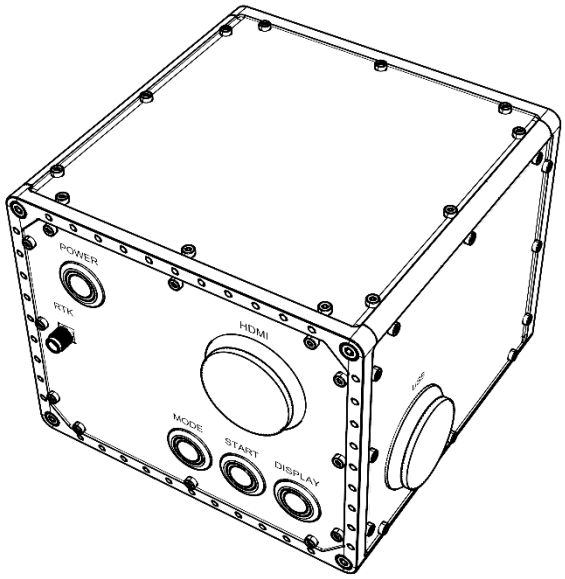
Spectral DEVICES INC.

Product Sheet

Multisensor Drone Camera for Agriculture



MSDC-2-4-AGRI-1-A
Version 03
January 19, 2024
Specifications subject to change

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Background information

Trademarks

Spectral Devices Inc., MSDC, MSC2, MSDC-2-4, MSDC-2-4-AGRI-1-A

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1. Description

The multispectral drone camera is a turnkey multispectral imaging solution for easy integration into DJI M300 RTK drones enabling the capture of geotagged aerial images for further analysis in data mapping software.

Each MSDC-2-4 (Fig.1) includes up to 4 snapshot multispectral cameras with lenses optimized for customer specified field of view and ground resolution. A built-in vision computer provides a high degree of control over the cameras, ensuring synchronized operation and recording of images. The MSDC-2-4 comes with a built-in GPS and RTK base station enabling centimeter-level positional accuracy (Fig.2). The MSDC-2-4 also comes with a solar sensor providing up to 19 channels of spectral solar data along with sensor orientation. Although the system is designed to work with the DJI M300 RTK drone, integration on other drone models is possible if sufficient payload capacity and 12-24V power is available.

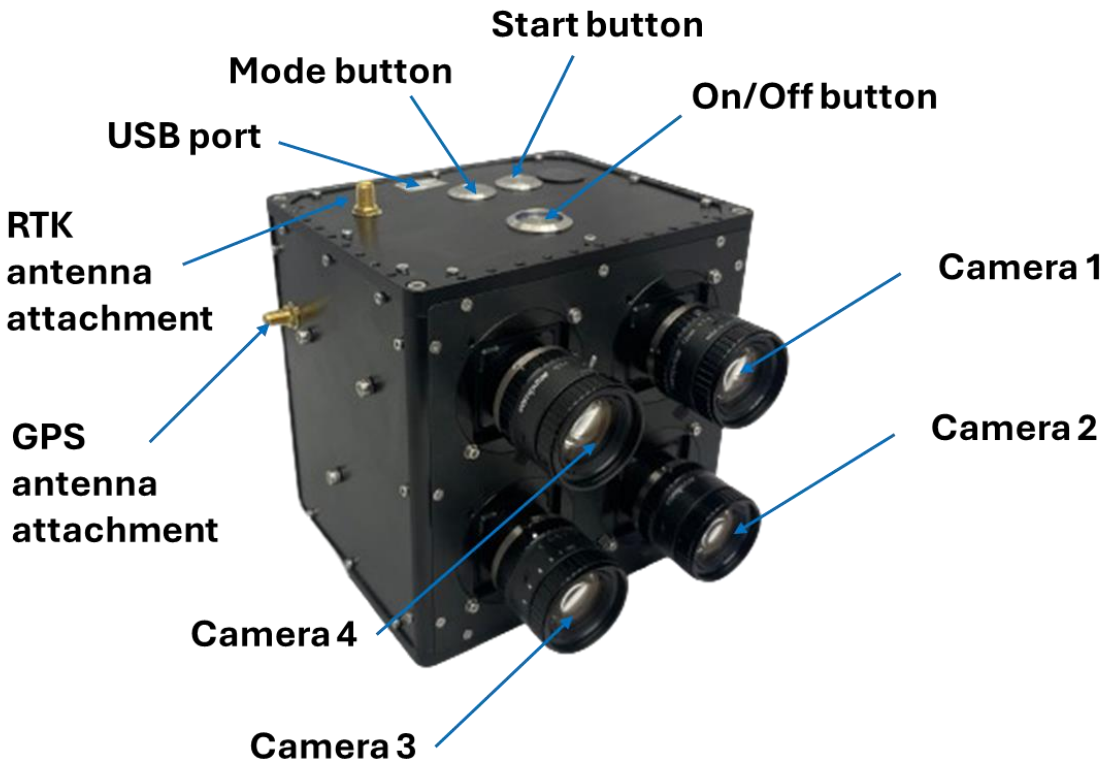


Figure 1. *MSDC 2-4 system (note: position of switches and access ports dependent on internal camera configuration)*

System configuration is performed using text-based configuration files on the USB drive. Operation is simplified to only two pushbuttons. Start and stop buttons control image capture on demand. A live multispectral video feed is available for downlink. Each MSDC-2-4 is energy-efficient, lightweight, and comes fully configured with camera control and image capture software.

