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NatureScan: RGB and Multispectral Drone Data Collection for Ecological Monitoring

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Alice Robbins^{1,2}, Juan Carlos Montes-Herrera^{1,2,3}, Ben Sparrow^{2,3}, Arko Lucieer¹

¹School of Geography, Planning and Spatial Sciences, University of Tasmania;

²Terrestrial Ecosystem Research Network; ³School of Biological Sciences, The University of Adelaide

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Alice Robbins

University of Tasmania

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We use this protocol and it's working

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Disclaimer

In the context of this protocol, we use the term 'drone' to refer to a remotely piloted aircraft system (RPAS) also referred to as uncrewed/unoccupied aerial vehicle (UAV) or uncrewed/unoccupied aircraft system (UAS). This protocol assumes that the operator is already familiar with the assembly and operation of the DJI Mavic 3 Multispectral drone and DJI D-RTK 2 base station as outlined in the respective DJI Official User Manuals. It is not a substitute for the comprehensive assembly instructions in the manual.

Approvals and procedures for land-access, permits, drone operations, and compliance as per national regulations (e.g., **[Australian Government Civil Aviation Safety Authority \(CASA\) regulations](#)**) are outside the scope of this document. The protocol is best used with two staff: a pilot and a spotter.

Abstract

This protocol describes the standardised procedure for collecting RGB and multispectral data for on-going ecological monitoring at the 1 to 50-hectare scale. The instructions outlined in this protocol are for the DJI Mavic 3 Multispectral drone with the Real-Time Kinematic (RTK) module installed for direct georeferencing using the DJI D-RTK 2 base station.

Instructions include a desktop-based assessment, flight planning, data collection, and a data backup and metadata scheme. The steps outlined here support the creation of drone protocols and analysis-ready data products for the **[NatureScan](#)** project. While this protocol is specific to the use of the DJI Mavic 3 Multispectral drone, much of the content should transfer to other consumer-grade drone configurations.



Guidelines

- Approvals and procedures for UAV operations and compliance as per flying regulations are outside the scope of this protocol.
- Coordinate with local authorities and landowners to ensure all permissions and road access are obtained before conducting flights.
- Ensure all drone operations comply with official aviation safety regulations. For Australia, check Civil Aviation Safety Authority (CASA) regulations and your organisation's Remotely piloted aircraft operator's certificate (ReOC) processes.
- Both the pilot and spotter must be certified to operate the drone and trained in emergency landing protocols.
- Conduct pre-field Job Safety Assessments (JSAs) for each flight mission and submit them to the Chief Remote Pilot for approval.

Materials

Mission Planning - Desktop Assessment

Time requirements

- Flight mission planning and selection will vary depending on the complexity of the project area and availability of spatial layers and other relevant information.

Personnel requirements

- One person is required when completing the desktop component of flight mission planning. The person needs to be familiar with and experienced in using GIS software. The person may require assistance from personnel that are familiar with the project area/region and experienced in collecting drone data in the field.

Equipment

- Computer with GIS mapping software
- Geographical tools (satellite imagery and GIS layers), biological, historical, logistical, and political data.

Mission Planning - DJI Pilot 2

Time requirements

- Allow up to 1 hours.

Personnel requirements

- One person is required when completing the mission planning using DJI Pilot. The person needs to be familiar with the use of DJI Pilot 2.

Equipment

- DJI Pilot on the controller.
- microSD card or USB-C cord to import KMZ onto controller (and DEM if required for Terrain Follow).

Data collection

Time requirements

- Allow up to 2 hours.

Personnel requirements

- Two people are required for drone data collection. Both should be certified to fly the Mavic 3M, and one person should act as a spotter during the flight.

Equipment

- Mavic 3M case with drone, controller, spare propellers and sufficient batteries for the flight.
- DJI D-RTK 2 base station case with D-RTK 2 antenna, tripod and sufficient batteries.
- Sturdy rubber mat to launch/land drone.
- Laptop for data backup, formatting cards, etc.
- microSD cards, microSD card reader and SSD for data backup.
- Radios and air band radio
- Generator (if required to charge batteries in the field).

Data backup and metadata scheme

Time requirements

- Allow up to 2 hours.

Personnel requirements

- One person is required for data backup and recording flight and site metadata. This person should be familiar with the field equipment, recommended folder structure and the file types of drone and GNSS data.

Equipment

- Computer with a file transfer and folder comparison tool installed (e.g. TeraCopy and WinMerge).
- MicroSD card reader
- SSD for data backup (if completing in the field).

Safety warnings

- !
 - Do not operate the drone in rain, precipitation, or wind speeds exceeding 18 m/s.
 - Ensure flight operations are paused if obstacles or hazards are detected in the surroundings.
 - Comply with official aviation safety regulations.

Notes on Battery maintenance

- Do not use batteries with any visible damage including swelling.
- Charge Intelligent Flight Batteries using a DJI-approved charging device.
- Store batteries at room temperature in a dry and ventilated place. Transport in the provided case, and do not leave batteries in vehicles except during transportation.
- Ensure battery cases are labeled for transport (e.g., Class 9 - Miscellaneous dangerous goods)
- If a battery is used to less than 20% charge, it will need to be charged after the mission before being stored as above. This ensures the battery enters hibernation mode and discharges at a safe rate.
- For detailed information on battery use and maintenance, please see the relevant manufacturer equipment safety guidelines.

Ethics statement

- Avoid disturbing wildlife.
- If needed, use non-invasive reference points for marking base stations in protected or sensitive areas, such as close to roads and national parks.
- Adhere to ethical data collection practices that prioritise safety and minimise environmental impacts.

Before start

Drone data collection should be approached in four stages:

1. Desktop component to identify project area based on environmental, scientific, historical and logistical information (Section 1)
2. Mission Planning using DJI Pilot prior to departing for fieldwork (Section 2 - 9)
3. Data collection (Section 10 - 19)
4. Data backup and metadata scheme (Section 20 - 25).

Mission Planning - Desktop Assessment

1 Identify and complete a desktop-based assessment of the intended site.

This includes:

- Reviewing aerial imagery, spatial data and on-ground knowledge of the study area.
- Assessing the impacts of seasonal changes including phenology and sun angle.
- Using a GIS to create a KMZ file of the monitoring site.
- Assessing topographic change of the proposed monitoring site.

1.1 Review aerial imagery, available spatial data for the study area and existing on-ground knowledge of the project area.

Drone data collection should be driven by a thorough desktop assessment to address monitoring objectives. This includes reviewing scientific and environmental information, in addition to political, historical, and logistical considerations.

- It is beneficial to define more than one site during the desktop scoping stage, as the suitability and accessibility of sites will be reassessed in the field.
- Intended sites for drone data collection should be tailored to the purpose of the project and this should include consideration of any relevant phenological processes (see Step 1.2) that are critical for the analysis of ongoing environmental patterns.
- **An overview of different information that can be considered is provided below.** The availability and relevance of this information will vary dependent on the study area, and this is a guide only.

