Headwall Nano-Hyperspec® VNIR

&

DJI MATRICE™ 600 Pro

Professional Hyperspectral Solution

THE FUTURE OF POSSIBLE

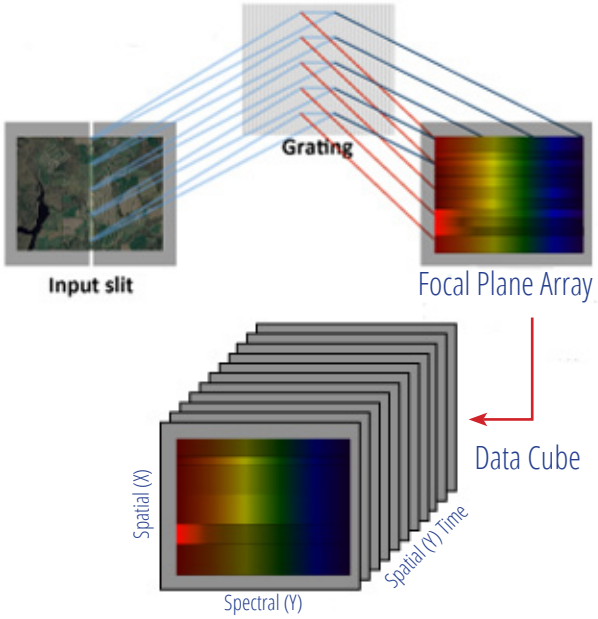
Introduction

The ultimate duty of most commercial UAV platforms is to become a trusted host to a sensor that is gathering specific data for an end user. The key to success is establishing seamless harmony between the sensor and the UAV platform. However, integrating sensor systems onboard UAV's can be very challenging and requires expert engineering and a full understanding of each unique system.

To properly integrate high precision instruments such as the Headwall Nano-Hyperspec VNIR within a UAV requires a careful balance of aerodynamics, weight and balance, optics, electrics, and data management. The MATRICE™ 600 Pro is a high-performance, high endurance multi-rotor UAV built for applications such as remote sensing missions which utilize hyperspectral instruments that require a high degree of data fidelity. Therefore, integration requires applications and engineering expertise to craft a proven, ready to fly system. The result is a reliable airborne platform from which end users can gather accurate data.

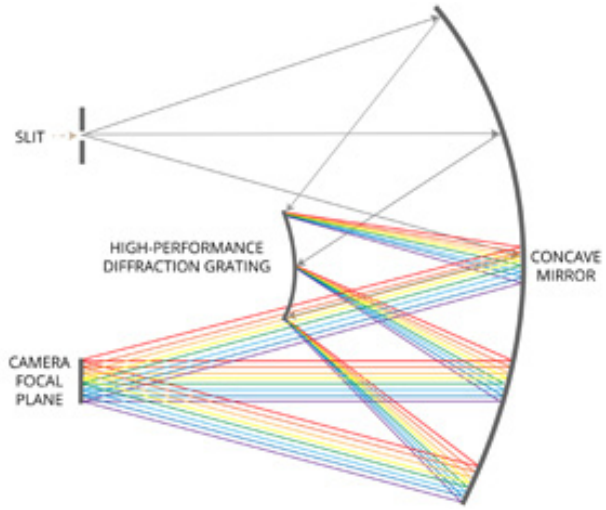
Hyperspectral and Multispectral Fundamentals

When reading a document, a person will read the words in a sentence one line at a time and then tie these elements together to comprehend the writer's message. Headwall's hyperspectral imaging instrument is based on a push broom or line scanner design. The instrument has a narrow slit of a given length through which light enters before being dispersed into individual wavelengths onto a two-dimensional detector (known as the focal plane array). The FPA contains hundreds or thousands of detector pixels and captures the dispersed light.



Spectral imaging collects reflected light through an image slit, which is then disbursed via a precision diffraction grating onto the FPA. A 'data cube' is a frame-by-frame composition of these images as the aircraft flies over the scene.