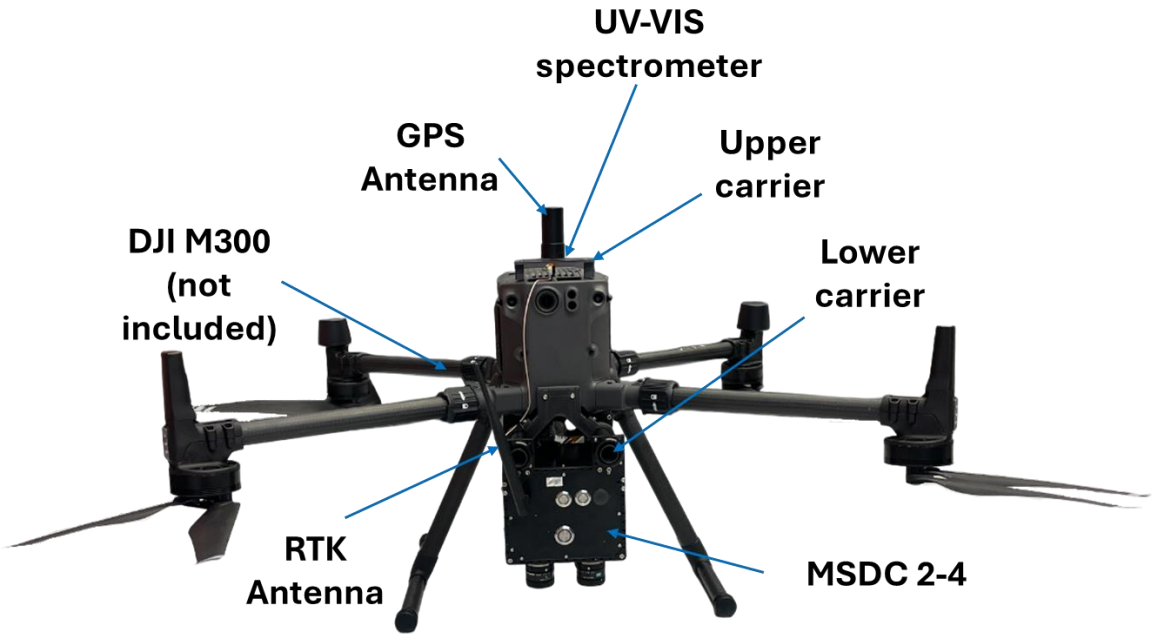


Figure 2. *MSDC system mounted on a DJI M300 drone.*

The MSDC-2-4-AGRI-1-A drone camera system, designed specifically for the agricultural sector, represents a significant leap in remote sensing technology. This state-of-the-art system features a unique assembly of four sophisticated cameras, making it a formidable tool for precision agriculture and land management. The AGRI model is designed to allow users to perform spectral analysis on a variety of key metrics to assess the plant health and hydration status.

2. Key Features

- Diverse Camera Array
  - Includes an RGB-NIR camera with bands at 450, 550, 650, and 800 nm
  - Narrow band Red Edge monochrome camera (720 nm)
  - SWIR camera at 1500 nm
  - High-resolution color camera (5MP)
- Seamless Integration and User-Friendly Design
  - Compatible with a wide range of drones capable of carrying a payload of 1.7 kg and supplying 12-24VDC power
  - Designed with user-friendliness in mind, ensuring ease of use even for those new to drone technology
- Built-in Vision Computer
  - Real-time HDMI output of multispectral images
  - Sustained frame rates of up to 2 FPS with simultaneous recording to USB drive
  - Over 8 h of sustained frame recording at 2 FPS with a 512 GB USB drive
- Built-in GPS
  - High performance GPS with 10 Hz update rate

Includes RTK base station for centimeter-level accuracy and 20 km range

- Solar sensor
  - 19 channel spectrometer
  - Built-in IMU for orientation
  - Built-in directional sensor
- Enables comprehensive analysis of crop health, soil conditions, and more.
  - NDVI, GNDVI, EVI, MSAVI, etc.
  - NDWI, MSI, NDMI
  - NBI
- Advanced Post-Processing Software
  - The system comes equipped with sophisticated image post-processing software
  - Allows for radiometric correction of images, ensuring accuracy and reliability of data
  - Geotagging for precise location mapping
  - Support provided for orthomosaic map generation