A	B
Scientific and Environmental Information	Vegetation cover and type
	Reserves and protected areas
	Ecological communities
	Flora and fauna records
	Previous survey data for the area of interest
	Discussions with landholders/managers
Historical information	Location and compatibility with any existing monitoring sites.
	Land use and management history
	Fire history
Logistical Considerations	Ease of access to suitable sites
	Vehicle access

A	B
	Traversability
	Financial limitations
	Development or intervention footprint
	Local flight regulations
Political or Legislative Considerations	State priorities
	NRM region priorities
	Site ownership and tenure
	Listed communities & species

1.2 Assessing the impacts of seasonal changes including phenology and sun angle.

Seasonal impacts can impact data quality and should be considered prior to data collection as part of the desktop assessment phase.

- **Phenological changes:** if the ecosystem or feature of interest undergoes any significant phenological changes, data collection should be aligned to capture this. This will improve the usability of the processed data for future analysis.



Collecting drone data during phenological changes is advantageous for future analysis. Shown above is an acacia community (left) and grassland (right) in flower, which introduces spectral variability that is helpful to classify vegetation communities and species.

- **Sun angle:** the time of day or year that data is collected will impact data quality. To minimise variation in solar angle and shadows, flights should be conducted as close to solar noon as possible (within 2-3 hours).

- If the study area is located at high latitudes (e.g. Tasmania) low sun angles during winter will impact the data, particularly the quality and variability of multispectral data.
- Fieldwork at high latitudes should be conducted for spring to autumn where possible. Use online [Solar Calculators](#) to assist with flight mission planning.



Sun angle, either from time of day or year, will impact data quality. Collecting data later in the day or during winter will result in long shadows and a poor spectral response which impacts multispectral data quality. Shown above is data collected at a site in Tasmania in May at 2pm (left) compared to the same site in February with data collection aligned with solar noon.

1.3 Use a GIS to generate a KMZ file of the drone monitoring site.

Note: this step assumes the user has knowledge of and is comfortable using a GIS (e.g. QGIS, ArcGIS, Google Earth Pro) to generate a KMZ file of the site.

1. Navigate to the area of interest and create a polygon of the intended monitoring site.
2. Export polygon and save as KMZ file.
3. **The KMZ file must be exported and saved with World Geodetic System 84 (WGS84) as the coordinate system to be compatible with DJI Pilot 2.**





An example monitoring site polygon, shown in magenta. The selection of this site was guided by an established monitoring plot, shown in green.

1.4 **Assessing topographic change of study area.**



For monitoring sites with varying elevation, enabling Terrain Follow in the flight mission settings during data collection is recommended to ensure consistent image overlap. Selecting the appropriate Terrain Follow parameter and Digital Elevation Model (DEM) is dependent on the drone platform and the study area.

- In general, terrain follow should be enabled if there is an elevation difference greater than 20 metres across the site.

There are three options for Terrain Follow:

1. Import Local File (recommended): review the spatial data available for the study area using **Elvis – Elevation and Depth – Foundation Spatial Data**. Availability of elevation data can be limited in remote areas of Australia.

- If there is a suitable elevation model available for the study area, select the data required and complete the relevant fields to order data from ELVIS.
- **It is critical to select WGS84 Lat/Longs (EPSG:4326) to ensure the local DEM is compatible with DJI Pilot 2.**
- The local DEM can be imported directly onto the drone controller or onto a microSD card and selected during mission planning

2. Download from Internet: if this option is selected in DJI Pilot 2 during mission planning (Altitude Mode → AGL → DSM Files → Download from Internet) the **ASTER Global Digital Elevation Map (GDEM)** will be used for Terrain Follow.

- The resolution of this DEM is approximately 30 metres and caution should be taken with using this elevation model in complex terrain or to map complex/tall vegetation.

3. Real-Time Follow: this option is not available for all drone platforms. For some platforms, including the DJI Mavic 3 Multispectral drone, this option uses the drones vision positioning system to correct for elevation change during the flight. Refer to associated user manuals for guidance on using this option.

Mission planning - DJI Pilot

- 2 The following section outlines recommended flight mission parameters for standardised data collection to inform on ecosystem condition over time.

This includes:

- Forward and side image overlap
- Flight path direction and
- Speed

Two flight mission parameters are adjusted based on ecosystem structure and the pixel size required to capture the feature of interest in the survey area for on-going monitoring purposes:

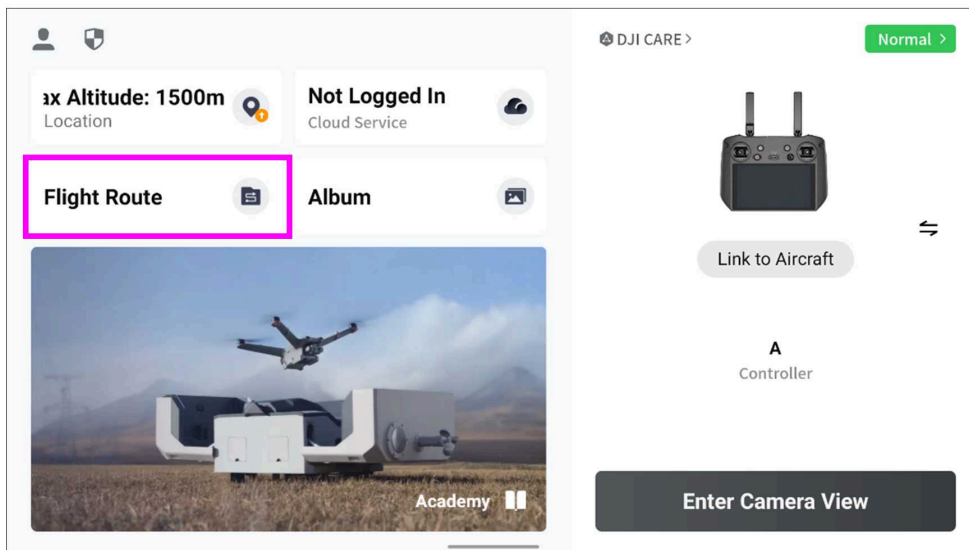
- Flight altitude, which controls pixel size and
- Target Surface to Takeoff Value to accounts for canopy structure and for consistent image overlap.

Additional considerations for the long-term management of drone data include:

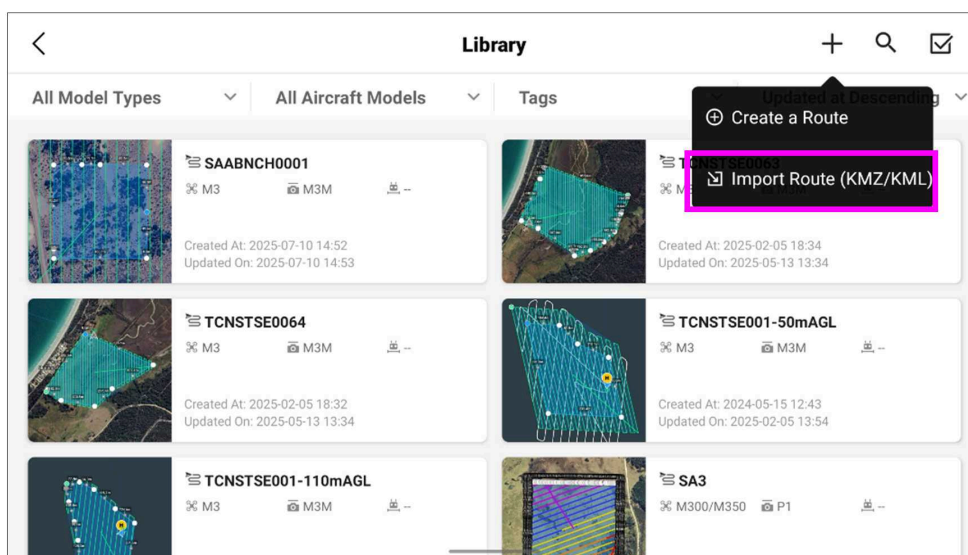
- Flight duration
- Spatial coverage
- Data quantity

