FIT TO FLY

DAVID BANNON DISCUSSES THE GROWING POPULARITY OF HYPERSPECTRAL IMAGING IN THE UAV SECTOR, EVALUATES THE CHALLENGES INVOLVED AND LOOKS AHEAD TO INNOVATIONS IN THIS DEVELOPING MARKET

A critical and integral component of remote sensing across various industries, hyperspectral imaging is gaining ground. Or, rather, gaining flight. Considered the preferred imaging technique aboard unmanned aerial vehicles (UAVs) because of the vast quantities of data that can be captured, hyperspectral imaging is leading the way in high value, precision-based sensor technology.

Hyperspectral imaging can capture hundreds of narrow bands over a continuous spectral range, providing a complete, high-resolution spectrum for every pixel of the scene within the field of view. The sensor uses this information, known as spectral signatures, to generate the chemical composition of the object in the scene and thus identify and differentiate materials. The imagery is collected and represented in the form of a data cube, which can be processed either immediately or post-flight and then analysed according to the specific project requirements.

The range of applications suited to hyperspectral imaging is diverse. Traditionally used in military defence and now key in forestry, environmental monitoring, agriculture, mineral exploration and disaster remediation purposes, it is the specific characteristics of each application that are important to the end users in each field. While some users may only require a data capture tool in order to, for example, ascertain the normalised difference vegetation index (NDVI) of an area, others may have more demanding challenges to overcome. These could include monitoring vegetative plant stress, searching for water, determining the location of invasive species and identifying mineral composition – reasons which are often critical to users' businesses.

As an example, hyperspectral imaging is playing an increasingly large role in the precision agriculture industry. Countries worldwide depend on the revenue derived from nuts, wine-grapes and other speciality crops and therefore require precise and actionable data to make economic and life-sustaining decisions.

Hyperspectral sensors are built robustly and reliably to accommodate temperature fluctuations without affecting measurement accuracy. They also have to be strong enough to cope with the diverse weather conditions found in many applications all over the world, from the hot, leafy rainforests of Latin America to the icy environment of the Antarctic. The rising popularity of and vested interest in UAVs and their deployment demands a sensor instrument that can withstand such wide-ranging conditions. Built to survive potential UAV collisions, protecting users' investment, hyperspectral imagers are a solution fit for the job.

Flying high

While hyperspectral imaging is just one method of capturing data – HD video cameras, LIDAR and multispectral imaging also add their own value to particular projects – it's no surprise that it is considered the sensor of choice when it comes to airborne applications. Not only do hyperspectral sensors enable precise identification of an object through analysis of its chemical composition, but the tool's exceptional spectral and spatial resolution also facilitates quantification of the object in the scene, a unique capability in sensing technology. The generated data can also be used to track changes over time of an environmental area or scene, providing users with greater versatility in their monitoring tasks.

A user's choice of sensor technology will, of course, depend on their needs. The UAV sector requires imagers that can capture data from a location that no other vehicle can access. Material that may only be visible from above – a tree canopy, for instance – could generate different data from that obtained further down the same object. Deploying a ground-based sensor will likely neglect much of the target in the scene, leading to an inaccurate representation. Hyperspectral sensors are capable of withstanding the stress associated with harsh airborne environments and, when mounted on UAVs, can access hard-to-reach territory that people and land vehicles cannot.

The hyperspectral imager's ability to capture an extensive amount of rich data, generate exact precision through more spectral bands and a higher degree of resolution, and process the information rapidly in real time demonstrates the expert capability of the technology. By comparison, a multispectral imager will yield a certain quality and amount of data that is limited to identification of objects on the ground.

Recent developments in hyperspectral imaging offer additional, key advantages to users. Factors such as variations in the earth's surface and the tilt of the sensor mean that collected data can generate a distorted image, impeding users in identifying the exact location of an object – for example, a pesticide in crop land. An orthorectification capability corrects the distortion in the post-processing phase of the project, ensuring that it corresponds to real world map projections and coordinate systems and enabling accurate precision of an object to a point on the ground. This then allows users to achieve direct and accurate measurements of the objects in the scene.

Thanks to their small size, light weight and affordability, hand-launched UAVs such as the Aibotix X6 are preferred for applications such as precision agriculture

A further benefit of hyperspectral imaging is aberration correction. A recent introduction to the sensing technology, this function corrects any optical blurring of edges, improving the resolution to make them as crisp and clear as the centre of the image. Combined with a hyperspectral sensor's ability to capture a wide field of view, aberration correction allows for maximised width of flight swaths, enabling UAV users to cover more ground in the same time. This is a crucial advantage to users, allowing the UAV to stay aloft longer, thereby optimising flight efficiency and capturing more data faithfully from edge to edge.

A balancing act

Although hyperspectral imaging offers abundant advantages, UAV users must take into account the various challenges and requirements when selecting a sensor. While a key benefit of hyperspectral imagers is their exceptional ability to yield a copious amount of high quality data, extracting the relevant information from the data cube can prove to be a process-intensive exercise. Deciding which material to extract and distribute, and how to do so efficiently, requires users to analyse the spectral signatures. According to the chemical composition of objects in the collected data, users can identify the target conditions which will, in turn, determine what information is relevant. This can be a lengthy process and must be taken into consideration in each application.

For users in applications with unrestricted time frames for post-processing of data, the rich quantities collected are of huge benefit. Yet, in tasks involving people working on the ground while the UAV is aloft, a more real-time challenge emerges. Applications such as military defence, disaster monitoring and environmental remediation require users to process the captured data instantly for immediate use. This necessitates a sensor with a fast data channel capability to process the information rapidly and efficiently.