3. Specifications

Table 1. *List of cameras in the MSDC-2-4-AGRI-1-A system*

CAMERA	TYPE	#BANDS	RESOLUTION/BAND	BANDS	BANDWIDTH (FWHM)
MSC2-RGBN-1-A	Area scan	4	512 x 512	450, 550, 650, 800 nm	70 nm
MSC2-SW13-1-A	Area scan	1	656 x 520	1500 nm	100 nm
MSC2-M42-1-A	Area scan	1	1024 x 1024 (2x2 binned)	720 nm	10 nm
MSC2-M50-1-A	Area scan	3	2448 x 2048	440 nm, 510 nm, 600 nm	110 nm, 130 nm, 80 nm

Table 2. *Specifications of the MSDC-2-4-AGRI-1-A system*

Lens compatibility	All Spectral Devices C-mount lenses
Thermal control	Passive conduction of camera heat to enclosure
Water-resistant	Yes (IP54)
Dust-resistant	Yes (IP54)

Cable access	External access to USB, HDMI, power cable, Solar sensor cable, GPS antennas (GPS antenna and RTK).
External construction	Aluminum with Stainless-steel hardware
Surface finish	Black anodization with laser etching
Cable entry	One or two Ø5-6mm cables through removable seal
Dimensions	136 mm x 136 mm x 110 mm (150 mm with lenses)
Weight	1.70 kg with lenses. 1.38 kg without lenses