- 3 **Import KMZ file into DJI Pilot 2.**

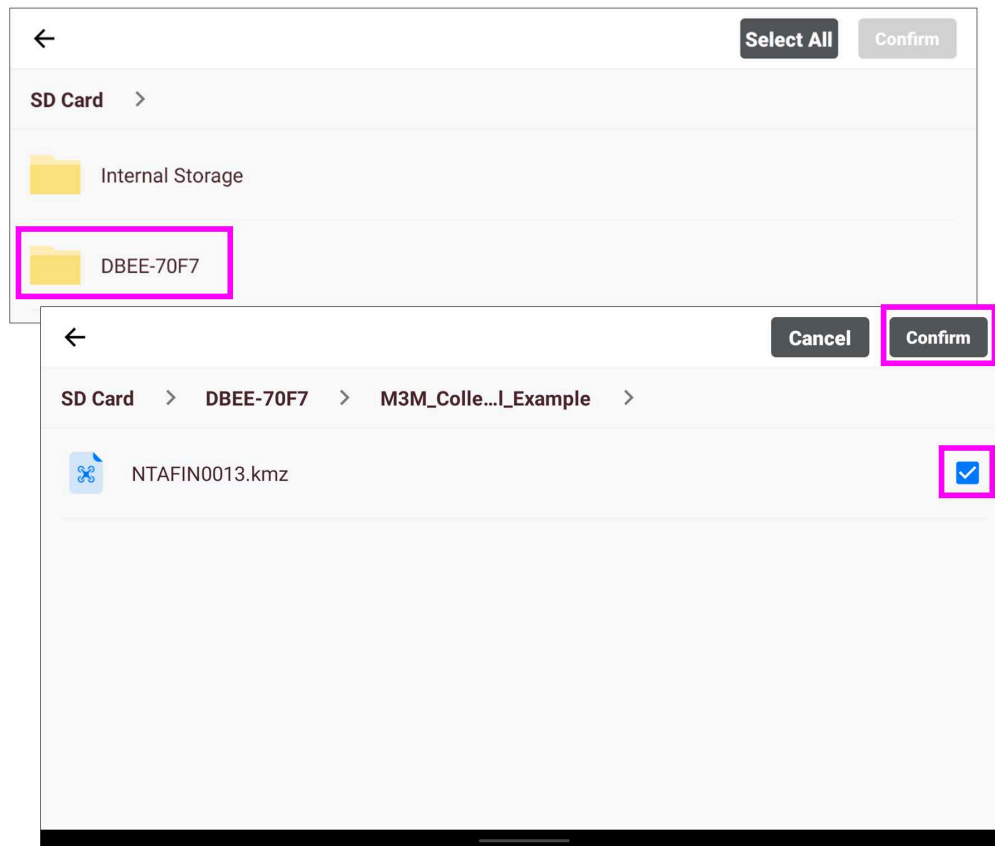
Open the DJI Pilot app and select 'Flight route'



3.1 Select 'Import Route (KMZ/KML)' to import the KMZ/KML file



3.2 Load the mission by navigating to the KMZ file. Select the flight mission file and click "Confirm".

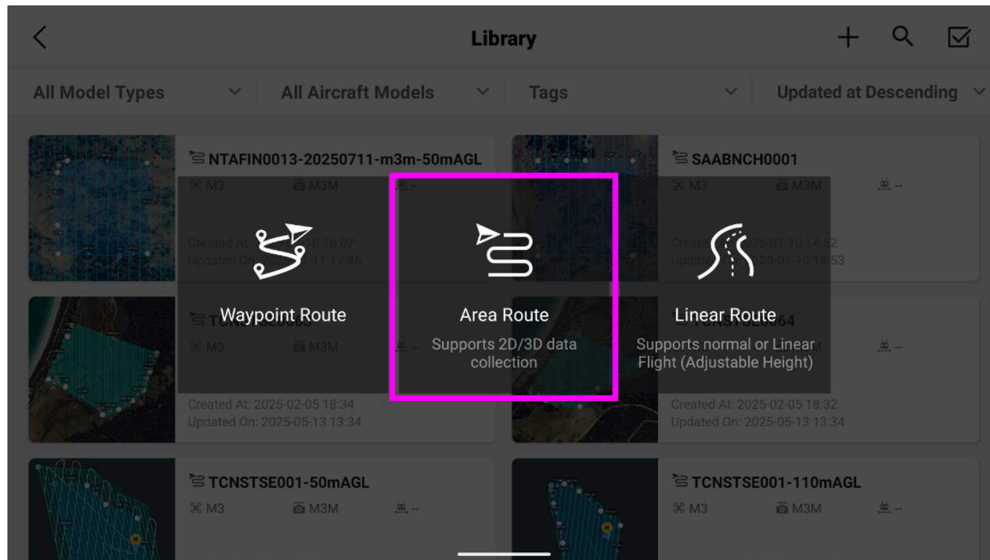


Note

The KMZ file is loaded from a microSD card in the example above. Allow access to the SD Card to load KMZ file.

- 3.3 Select "Area Route" and **cache the study area base map** by zooming and panning around the flight mission area. This step can only be done with an internet connection and should be completed prior to departing for fieldwork.

If the base map is not cached, background imagery will not be available during data collection in the field.

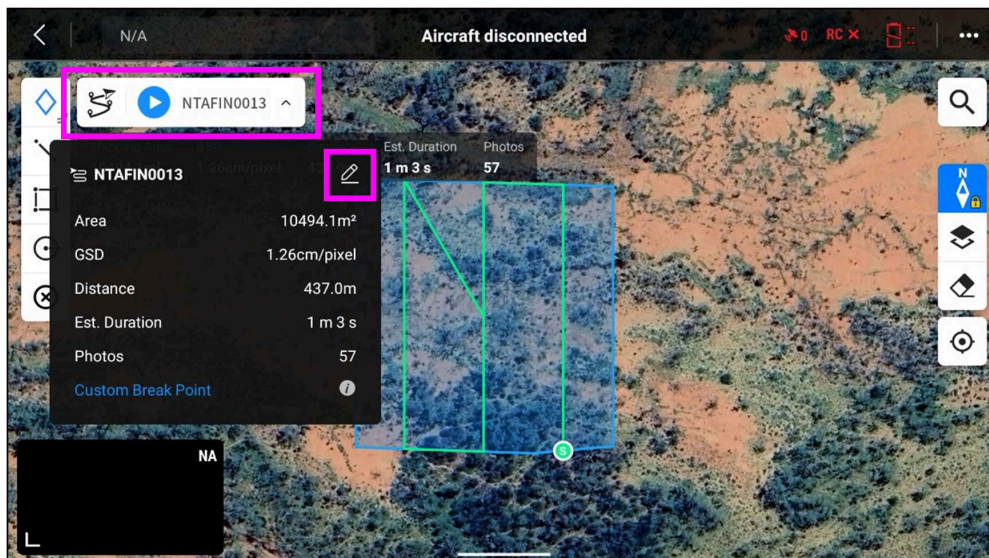


Mission Planning - DJI Pilot: Update flight mission settings

4 General and Advanced flight mission settings

The following section outlines flight parameters that need to be adjusted in the mapping mission file in DJI Pilot 2.