In an airborne application, the instrument is flown over an area of interest (AOI) at a set altitude and speed. As the slit is moved along the track of the scene (AOI), a two-dimensional data frame with wavelength and spatial information is created and stored. This is similar to reading words one sentence at a time. As the slit is moved to the next position by its width, another frame is created which is analogous to reading the next line of text. The frames are stored and then stitched together using geo-referenced data to form a data cube just as logical placement of sentences form a paragraph. The paragraphs are assembled to convey the writer's message in the form of a document. The data cubes for a given AOI are stitched together to provide a complete picture of the scene. When viewing a data cube, a two-dimensional gray-scale image is observed with each pixel in the image having both spectral and spatial information.



All-reflective concentric imager design used by Headwall's Nano-Hyperspec VNIR

Hyperspectral continuously collects and arranges image information like words are arranged into sentences and paragraphs. With multispectral sensing, you are collecting only a few spectral bands (with gaps between the bands) that may cause image information to be missed. In general, hyperspectral is recommended if the objective is to collect *all* the spectral data within the scene. However, if you have a clear understanding of the AOI and only need a few spectral bands to monitor variables of interest, then a multispectral system is sufficient. Headwall offers both hyperspectral and multispectral systems since the need for both techniques exists across the range of remote sensing missions.

Headwall's spectral imaging sensors are patented, aberration-corrected, and feature an all-reflective concentric design. Fundamental to this design are Headwall's own master gratings for optimal optical throughput efficiency and signal-to-noise. Since Headwall designs and manufactures its own gratings, sensors can be tuned to peak the performance for a given wavelength range, allowing for custom solutions that meet strict application criteria.

Why UAVs Represent a Valuable Platform

Hyperspectral imaging sensors collect data on a frame-by-frame basis, so motion of the UAV is fundamental to its operation. The combination of these frames is what is called a hyperspectral data cube. Headwall's sensor is an along-track (pushbroom) design where the image is collected one line at a time and where all pixels are collected along that line simultaneously. While

aircraft and satellites are often used to carry these precision instruments, they are well out of the financial realm of most research scientists. The marriage of UAVs and hyperspectral sensors thus became a perfect one, mostly because of affordability but also because they are easily deployed. Missions can be launched whenever and wherever with a UAV, but not generally with satellites and manned aircraft.

When selecting a UAV, one of the first decisions is basic: fixed-wing or multi-rotor. Both have advantages, but generally speaking a multi-rotor UAV has vertical takeoff and landing (VTOL) capabilities and is easily transported to the mission area. Complementary technologies include LiDAR, a GPS/IMU, thermal, RGB, and others can be added to the payload. Size, Weight, and Power (SWaP) demands climb rapidly when instruments are combined, and the ability of the MATRICE 600 Pro to fit and lift multiple instruments is a key difference-maker.

The DJI MATRICE 600 Pro

The MATRICE 600 Pro (M600 Pro) inherits everything from the preceding M600 with improved flight performance and improved load capacity. Pre-installed arms and antennas reduce time required for setup, and the system's design makes it easy to mount additional modules.

The airframe is equipped with the latest DJI technologies, including the A3 Pro flight controller, Lightbridge 2 HD transmission system, intelligent batteries and battery management system. Standard batteries for MATRICE are specified at 4500 mAh at a voltage of 22.2V. The maximum speed of MATRICE is 40 mph / 65 kph (no wind), and its maximum takeoff weight is specified at 15.5 kg (34 pounds).

The Importance of Stabilization

Sensitive instruments on any UAV are at the mercy of aerodynamic irregularities such as pitch, roll, yaw, and turbulence. Even small variances in an otherwise smooth flight profile will cause a noticeable effect once image data is analyzed. Orthorectification is the process of removing the effects of image perspective (tilt) and relief (terrain) for the purpose of creating a planimetrically correct image. The resulting orthorectified image has a constant scale wherein features are represented in their 'true' positions.

Achieving an orthorectified image is a function of post-processing software (which Headwall offers as part of its Hyperspec III platform) plus excellent gimbal stabilization. Choosing a UAV platform for hyperspectral data collection takes careful consideration, especially when understanding the mission requirements. It's therefore crucial that the UAV perform in a manner so that it can cover the full target area with optimal overlap plus high resolution and clarity. The result is an airborne platform truly focused on outstanding image data collection.