4. Drawings

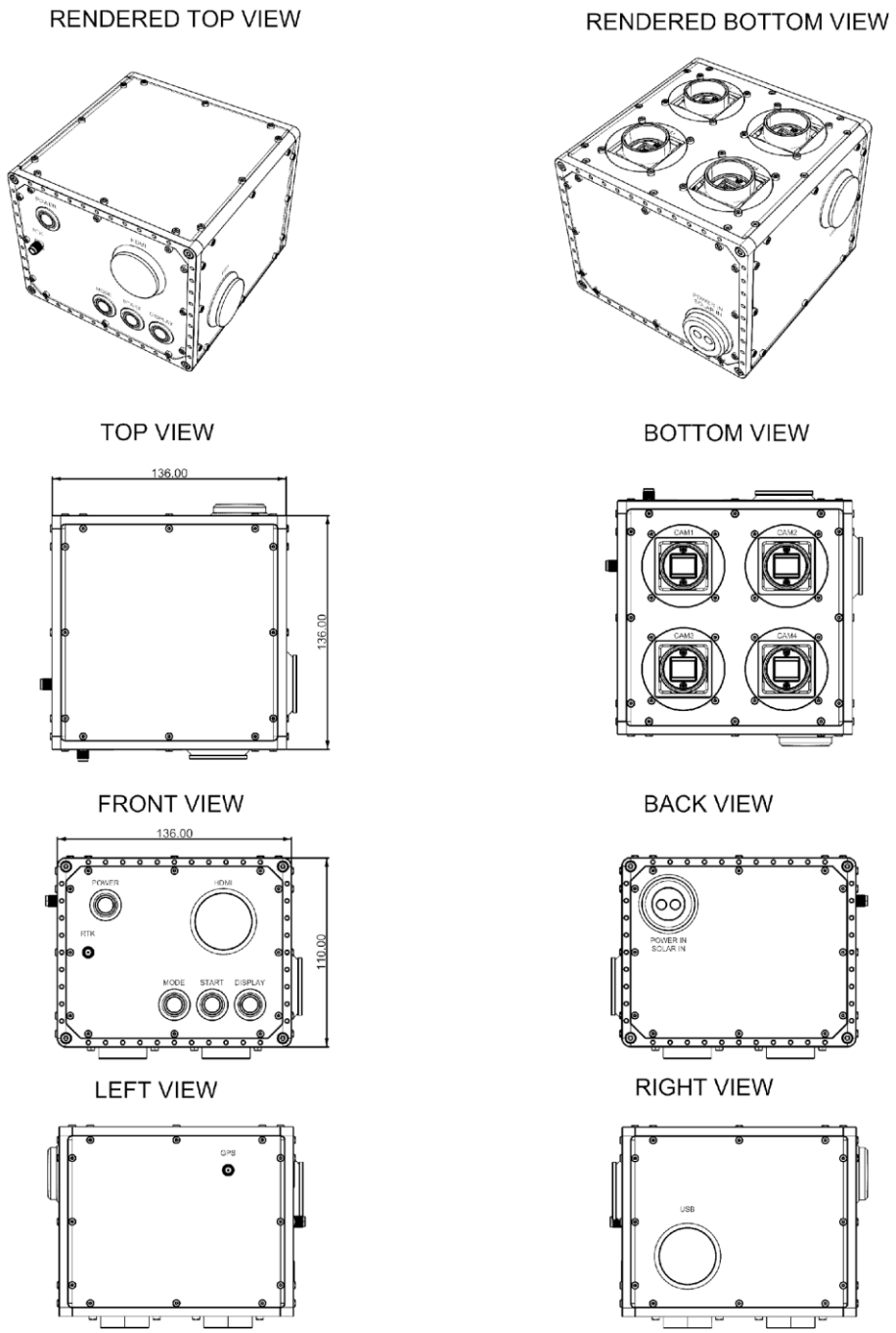


Figure 3. *MSDC system drawing.*

5. Package Contents

Package contents include the MSDC-2-4-AGRI-1-A camera system, RTK base station, drone upper and lower carrier, accessory pack (antennas), and sun spectrometer (solar sensor) (Fig.3 [Top]). All items supplied in a waterproof equipment case (Fig.3 [Bottom).

Figure 4. *MSDC system package contents.*

6. Applications in Agriculture

The system can be used to perform a variety of spectral analysis relevant to agriculture. Assessment of chlorophyll content of the plants, which is an indicator of greenness, density, crop vigor and yield potential can be estimated with metrics such as NDVI, GNDVI, EVI, and MSAVI. The hydration status can be estimated using NDWI, MSI and NDMI. Unlike conventional agriculture cameras the SWIR camera allows for NDMI estimation which is a more accurate metric for determination of vegetation water content and monitoring irrigation status. Additionally, the SWIR camera allows for burn assessment index (NBI) estimation, which can be valuable for mapping burned areas and monitoring post-fire recovery.

Table 3. *Metrics for Agricultural Multispectral analysis. Note that the list is not limited to the metrics listed.*

METRIC	FULL NAME	BANDS	EQUATION
NDVI	Normalized Difference Vegetation Index	NIR, Red	NDVI = (NIR - Red) / (NIR + Red)
GNDVI	Green Normalized Difference Vegetation Index	NIR, Green	NDRE = (NIR - Green) / (NIR + Green)
NDRE	Normalized Difference Red Edge Index	NIR, Red Edge	NDRE = (NIR - RedEdge) / (NIR + RedEdge)
EVI	Enhanced Vegetation Index	NIR, Red, BLue	EVI =G*((NIR - Red) / (NIR + C_1*Red - C_2*Blue + L)), where C_1 and C_2 are coefficients for atmospheric resistance, L - value to adjust for canopy background
MSAVI2	Modified Soil Adjusted Vegetation Index	NIR, Red	MSAVI2 =(2*NIR+1-SQRT((2NIR+1)-8(NIR - Red))
MSI	Moisture Stress Index	NIR, SWIR	MSI = (SWIR / NIR)
NDMI	Normalized Difference Moisture Index	NIR, SWIR	NDMI = (NIR - SWIR) / (NIR + SWIR)
NBR	Normalized Burn Ratio	NIR, SWIR	NBR = (NIR-SWIR)/(NIR+SWIR)

Crop Health Monitoring: Utilize the RGB-NIR and red edge cameras to assess plant health, detect diseases early, and optimize crop yields.

Normalized Difference Vegetation Index (NDVI):

Formula: NDVI = (NIR - Red) / (NIR + Red)

Significance: NDVI values range from -1 to +1. A higher NDVI indicates greater plant health, reflected by the higher chlorophyll content in the vegetation. This is crucial for assessing crop vitality and identifying areas needing attention.

Note: NDVI results can be affected by the soil moisture levels and are not accurate for large changes in vegetation density. More advanced metrics (NDRE, EVI, MSAVI) can be used instead depending on the factors affecting the result.

Green Normalized Difference Vegetation Index (GNDVI):

Formula: NDRE = (NIR - Green) / (NIR + Green)

Significance: GNDVI values range from -1 to +1. A higher GNDVI indicates greater plant health, reflecting more dense and "green" vegetation. This is crucial for assessing crop vitality and

identifying areas needing attention. The index can estimate water and nitrogen uptake in the crop canopy. It is more stable than NDVI and performs better for crops with dense canopies or in more advanced stages of growth.

Normalized Difference Red Edge Index (NDRE):

Formula: NDRE = (NIR - RedEdge) / (NIR + RedEdge)

Significance: NDRE values range from -1 to +1. A higher NDRE indicates greater plant health, reflecting denser and greener vegetation. This is crucial for assessing crop vitality and identifying areas needing attention. This metric performs better in crops at late stages of growth.