- 4.1 Toggle the mission menu and click the "Edit" pencil icon to update flight mission settings.



- 4.2 A panel to edit the mapping mission settings will appear on the right.
1. Update the Area Route name. The recommended naming convention is PlotID-YYYYMMDD-sensor-mAGL (e.g. 20250711-NTAFIN0013-m3m-50mAGL)
 2. Update the Aircraft settings (M3E Series, M3M) and sensor selection (RGB + MS).
 3. Ensure that Ortho Collection is selected and the polygon area is correct.



- 4.3 Update the flight parameters for general and advanced settings as listed in the table below.

	A	B	C	D
		Parameter	Value	Note
General Settings		Area Route	PlotID-YYYYMMDD-sensor-mAGL	e.g. NTAFIN0013-20250711-m3m-50mAGL
		Aircraft	M3E Series M3M RGB+MS	
		Ortho GSD	Default	Allow other flight parameters to determine.
		Altitude Mode	Relative to Takeoff Point (ALT)	In areas with varying topography select AGL to enable Terrain Follow. Import a DEM or enable Real-Time Follow as required.



A	B	C	D
	Route Altitude (m)	Dependent on ecological feature	Route Altitude will be determined by the pixel size required to capture vegetation of interest in survey area. See Step 5 for more information.
	Elevation Optimization	Enable	Improves elevation and georeferencing accuracy during image processing.
	Safe Takeoff Altitude (m)	20	Pilot to reassess on site.
	Speed (m/s)	Default and maximum value	Select maximum speed possible, determined by other flight mission parameters
	Course Angle (°)	0	A north-south direction is optimal to minimise variation in multispectral data capture (BRDF effects).
	Upon Completion	Return to Home	Manual landing recommended.
Advanced Settings	Target Surface to Takeoff Point (m)	Canopy < 10 m: 0 m	Vegetation height and terrain complexity must be considered when setting a suitable target surface. In rangeland and grassland sites, use the default value of 0 when the takeoff point is the same as the elevation of the site. In forested environments, set this to the height of the representative crowns in the plot. For tall forests (> 50 m) caution should be taken to ensure the maximum flying height remains below the legal limit (120 metres above ground level). See Step 6 for further guidance on setting this value.
		Canopy 10 to 15 m: 10 m	
		Canopy 15 - 50 m: Representative Canopy Height	
		Canopy > 50 m: Representative Canopy Height, limit route altitude to 80 metres and adjust accordingly	
	Side Overlap Ratio (%)	80	Overlap between flight lines – High overlap ratios ensure accurate image alignment and matching in orthomosaic processing workflows.
	Frontal Overlap Ratio (%)	80	Overlap along flight lines - High overlap ratios ensure accurate image alignment and matching in orthomosaic processing workflows.
	Margin (m)	50	Pilot to reassess in field, may need to be adjusted for operational safety: roads, property boundaries etc.

	A	B	C	D
		Photo Mode	Timed Interval Shot	
		Custom Camera Angle	Disable	
		Rotue Start Point	Default	Set to furthest point from takeoff – pilot to assess in field.
		Takeoff Speed	Default	Manual takeoff recommended

5 Determine an appropriate Route Altitude (m).

The Route Altitude (m) directly impacts the pixel size of drone data. Selecting an appropriate Route Altitude should be driven by consideration of the appropriate pixel size of the multispectral sensor to capture the feature of interest in the monitoring site.

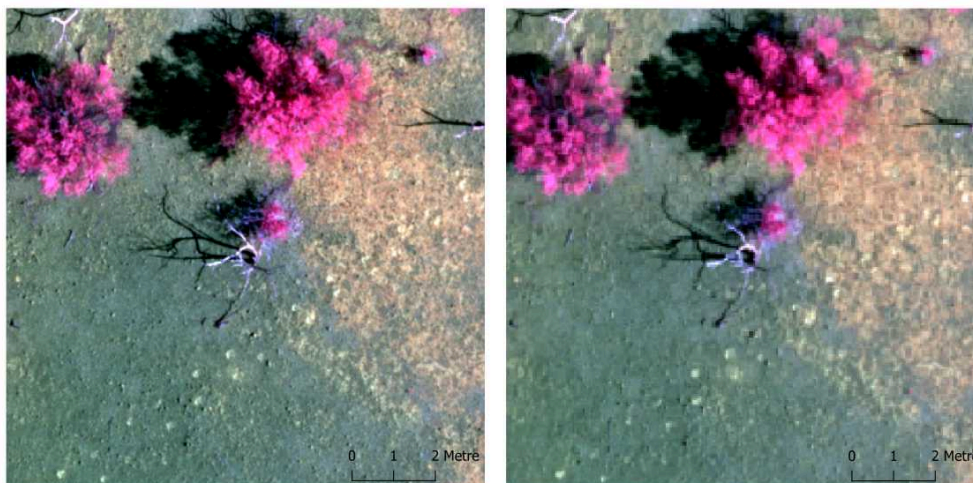
- **For smaller features or fine scale vegetation communities**, such as animal tracks, flowers or communities with fine scale features (such as grasslands and wetlands), a lower route altitude is recommended. **A route altitude of 50 meters above ground level is recommended** for smaller features and fine scale vegetation communities - this will return an Ortho GSD of 1.3 cm for the RGB camera and 2.3 cm for the multispectral sensor.
- **For larger features or plot level monitoring objectives**, such as shrubs, assessing canopy health or vegetation condition, higher altitudes are recommended. **A route altitude of 100 meters above ground level is recommended** for larger features or plot level monitoring - this will return an Ortho GSD of 2.6 cm for the RGB camera and 4.6 cm for the multispectral sensor.

Approximate resolutions for varying Route Altitudes for the Mavic 3M are shown below, and the Route Altitude should be reassessed in the field and adjusted as necessary.

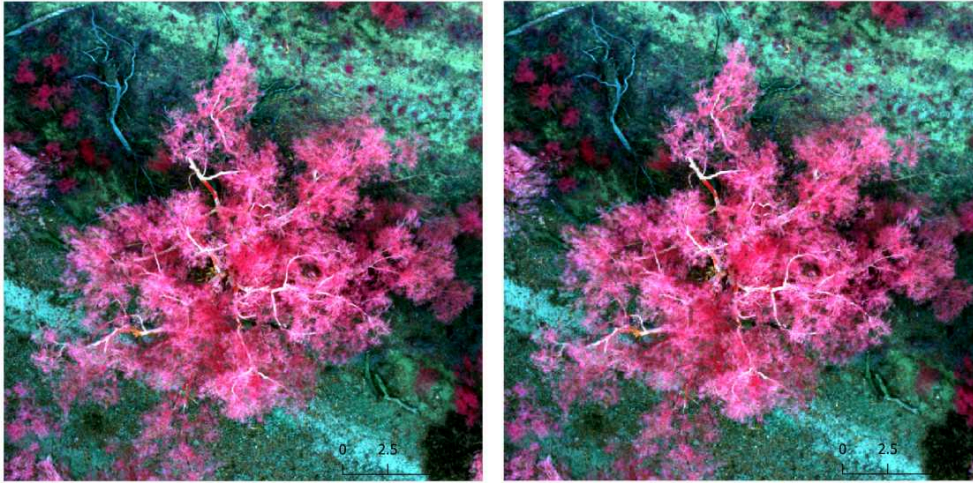
	A	B	C
	Route Altitude (m)	RGB GSD (cm)	Multispectral GSD (cm)
	15	0.4	0.69
	20	0.54	0.92
	30	0.81	1.38
	40	1.07	1.84
	50	1.34	2.31



	A	B	C
	60	1.61	2.77
	70	1.88	3.23
	80	2.15	3.69
	90	2.42	4.15
	100	2.69	4.61
	110	2.95	5.07



The impact of Route Altitude on smaller features, such as animal tracks, should be considered prior to data collection. Above left is the final data product for the multispectral sensor at 50mAGL (~1.84 cm resolution) compared to 100mAGL (~5 cm resolution).