A further challenge in hyperspectral imaging on UAVs is the low size, weight and power (SWaP) requirement. Today's UAVs are exceptionally small and light. As such, they demand small and light payloads to match. However, these payloads must offer high performance functionality for optimum efficiency. With a restricted SWaP claim on which to mount the sensing instruments, hyperspectral sensor manufacturers have had to ask: what are the most valuable functions for the UAV flyer? They are confronted with an organisational exercise in order to create a payload that will optimise aircraft efficiency for extended flight times and endurance. To achieve this, users need to invest in a lightweight hyperspectral sensor system with added value and functionality.

With regard to the assembly of the hyperspectral sensor and UAV, it is essential that users give forethought to the technical capability required to ensure synergy between the platforms. For best results, the UAV and sensor must be fully integrated to ensure operational optimisation. Many end users in previously mentioned applications may own UAVs or other aerial assets and will likely require advice and assistance when selecting sensor technology and assembling the package.

Looking ahead

Hyperspectral imaging is an exciting, evolving and innovative technology in the remote sensing market and its value is clear. Vast quantities of highly granular imagery, rapid data collection and processing of quantified materials, and spatial and spectral fidelity for exceptional specificity and discrimination are just some of the benefits UAV users can exploit. Selecting the right hyperspectral sensor requires understanding the fundamental technologies available and identifying which is best suited to a user's specific airborne application.

Integration of the sensor design, UAV selection and software optimisation elements is crucial in order to achieve the desired results. Combined with a high-performance, low-weight data cube with added functionality, hyperspectral sensors are taking the market by storm. With future innovation primed for exploitation and distribution of the data cube, in order to make sensors more application-specific for users, hyperspectral imaging is set to fly even higher.

COMBINED WITH A HIGH-PERFORMANCE, LOW-WEIGHT DATA CUBE WITH ADDED FUNCTIONALITY, HYPERSPECTRAL SENSORS ARE TAKING THE MARKET BY STORM

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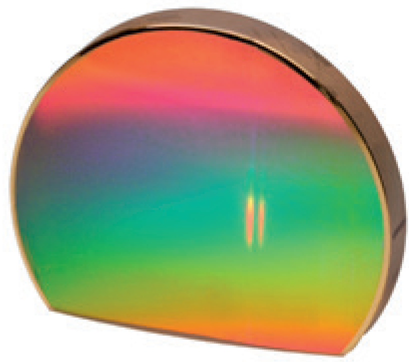
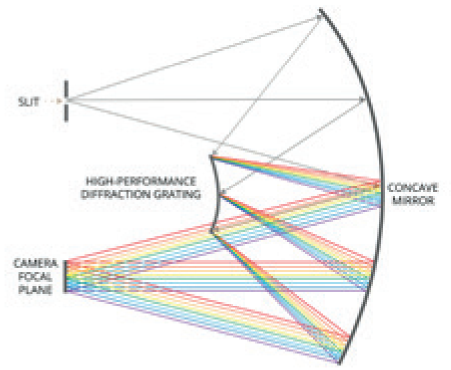
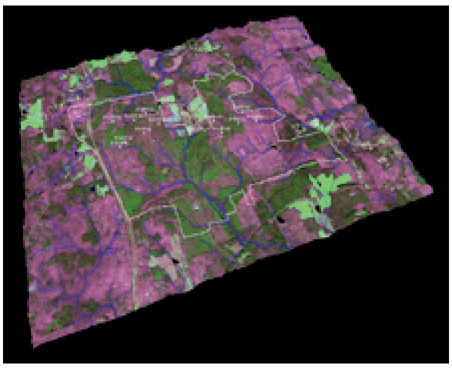
As UAVs get smaller and lighter, so too must the payloads they carry. Headwall's Nano-Hyperspec contains a very small, light hyperspectral sensor with embedded data storage and directly attached GPS



Headwall Photonics produces its own application-specific diffraction gratings for every hyperspectral sensor it manufactures. The gratings are made in concave, convex, and planar designs and with precise groove profiles to achieve aberration-corrected imaging performance.



This 'concentric imaging' configuration uses mirrors and diffraction gratings to manage incoming light. Its lack of moving parts and robustness make it ideal for airborne applications



The result of hyperspectral imaging is an image 'data cube', which comprises all the spatial and spectral information seen in the field of view as the aircraft or UAV moves over land. Interpreting the data cube yields precise information about the chemical composition of plants, geologic materials, diseases, nutrient levels, irrigation conditions and much more

NANO HYPERSPEC

Headwall's Nano Hyperspec demonstrates these latest advancements in hyperspectral imaging. Nano-Hyperspec differentiates itself from other market offerings with its integration capability. We have custom-designed it in line with end users' requirements and developments in the UAV sector, such as the move to smaller, lighter vehicles, so that it combines large embedded data processing and storage, aberration correction technology and an orthorectification capability in an integrated small and lightweight package. Close integration of the GPS unit, sensor and data processor in a smaller package enables more time aloft, saving battery life and capturing more data for enhanced operational efficiency.

The sensor is based on aberration-corrected optics to deliver high signal-to-noise (SNR) – a particular benefit in airborne applications where available light varies. It also provides a very wide field of view, which enables optimum flight path efficiency, and excellent spatial and spectral resolution across the entire spectral range – a fundamental design characteristic for optimum hyperspectral imaging results. Generating output in a data cube of only 10cm by 10cm – similar to the size of a large Rubik's cube – the 0.6kg lightweight sensor removes the need for additional hardware and cable accessories, easily accommodating the SWaP constraints inherent in UAVs.