Enhanced Vegetation Index (EVI):

Formula: EVI =G*((NIR - Red) / (NIR + C_1*Red -C_2*Blue + L)), where C_1 and C_2 are coefficients for atmospheric resistance, L - value to adjust for canopy background.

Significance: EVI values typically range from -1 to +1, similar to NDVI. Higher EVI values generally indicate healthier and more vigorous vegetation, while negative values may indicate non-vegetated surfaces or water bodies. Additionally, this metric corrects for atmospheric conditions and canopy background noise. Compared to previously listed metrics it is more sensitive in areas with dense vegetation and to canopy structural variations such as leaf size and canopy type.

Modified Soil Adjusted Vegetation Index (MSAVI):

Formula: MSAVI2 =(2*NIR+1-SQRT((2NIR+1)-8(NIR - Red))

Significance: Values typically range from -1 to +1, similar to NDVI. Higher MSAVI values generally indicate healthier and more vigorous vegetation, while negative values may indicate non-vegetated surfaces or soil. Used as NDVI or NDRE when there is a lot of soil. In early crop development stages such as at the emergence of seedlings.

Soil and Moisture Analysis: Employ the SWIR camera for detailed soil moisture mapping and irrigation planning.

Moisture Stress Index (MSI):

Formula: MSI = (SWIR / NIR)

Significance: Higher MSI values indicate higher water stress in plants. This index is instrumental in irrigation planning and drought assessment.

Normalized Difference Moisture Index (NDMI):

Formula: NDMI = (NIR - SWIR) / (NIR + SWIR)

Significance: NDMI helps in monitoring water content in vegetation. Values close to +1 indicate high moisture content, while lower values suggest dry conditions, aiding in water management strategies.

Burn Analysis:

Normalized Burn Ratio (NBR):

Formula: NBR = (NIR-SWIR)/(NIR+SWIR)

Significance: burned areas typically have lower NBR values (more negative) than unburned or healthy vegetation, as the reflectance in the SWIR band increases due to the loss of vegetation cover and water content in burned areas. NBR is valuable for assessing the impact of wildfires, mapping burned areas, and monitoring post-fire recovery. It is commonly used in remote sensing applications to quantify the severity of burn scars and evaluate vegetation health in the aftermath of wildfires.

Precision Farming: Tailor farming practices based on accurate, real-time data to enhance productivity and sustainability.

Plant Counting and Biomass Estimation:

Formula: Based on image processing algorithms that identify individual plants and estimate biomass based on canopy coverage.

Significance: Accurate plant counting and biomass estimation aid in predicting yield and assessing crop quality.

7. Software

With every MSDC-2-4, Spectral Devices provides msInspector, a Windows-based application featuring a graphical user interface (GUI). The software makes inspection and geotagging of images collected with the MSDC series multispectral drone cameras from Spectral Devices Inc quick and easy.

The software onboard the MSDC-2-4 performs real-time preprocessing of images from each camera. For example, multispectral images are demosaiced and saved in TIFF format onto the removable USB drive. While single band cameras, such as the SWIR and Red Edge are saved directly to the drive. Images are saved into a hierarchical folder system ensuring no data is overwritten between flights. msInspector uses configuration, calibration, and correction files specific to each MSDC camera. The calibration files are supplied by Spectral Devices. msInspector provides a series of batch operations allowing the user to load images, solar sensor data, and GPS data. At each step, data can be visualized. The geotagged images can be saved to a folder chosen by the user.

Features

1. Simple, easy to use tabbed GUI.
2. Data visualization (images, GPS and solar sensor data)
3. Geotags large numbers of images in a single operation.
4. Tags solar sensor data to the images.
5. Exports geotagged images in multiple formats to the desired folder.
6. Provides tags required by 3rd party mapping software.

In the camera tab the user can review all the collected images and apply non uniformity corrections to the images (Fig.4).