The impact of Route Altitude on larger features or plot level monitoring is less relevant. Above left is the final data product for the multispectral sensor at 50mAGL (~1.84 cm resolution) compared to 100mAGL (~5 cm resolution). The impact of Route Altitude at this scale is negligible, and a higher route altitude is recommended for reduced collection and processing times, and less storage requirements of raw and processed data.

6 Set Target Surface to Takeoff Point value (m)

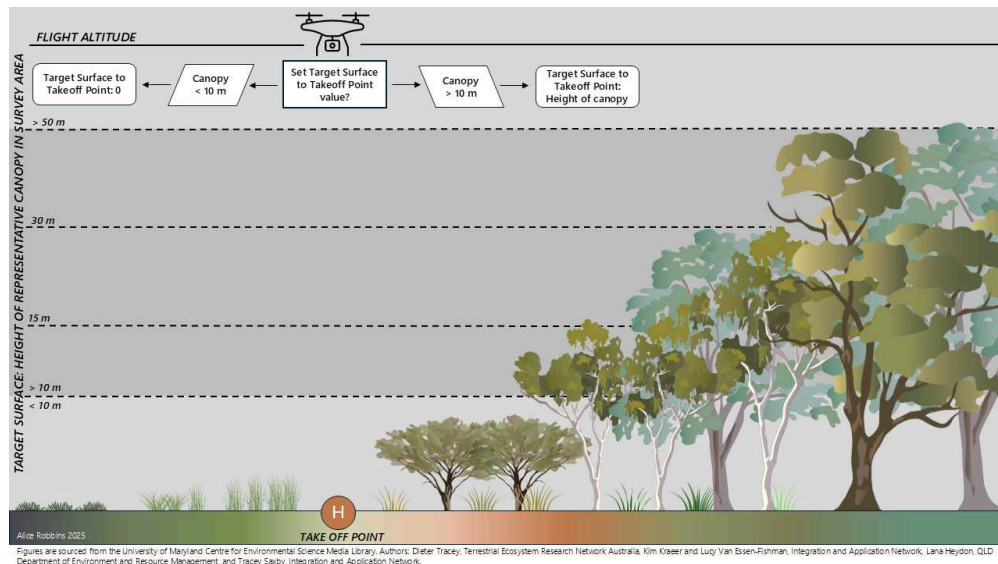
Image overlap is set based on the elevation of the takeoff point of the drone. For sites with tall vegetation (>10 metres) a Target Surface to Takeoff value needs to be set to ensure that the canopy is covered with sufficient image overlap. If this value is not set, the height of the "target surface" (ie the canopy) will not be taken into consideration, reducing image overlap which can lead to gaps in the processed orthomosaics.

- **Caution should be taken flying in tall or dense vegetation:** ensure the drone remains within line of site and be wary of raptor encounters.
- The Target Surface to Takeoff Point value may need to be reassessed in the field.

The Target Surface to Takeoff Point value should be selected based on the height of the representative vegetation in the monitoring site.

- **Rangeland and grassland sites (< 10 metre canopy height):** where the takeoff point is the same as the elevation of the site the default value of 0 should be used.
- **Shrubland, woodland and forest sites (10 - 30 metre canopy height):** set value to the height of the representative tree crowns in the plot.
- **Tall forests (> 30 metre canopy height):** set value to the height of the representative tree crowns in the plot and the flight altitude to 80 metres above ground level. Adjust flight altitude as necessary to remain below 120 metres above ground level.





- 7 After updating the mission settings, the general and advanced settings should be as below.



Altitude Mode

Relative to Takeoff Point (ALT)

Route Altitude (12~1500m)

-100 -10 -1 50.0 +1 +10 +100

Elevation Optimization *i*

Safe Takeoff Altitude *i* (2~1500m)

-100 -10 -1 20 +1 +10 +100

Speed (0.1~4.4m/s)

- 4.4 +

Course Angle (0~359°)

- 0 +

Upon Completion

Return To Home

Advanced Settings >

Altitude Mode

AGL

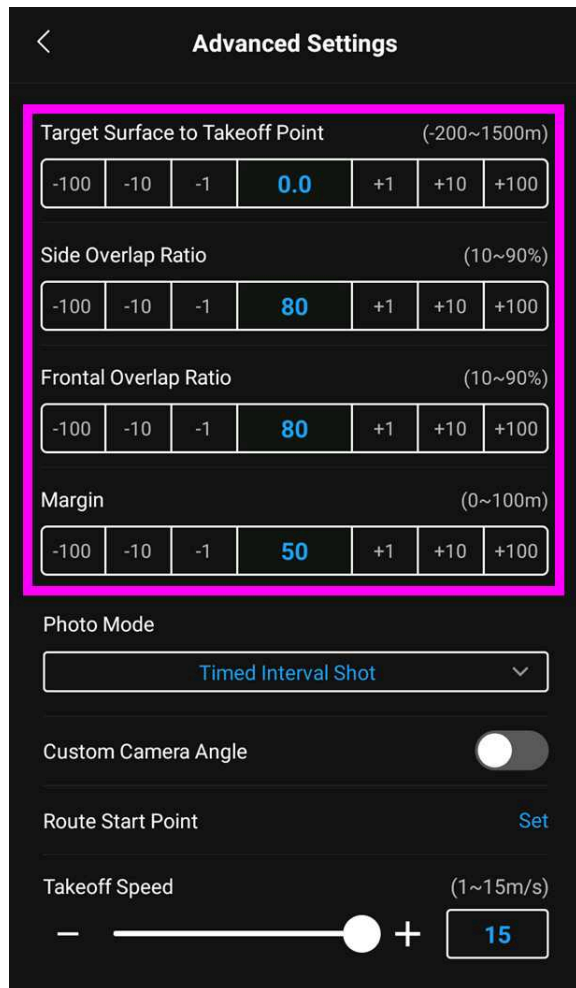
Real-Time Follow

DSM Files Reselect >

Terrain Follow Altitude (25~1500m)

-100 -10 -1 50.0 +1 +10 +100

Change Altitude Mode to AGL to enable Terrain Follow. Select between Real-Time Follow or an imported DSM.



