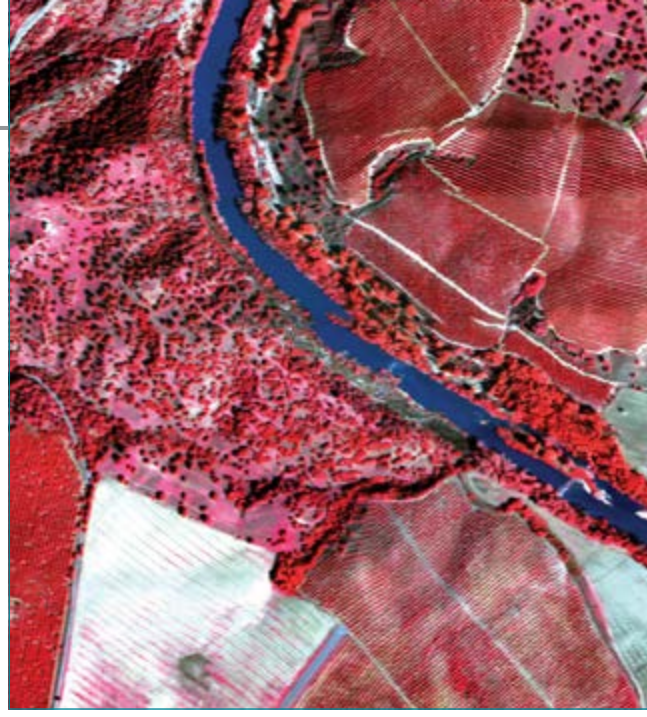


Invisible touch

Hyperspectral imaging is gathering pace in the military domain. **Beth Stevenson** looks at how industry is integrating this valuable technology into current and future ISTAR systems.

Operators of unmanned technology are benefiting from additional capability beyond the trusty EO/IR payload carried by most platforms, as spectral sensors look to do more than just record what they see.

Hyperspectral imaging (HSI) utilises more bands of the electromagnetic spectrum than other sensors, and there are many different applications for such a refined technology, ranging from ground mapping to ISR.

The human eye, for example, can only visualise light in three bands – red, blue and green – while hyperspectral sensing can detect multiple wavelengths. As a result, it is able to capitalise on colour differentials between objects and their background by distinguishing between the detected spectral properties.

In turn, it then creates a 'spectral signature' of different elements. By categorising such properties, a greater level of detail can be obtained from a collected image, essentially allowing an operator to see beyond what the human eye or an IR sensor can.

INFORMATION INTERPRETATION

'Hyperspectral information is what we call "non-literal information" – we have to go into the individual spectra and try and process that so there is some information that you can then interpret,' Mark Salvador, chief engineer at Exelis Geospatial Systems, told *Unmanned Vehicles*.

However, it is not just a case of adding the sensor to the vehicle – the additional spectral capability comes with greater space, processing, exploitation and dissemination demands.

The lack of processing algorithms has previously been one of the main hurdles to a fully commercialised hyperspectral system, but now industry is working to combine all elements of this technology into a more useable package.

'The critical element here is in the past in the hyperspectral community we would collect data on the aircraft, wait until the aircraft landed and process the data on the ground because of the volume of data associated,' explained Salvador. 'With automated, real-time, onboard processing, we can process that data in the air, and instead of waiting to download volumes of data, we can now take the detection and identification of materials that are processed in the air and send that down instead.'

HSI serves as another level of information that UAV operators have not been exposed to yet, and, alongside colour imagery, adds more operating detail.

Headwall sensors can cover a wide range of the electromagnetic spectrum. *(Photos: Headwall)*

HSI sensors have been used on the SkyJib VTOL UAV for research applications.

'I think whenever payloads are discussed for existing or new UAVs, on the US military side hyperspectral is always one of the possible new payloads that is on there because it's proven itself and can tackle certain missions that are out there,' noted Salvador. 'I think that is just going to grow into other missions and spaces. It's certainly a sensor payload that is always considered when a sensor payload is assessed.'

HSI systems are currently being used on board UAVs for both commercial and military applications, and the technology is by no means new, with well-known unmanned platforms integrating the technology.

CONTRACT AWARDS

Raytheon is under contract to provide 23 Airborne Cueing and Exploitation System Hyperspectral (ACES HY) systems to the USAF for use on board the MQ-1 Predator UAV, among others.