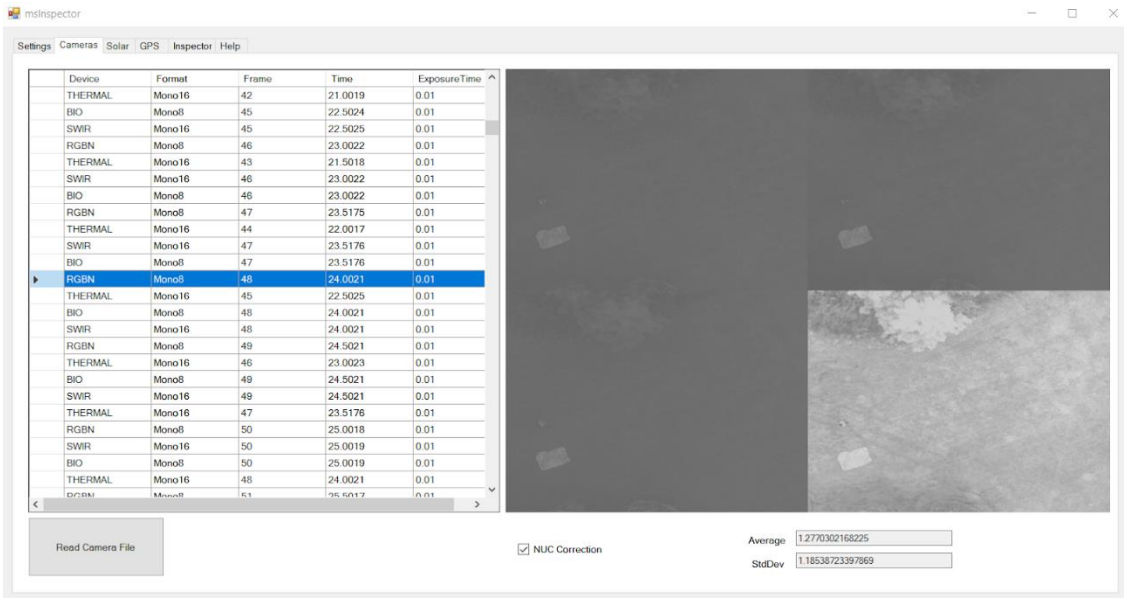


Figure 5. *Camera tab in the msInspector.*

Solar tab (Fig.5) in the msInspector allows the user to review data collected by the solar sensor during the flight. Data includes the spectrometer reading across the VIS-NIR spectrum, sensor orientation (yaw, pitch, roll), and solar direction relative to the sensor.

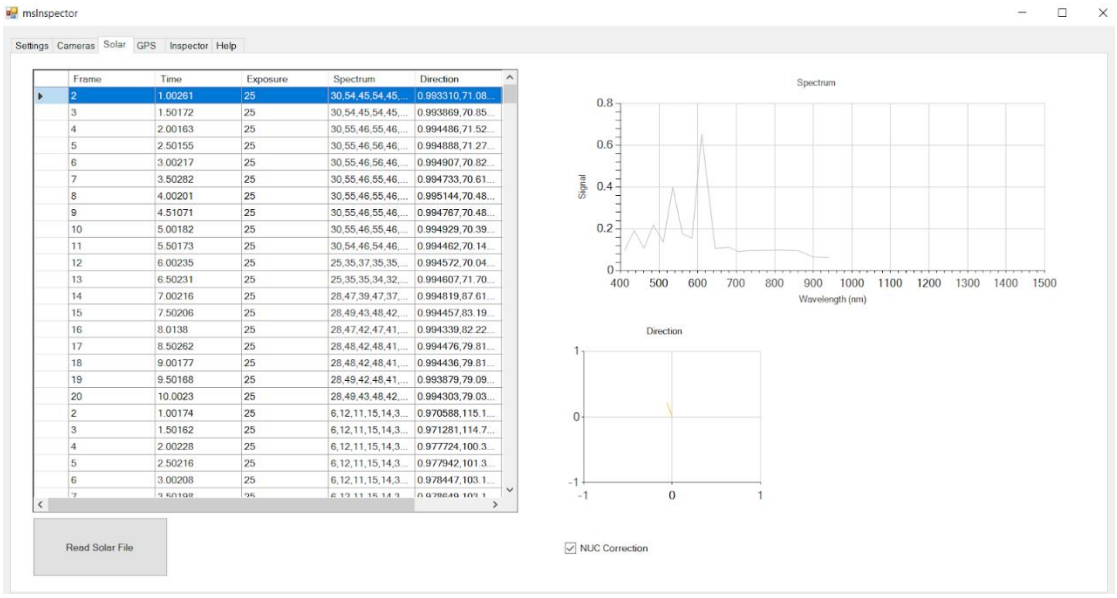


Figure 6. *Solar tab in the msInspector.*

GPS tab (Fig.6) in the msInspector allows the user to review GPS data collected by the GPS sensor (longitude, latitude, and altitude) during the flight. A map is displayed showing the location of the flight along with the flight path.