8 Considerations for mapping beyond the 1-hectare plot scale and for long-term management of drone data.

- **Spatial coverage:** provided below is the expected flight time duration, data quantity and required batteries for Mavic 3M flights at 50 and 100 meters above ground level, at the 1, 5, 10-, 20-, 40- and 50-hectare scale. This table can be used to guide flight mission planning beyond the 1-hectare plot scale.
- **Flight duration:** With consideration a set low battery level (30% as recommended in this protocol) the DJI Mavic 3 Intelligent Flight Battery provides approximately 20 minutes of flying time. This will vary dependent on environmental conditions (e.g. lower flight time per battery in hot or windy conditions).
- **Data quantity:** it is worth considering the quantity of data that will be collected based on flight mission settings and how this will be handled for long-term monitoring. Flights at 50 metres above ground level will yield higher quantities of data than higher altitude flights at the same scale. For flight areas greater than 20 hectares, it is recommended to choose a higher route altitude to avoid excessively large quantities of raw data.

- **Maintaining Visual Line of Site (VLOS):** mapping at larger scales and higher route altitudes can be limited by legal requirements to maintain Visual Line of Site (VLOS) with the drone. Reassess the flight path in the field and adjust as necessary to maintain VLOS for the duration of the mission.

	A	B	C	D	E	F	G
	Route altitude (mAGL)	Scale (hectare)	Flight duration (minutes)	Data quantity (GB)	JPG images (count)	TIFF images (count)	Batteries required (count)
	50	1	14	20	415	1660	1
	100	1	5	6	123	492	1
	50	5	35	50	1042	4168	2
	100	5	10	14	291	1164	1
	50	10	60	84	1753	7012	3
	100	10	16	23	477	1908	1
	50	20	108	140	2904	11616	6
	100	20	26	37	775	3100	2
	50	40	175	245	5167	20668	9
	100	40	45	64	1335	5340	3
	50	50	220	310	6456	25824	12
	100	50	60	80	1687	6748	4

Note: Actual flight duration, data quantity and image count will vary. The values provided above are estimates only based on the recommended flight mission settings outlined in this protocol (no target surface to takeoff value was set). These estimates are calculated based on a scaled square flight path, and the shape of the flight mission polygon will impact flying times and data quantities. The data quantity is calculated using an average JPG file size of 8400 KB and an average TIF file size of 9800 KB.

Pre-field work: Recommended tasks for operational safety

9 Prior to departure on fieldwork the following tasks are recommended for safe drone operations.

Note: these tasks and associated settings are recommendations only. Some organisations may have specific protocols in place - always check with and adhere to organisation specific procedures.



9.1 Firmware updates

Verify the latest firmware is installed on all devices (drone, remote controller, base station and any batteries). If necessary, complete required firmware updates and complete a test flight.

9.2 Flight settings for safe operations.

Check and update the following flight settings for safe operations

- Return to Home (RTH): Adjust to same altitude as the mission.
- Max Altitude: 100 metres

Setting the max altitude at 100 metres above ground levels provides a 20-metre safety margin between the maximum altitude of the mission and legal requirements of drone operations imposed by CASA. This is recommended to allow for a twenty metre buffer for evasive maneuvers in case of any raptor encounters while flying. The pilot should assess this limit in the field and increase if necessary, remaining below 120 m above ground level.

9.3 Low Battery Warnings.

Confirm Low Battery Warnings are set to recommended settings for the following equipment:

- Intelligent Flight Battery: Low warning at 30%, Critically Low at 20%
- D-RTK 2 base station: Low Battery warning at 20%

9.4 Equipment checks.

Inspect all drone equipment for visible damage or wear, including airframe, propellers, sensors and batteries. Refer to the table below for suggested checks and recommended actions in case of defects.

A	B	C
Equipment	Check to be undertaken	Action to be taken if damaged
Drone – propellers	Inspect for damage such as cracks or chips	Replace propellers
Drone – gimbal	Inspect for cracks or damage	Refer to Chief Remote Pilot for repairs
Drone – vision positioning system and sun sensor	Ensure clean and free of obstruction and damage	Refer to Chief Remote Pilot for repairs
Intelligent Flight Battery	Inspect for visible damage including swelling	See Guidelines & Warnings for notes on battery maintenance
D-RTK 2 battery	Inspect for visible damage including swelling	See Guidelines & Warnings for notes on battery maintenance



A	B	C
RTK module (optional)	Check that RTK module is firmly mounted on the aircraft	Refer to Chief Remote Pilot for repairs

9.5 **Charge equipment.**

Charge drone controller and the required number of drone and D-RTK 2 batteries to full capacity one day prior to fieldwork and store in LiPO safe storage. Do not use damaged or swollen batteries.

9.6 **Memory cards.**

Verify that memory cards are properly formatted and sufficient storage is available for fieldwork.

9.7 **Submit a Job Safety Assessment.**

Prior to any drone surveys, flight missions must be assessed and approved by the Chief Remote Pilot. Follow organisation guidelines and complete any relevant Job Safety Assessments as required.

9.8 **Check weather conditions.**

- Check weather conditions for the study area prior to departing for fieldwork.
- [Windy.com](#) is recommended for reliable forecasts.
- It is recommended to delay fieldwork if weather conditions are not ideal for data collection.
- Preferred flight conditions are sunny and calm, or stable diffuse light under consistent cloud cover.
- Do not fly in the rain or in windy conditions with wind speeds that exceed 30 km/h. High winds will compromise data quality.

9.9 **Optional: Confirm base station coordinates.**

If the survey is a repeat visit to an established location:

- Ensure the coordinates for the base station are known and in the correct coordinate system (WGS84).
- Latitude and longitude are in decimal degrees.
- Altitude is ground height above ellipsoid minus 1.8 metres (height of the D-RTK 2 antenna).

Data collection - DJI D-RTK 2 base station set up

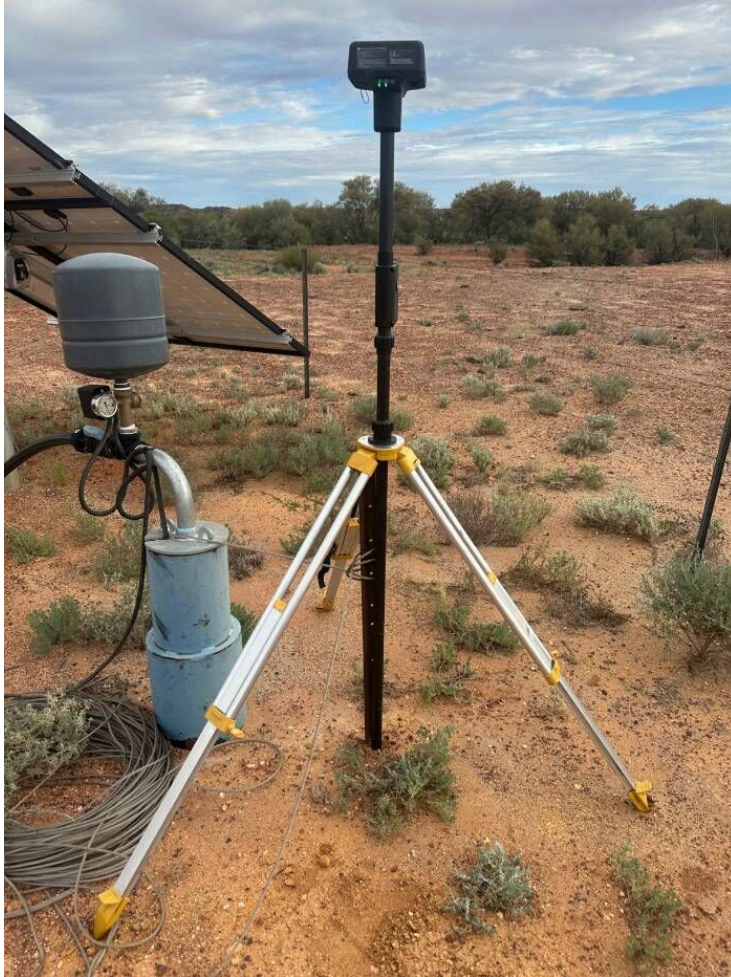
10 If no RTK module is installed, the user can skip the instructions for establishing a base station.