Tim Cronin, director of strategy and business development for surveillance and targeting systems at Raytheon Space and Airborne Systems, told *UV* that 19 systems have been delivered to date, with the last four under contract expected in 2014.

'Of the 23 systems ordered, we have delivered 19 of them, and a lot of those have been deployed and are in operational use on two different platforms,' he explained. 'One is the MQ-1 Predator that the air force operates, and the other is a manned, fixed-wing platform for another US DoD service.

'Those are the two platforms that we are supporting right now, but we have received a contract to study the integration of the system into a pod. We have done a preliminary flight test to gather data and everything looks really good, and we expect to get a follow-on contract this year to do initial testing and integration on an MQ-9 Reaper.'

EASY INTEGRATION

The development of the pod integration will allow ACES HY to be easily installed on other aircraft. The MQ-1 houses sensors in its nose, whereas a pod under the wing is required for MQ-9 integration.

'Once it is in the pod, the ability to put it on other platforms will be quite easy,' Cronin explained. 'We are opening it up to be used on more platforms and the integration time will be shorter.'

As well as developing the ACES HY technology, the company is also looking to integrate HSI into other systems that it develops, including the Multi-Spectral Targeting System.

'One of the upgrade paths for that is to install a hyperspectral capability,' Cronin explained. 'It probably won't be as comprehensive as ACES HY, but will add a hyperspectral element to the turret. So that would be independent of the ACES HY programme.'

Raytheon is currently awaiting a contract from the USAF for 17 advanced processing systems for ACES HY. 'We do not have the have the contract yet for the enhanced processors, but we do expect to get a contract in 2014,' noted Cronin.

'We have been developing processing enhancements for some time, and the processing is a big piece of it. We expect to be able to make these improvements once we get awarded the contract to improve the target detection and identification. It will also increase the speed at which we can detect targets.'

He said that the advanced processing will allow the user to sift through data quickly in order to find the information required, and all existing sub-contractors will participate in the contract.

BUSINESS ACQUISITION

Exelis acquired Space Computer Corporation and its processing capability in 2012, and in turn a place on the Raytheon-led ACES HY programme.

Exelis offers onboard processing for HSI, and is concentrating its efforts on developing the longwave hyperspectral system Blue Heron.

'That's technology that has transitioned from the US government, which we purchased the system for, and is essentially improving the implementation of the sensor under our own internal R&D dollars, and linking to onboard processing,' added Salvador.

The system was expected to be flown on a Cessna Caravan surrogate aircraft in early February as *UV* went to press, while Exelis is looking to support military testing of Blue Heron at some point in 2014.

'For that particular longwave system, one of the primary things that it does is detection of gases in the atmosphere,' continued Salvador. 'So there are various US military customers who are interested in that sensor as well as some of our allied international customers.'

UNCOMMON APPROACH

Exelis took on the task of further developing the processing, as well as incorporating the ➤

The MQ-1 has been deployed with ACES HY sensors. *(Photo: General Atomics Aeronautical)*

technology into a 20in gimbal, something uncommon for HSI technology.

'Most of the hyperspectral systems that are out there are typically just pointing straight down and you have to fly over target,' noted Salvador. 'In this application, since it is integrated into a gimbal, we can essentially look over and into adjacent areas without having to fly directly over them.

'If you're looking across a border, for example, or a location that you cannot fly directly over in a denied area or so forth, you can actually point this system across the horizon and look at a different location.'

He continued: 'One thing that has prevented us in the past is when you are not looking straight down but further across the horizon, there is more atmosphere to deal with, and that tends to limit the range and performance of the sensor, as well as affect the processing algorithms. So that's something we're working on and implementing with regards to our Blue Heron system.'

Salvador said that the system is suitable for some of the larger UAVs like Gray Eagle and MQ-9, both of which could handle it.

On the commercial side, Exelis is developing an Airborne Rapid Material Identification System (ARAMIS), a very near-IR (VNIR)/shortwave IR (SWIR) airborne hyperspectral system with onboard processing. Work has just begun, and the company hopes to have a lab-based system ready to collect data by the end of 2014.

'The real-time nature of processing for military systems may or may not transfer into the ARAMIS system, but what's important is that we can do onboard processing very quickly, and have results either on board or sent to the ground very quickly after collection,' Salvador noted, although data will still be processed within minutes.