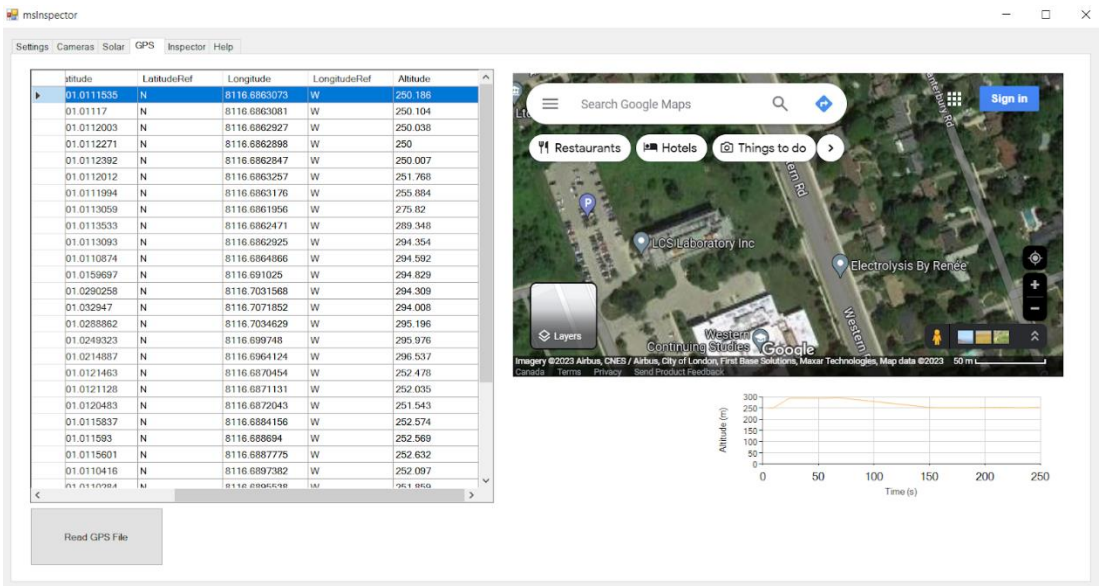


Figure 7. *GPS tab in the msInspector.*

The Inspector tab (Fig.7) in the msInspector allows the user to review all the data together. This data is used for image metadata generation. From this tab, geotagged images are exported with all the necessary metadata for image post-processing using software such as WebODM or Pix4DFields.

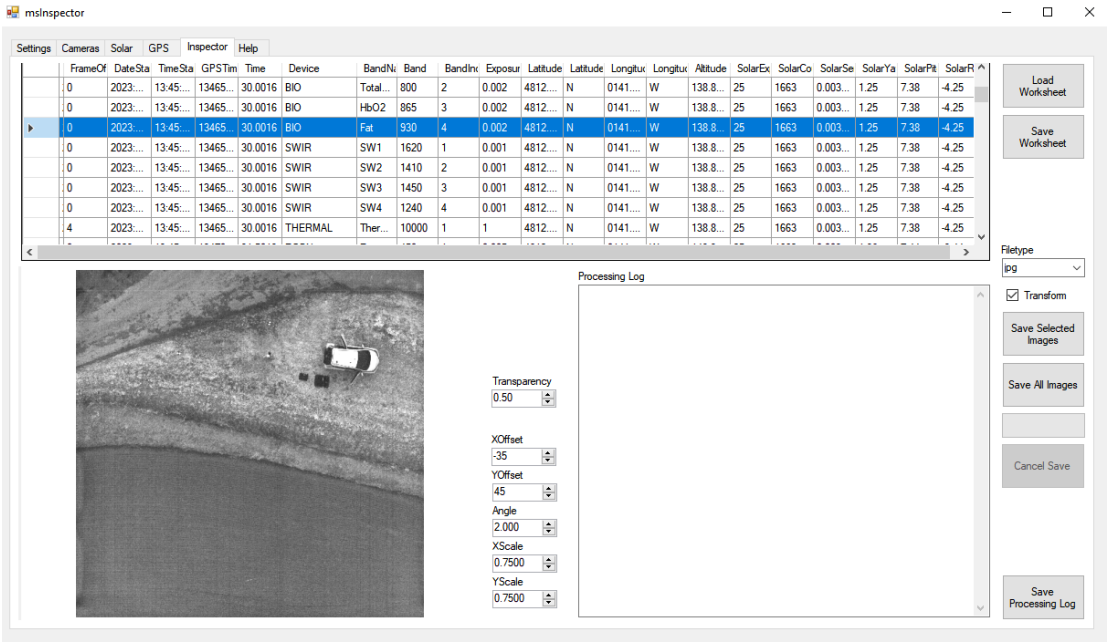


Figure 8. *GPS tab in the msInspector.*

7. Image Post-processing

Images exported from the msInspector are ready for 3D model reconstruction and orthomosaic map generation using open source software WebODM by Open Drone Maps or subscription software Pix4D.

Spectral Devices Inc. provides tutorials and guides for image post-processing.