The A3 Pro Flight Controller has triple modular redundancy and diagnostic algorithms that compare sensor data from three sets of GNSS units, with additional analytical redundancies for a total of six. A new dampening system for the A3's modules enable precise control of the Matrice 600 Pro, providing accurate data for stable flight performance.

The DJI Matrice 600 Pro is a professional-grade VTOL platform for hyperspectral remote sensing missions

Mission Planning Methodology

MATRICE 600 Pro is fully autonomous, operated by the ground control system. The mission is set up through two separate software platforms: A3 Pro Flight from DJI and Hyperspec III from Headwall. Mission planning for the MATRICE 600 with Nano-Hyperspec is a critical component of collecting precise data. The basic mission planning starts with defining the correct overlap/sidelap, speed, and altitude. These parameters will be defined by the sensors capabilities and the desired resolution. The resolution and flight time are dependent on the focal length and altitude.

Longer focal length = Higher resolution

Higher altitude = Lower resolution

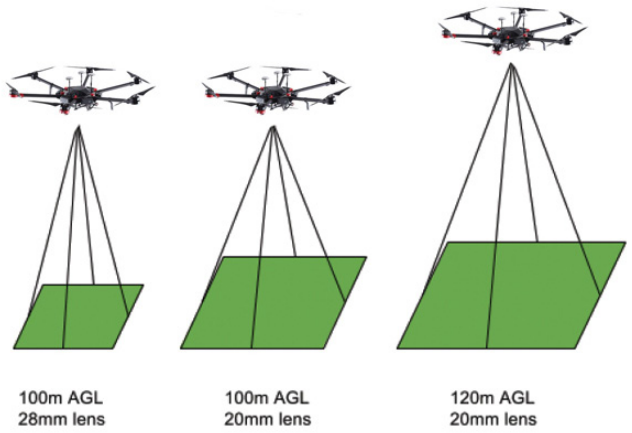
Larger focal length = Smaller ground footprint, thus more flight time to cover a given area.

Example:

One critical variation from mission to mission is the weather. Wind is a main driver for mission specific mission planning, as wind has the ability to shift the direction and orientation of the aircraft, as well as change the ground speed dramatically. Aircraft compensate for crosswind by *crabbing*, which essentially means it's flying diagonally to the flight line, slightly into the wind

with a little bit of roll, in order to stay on the heading.

All planes have a stall speed, which means that at a certain point the aircraft does not have enough lift to stay in the air. The advantage of VTOL UAVs is that they can 'hover' and fly at much slower speeds while still having the ability to reach speeds up to 40 mph. As shown on the illustration below, there is a relationship between Field of View (FOV), altitude, and lens selection for Nano-Hyperspec. These issues are important to address during the design phase.



AGL=Above Ground Level. The relationship between field of view and altitude with respect to lens choice.

Conclusion

The combination of long endurance, payload capacity, low vibration, and reliability makes the MATRICE 600 Pro an ideal UAV for the Nano-Hyperspec® VNIR sensor from Headwall. UAV's are very well suited to remote sensing missions, and MATRICE™ is especially configured for scientific-grade hyperspectral data collection.

Please consult Headwall for additional information regarding this airborne solution.

DJI MATRICE™ 600 PRO

Diagonal wheelbase: 1133mm	Hovering time with 6 kg (13.23 lb.) payload and standard batteries: 16 minutes
Max TO weight: 15.5 kg (34 lb.)	Retractable landing gear
Max speed: 65 kph (40 mph)	Max service ceiling above sea level with 2170R propellors: 2,500m (8,202 feet)

Headwall Nano-Hyperspec® VNIR (400-1000nm)

640 Spatial bands	270 Spectral bands
1.2 lb.	Power: 13W max.
Max frame rate: 300 Hz.	480GB storage (~130 min @ 100fps)

Headwall offers both multispectral and hyperspectral imaging sensors for the VNIR spectral range

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contact information

Headwall Photonics
580 Main Street
Bolton, Massachusetts 01740

phone: 1-978-353-4100

email: info@headwallphotonics.com