11 **DJI D-RTK 2 base station setup**

The base station should be established in an open area to prevent GNSS signals from being blocked, and in a position easily accessible from the drone launch area.

11.1 If establishing a site for repeat monitoring it is recommended that a permanent marker be used.

- Use a fixed and identifiable object (e.g. fence post).
- If there is no fixed and identifiable object, a permanent marker can be left in place (e.g. a star picket).



11.2 **Complete the base station set up:**

1. Check the antenna is level by referring to the antenna bubble - this should be within the black circle.
2. Check the D-RTK 2 battery is correctly inserted and fully charged.
3. Power on the antenna by pressing the power button twice.
4. Make sure the D-RTK 2 base station is operating in Mode 5 (Mobile Base Station). This is indicated by a blinking pattern of 5 times in the third LED (from left to right)



11.3 Metadata

After setting up the base station:

- Record a description of the marker (if used)
- Record a description of the location
- Take a photo of the base station set up.



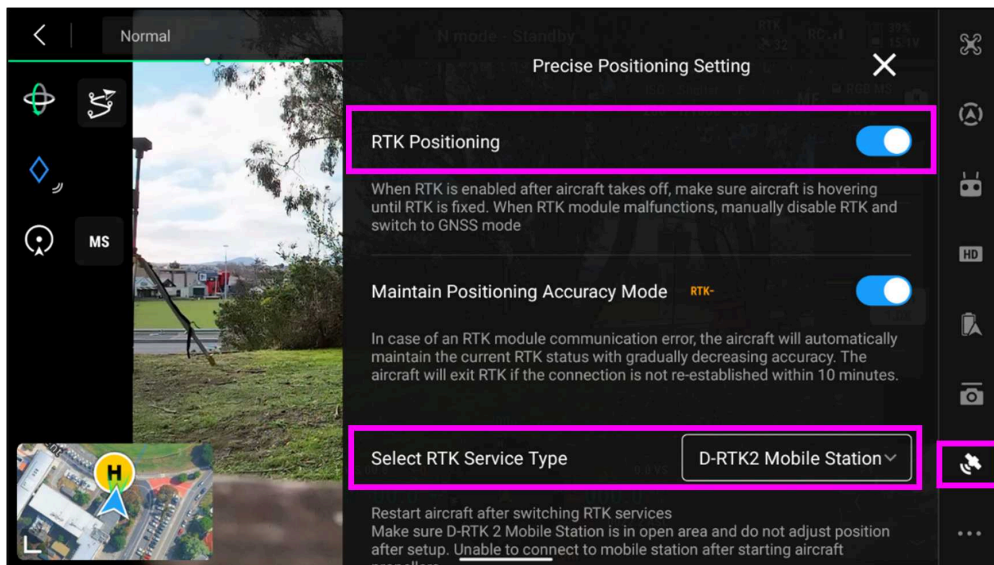
12 Optional - Adjust D-RTK 2 base station coordinates

- If a drone survey was previously completed at this site, refer to the metadata information from the last visit for the location of base station and known coordinates.
- Establish the base station at the same location before updating the coordinates as below.

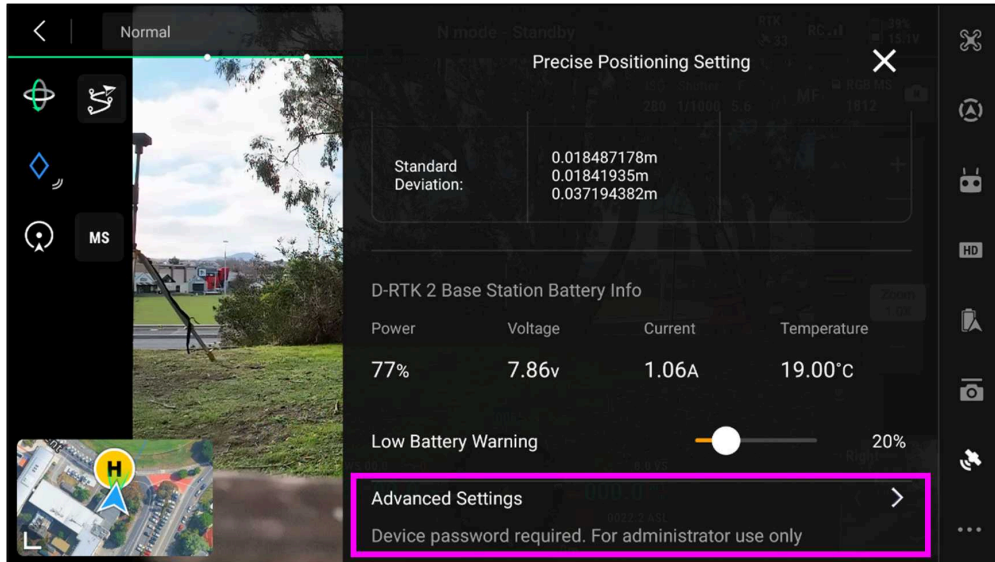
12.1 Open DJI Pilot and select "Enter Camera View". Select the "..." icon to access settings.



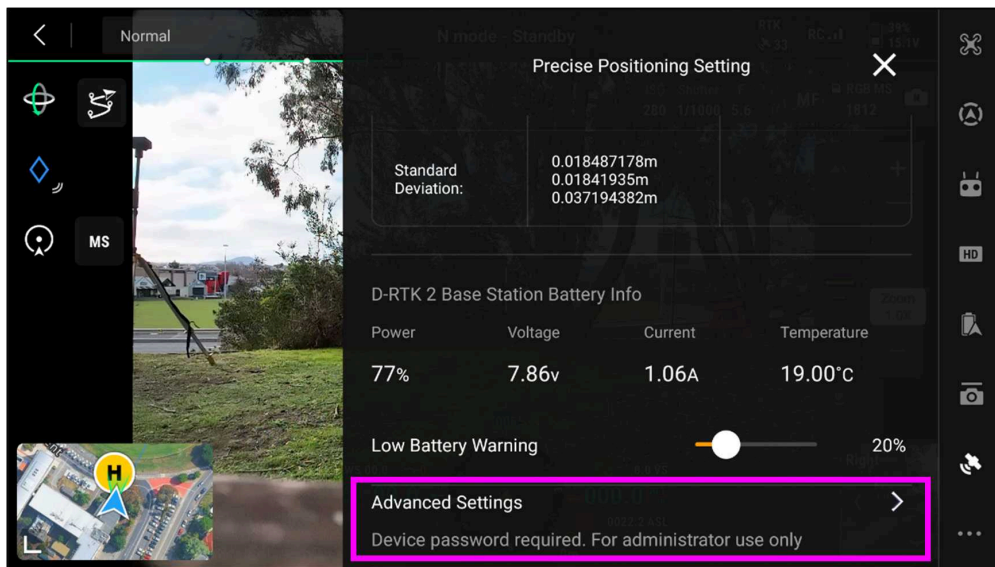
- 12.2 Select the Satellite icon and enable RTK positioning and select D-RTK2 Mobile Station under Select RTK Service Type.