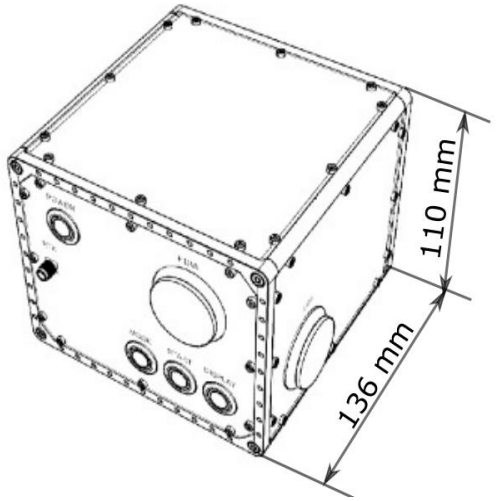
MSDC-2-4 AGRI

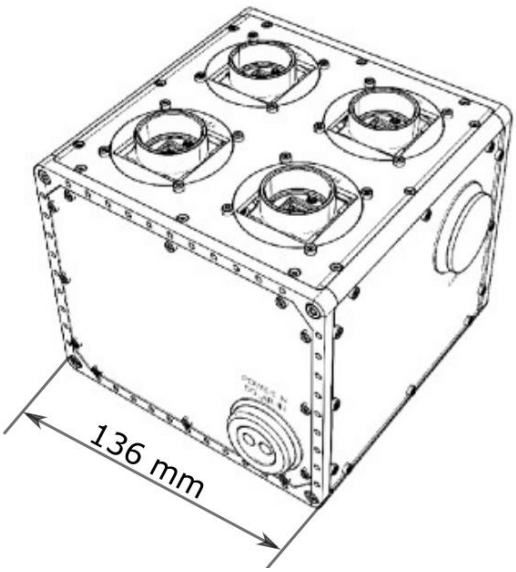
MSDC-2-4 AGRI is a multisensor drone camera system with NIR, SWIR, Red Edge and high-resolution color cameras. It is designed for monitoring crop health and hydration.

FEATURES

- Diverse Camera Array: 5 MP NIR, Red Edge and color camera, 1.3 MP SWIR camera
- Compatible with a wide range of drones
- User-friendly design
- Sustained frame rates @ 1 FPS
- Built-in high-performance GPS @ 10 Hz with RTK
- Solar sensor UV-SWIR 19 channel spectrometer
- Accommodates C-mount lens
- Configurable
- Enables comprehensive analysis of crop health, soil conditions, and more.

DIMENSIONS

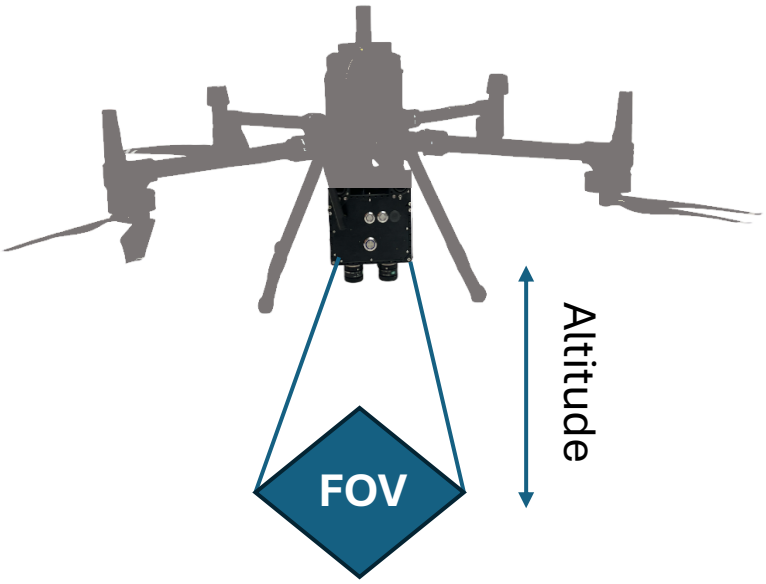




TECHNICAL SPECIFICATIONS

Feature	Description
# of bands	6
Band Locations	440 (±55) nm, 510 (±65) nm, 600 (±40) nm, 725 (±12) nm, 800 (±25) nm, 1500 (±25) nm
Pixels/band	NIR, Red Edge, Color: 2448x2048px, SWIR: 640x480px
Weight	1.7 kg with lenses 1.38 kg without lenses
Lens compatibility	C-mount
Thermal control	Passive conduction of camera heat to enclosure
Water resistant	Yes (IP54)
Dust resistant	Yes (IP54)
External construction	Anodized aluminum with stainless-steel hardware
Power input	9-36 V
Connectors	USB 3.0, HDMI, SD card reader, Two SMA connectors for GPS and RTK antennas

EXAMPLE FOV AND RESOLUTION



50 m Altitude

Lens	Camera	GSD, [cm]	FOV, [m]
12 mm	5MP	1.4	35x29
	1.3MP	2.1	27x21
25 mm	5MP	0.7	17x14
	1.3MP	1	13x10

100 m Altitude

Lens	Camera	GSD, [cm]	FOV, [m]
12 mm	5MP	2.9	70x59
	1.3MP	4.1	53x43
25 mm	5MP	1.4	34x28
	1.3MP	2	26x20

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