EARLY EXAMINATIONS

HSI is also arguably difficult to exploit because of the swathes of data produced. Back in 2001, the Air Force Research Laboratory (AFRL) put its efforts into researching the exploitation element of this sensing to integrate capabilities found across a range of such systems.

In the 'Rapid C4I High Performance Computing for Hyperspectral Imaging Exploitation' paper that it released, the AFRL explains that a web-based interface is being developed so that operators can select data sources, exploitation time intervals and a parallelised exploitation method for execution.

'A single hyperspectral image consists of 200 or more bands, times the number of spatial pixels in the horizontal and vertical direction, yielding data acquisition rates of tens to hundreds of megabytes per second,' the paper explains. 'Most of the data that will be collected will be stored in ground-based data repositories. High-performance computing can play a key role by supporting timely exploitation of these voluminous data sources.

'Global awareness is the air force's answer. The goal of global awareness is to provide ubiquitous, consistent and integrated battlespace information on demand that is tailored to the needs of the commander and the warfighter.'

In addition to exploitation issues, there is also the need to expand the spectrum over which hyperspectral data can be collected. Through the three-year NATO-led Phenomenology and Exploitation of Thermal Hyperspectral Sensing/SET-ET-072 effort, which began in January 2013, participating nations agreed on two objectives to enhance exploitation of HSI data.

The first was the need to make progress on the understanding of the phenomenology of longwave IR (LWIR) hyperspectral sensing and the contribution of medium-wave IR and SWIR hyperspectral sensing to support the LWIR exploitation; while the second was the need for a shared hyperspectral dataset to make progress in understanding the performance of HSI exploitation algorithms.

SUMMER TRIAL

'As a consequence, the SET-ET-072 nations unanimously recommend the creation of an RTG [research and technology group] whose objective would be to plan and execute a joint airborne summer trial conducted in 2014 and exploit the data collected,' the solicitation reads. 'This trial will be focused on the detection and identification of IED observables specifically, and CBRNE threats in general.'

The knowledge gained through the programme, including phenomenology, data and exploitation tools, is expected to contribute to the understanding of how to mitigate IED-related threats by focusing on the detection of specific observables during their life cycle.

The need for a spectral database is arguably preventing full commercialisation of such a technology, as collecting and independently storing such information can be tiresome and take up a lot of storage. The sheer volume of data itself can also make it difficult to exploit.

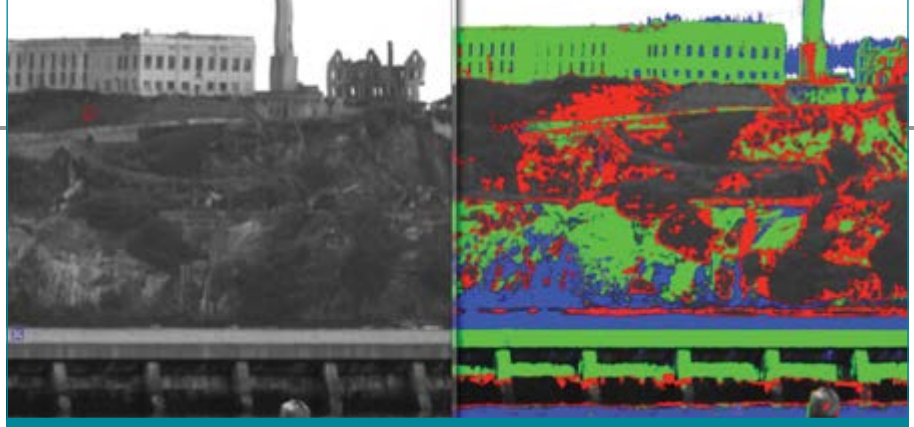
'If I want to find a material… that's out in the field somewhere, I need to know what that spectra looks like before I go and look for it,' noted Salvador. 'The military for many years has built its own spectral libraries of unique military-significant materials, and there are also commercial libraries that exist, but the overlap between a military-significant material and a commercially significant material can be quite large.

An HSI sensor, for example, could be used to provide characterisation of soil, something particularly important to precision agriculture, an area where UAV use is expected to grow.

COME TOGETHER

Headwall Photonics manufactures systems specifically for UAVs in both the commercial and defence markets, and company CEO David Bannon observed that a lot of users look to detect across the SWIR range, which covers around 900-2,500nm.

'There's also a lot of interest in putting together a broader range so you can go to 400-2,500nm to cover the full vegetation ➤



HSI offers a new depth to imagery gathered by unmanned systems. *(Images: Headwall)*

visible range as well as the SWIR,' noted Bannon. 'The way you would do that is put a VNIR and SWIR sensor together and allow it to fly that.

'As these airframes get larger, we're able to stick two very small hyperspectral sensors together to give that broad range capability. Additionally, some people like to fly lidar with hyperspectral, so a larger payload capability will allow you to couple compatible technologies together.'

SYSTEM PROVISION

Headwall has provided systems for Insitu's ScanEagle UAV, as well as a range of commercial customers and research institutes.

'[HSI] is extremely well suited to those commercial applications, and the market has evolved to be adopters of hyperspectral sensor technology,' continued Bannon. 'What has enabled that growth is the fact that years ago when we were selling primarily to the military market, we were providing just a sensor, and they would take that imager and work out how to put all of the related components next to it.

'What we've seen is there has been demand on the commercial side, but not necessarily the same level of spectroscopy or instrument knowledge.'

The company has been trying to simplify the integration onto the appropriate UAV for its systems. 'We've had to engineer the complexity out of these solutions to make them readily available, readily understood and readily adopted by the commercial side,' he added.

Besides airborne applications, utilisation of HSI in the ground robotics arena is becoming evident. The US Army Research Laboratory (ARL) has carried out studies to determine how HSI can aid with the navigation and obstacle avoidance of a UGV.

In its 'Hyperspectral Imaging and Obstacle Detection for Robotics Navigation' paper, the ARL describes experiments that it carried out that looked to provide an alternative to conventional broadband imaging sensors such

"It's not enough to just ride this earth. You have to aim higher"*

Think no further than a visit to the Farnborough International Airshow. With 47% of our trade visitors based outside of the UK, it's the perfect meeting place where you'll discover many international business opportunities. Visit FIA 2014 and you'll get much more than just big talk! **Talk Farnborough and visit www.farnborough.com today.**

* Jose Yacopi

talking
INTELLIGENT SYSTEMS?

CIVIL DEFENCE SPACE INTELLIGENT SYSTEMS FUTURES

+44 (0) 1252 532 800
www.farnborough.com

Farnborough INTERNATIONAL AIRSHOW
14-20 JULY 2014

Exhibit within the **Intelligent Systems Zone** - Contact **davinder.bhatia@farnborough.com**

as FLIR, which only use spatial signatures, and in turn limit the detection performance of the UGV.

'The HSI sensor mounted on the UGV is therefore expected to greatly improve the performance of obstacle detection by providing high-resolution spectral profiles of materials within the neighbouring areas of the UGV,' it explains.

SENSE AND AVOID

By creating detection algorithms and target classification techniques, the ARL was able to identify and avoid objects in line of the UGV using hyperspectral sensing.

'The developed algorithms satisfactorily detect objects such as military vehicles, barbed wire and a chain-link fence,' the paper continues. 'It can be expected that the developed hyperspectral sensing systems will help UGVs navigate an unknown area more safely with increased speed.'

'The algorithms will be a little bit different, but the sensors and processing and libraries tend to be the same,' Salvador said regarding the transfer of airborne HSI technology to ground-based systems. 'There are ground-based applications that we're looking at – the US military has looked at ground-based applications for some time, and now there are some commercial and international applications in security and surveillance.

'It isn't always an easy transition because the physics of transferring something looking straight across the ground, versus looking straight down at it, are different.'

THE RIGHT LIGHT

Because hyperspectral sensors are passive, they depend on a light source to provide the signal that gets back to the sensor. One problem with ground-based hyperspectral systems is that the light source has to be found from somewhere in the right proportions.

Headwall also offers its Hyperspec Snapshot for ground-based systems. 'It actually spun out of some of the work that we did for the US military when they were looking for sniper detection and objects at a distance of about a mile away,' Bannon concluded. 'What we've seen is that there is a growing demand. It is behind the aerial platforms in terms of demand, but there is certainly interest in deployments of HSI on different robotic platforms, and most of that is military.' UV