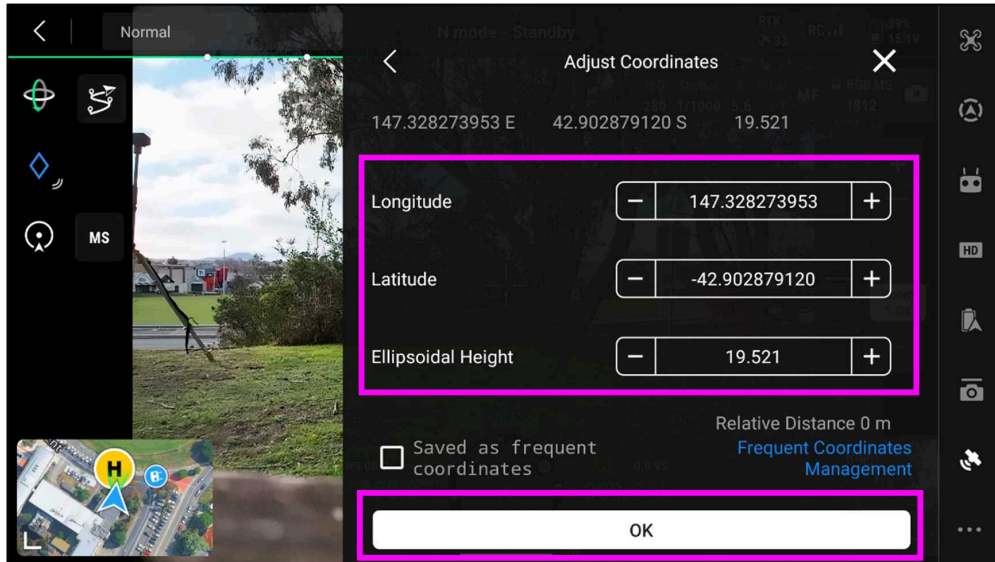
- 12.3 Navigate to and select Advanced Settings.



12.4 Select ADJUST COORDINATES and enter the latitude, longitude and ellipsoidal height coordinates for the base station.



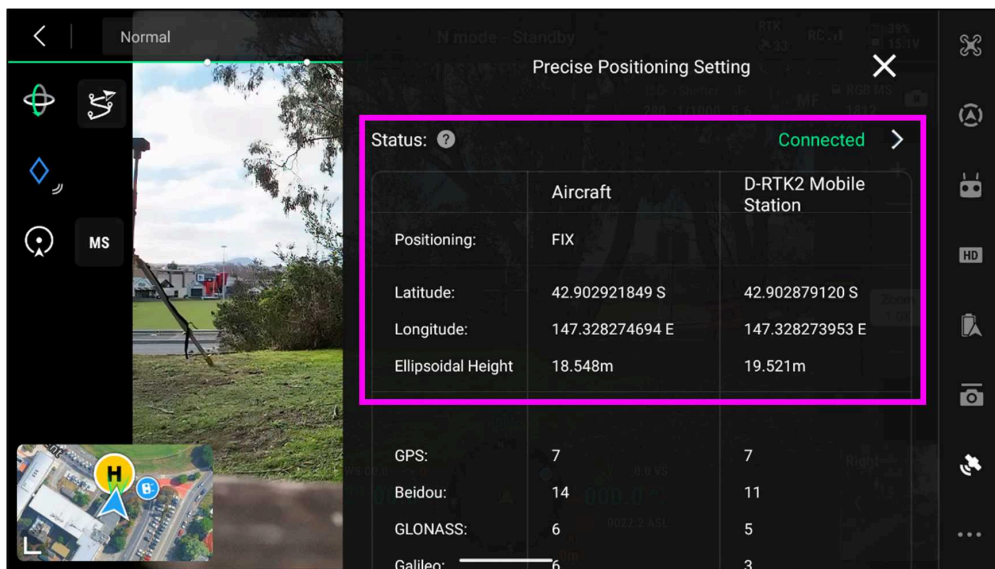
- Ensure the ellipsoidal height coordinate has been adjusted for antenna height (+1.8 metres) to 3 decimal places.
- Ensure the latitude and longitude coordinates have 8 decimal places.



12.5 Select OK and restart the aircraft by powering it off and on.

After aircraft restarts check the RTK Settings:

- D-RTK2 Mobile Station Status is connected.
- Base station coordinates have been updated.
- Aircraft Positioning has the status FIX



If a persistent RTK base station error appears, restart the base station, verify the coordinates and restart the aircraft.

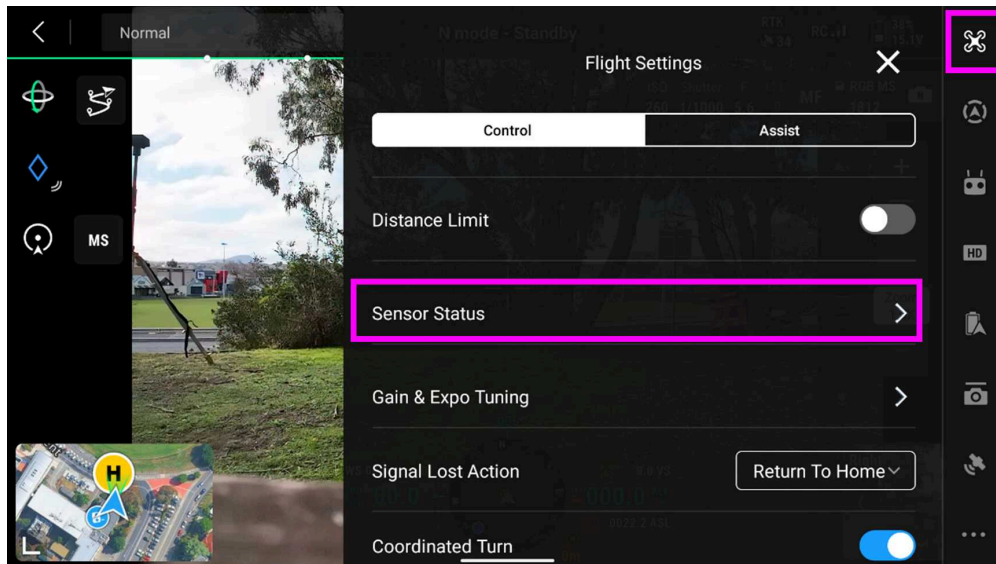
13 Prepare the aircraft

1. Remove the Mavic 3M from the pelican case. Unfold the front arms before unfolding the rear arms.
2. Remove the gimbal protector from the front of the camera.
3. Insert an Intelligent Flight Battery into the battery compartment of the aircraft. Make sure the battery is securely mounted and that the battery buckles have clicked into place.
4. Check the aircraft to ensure all parts (propellers, gimbal, airframe, sensors) are free of damage and in good condition.
5. Check that the drone has a microSD card with sufficient storage installed.
6. Turn on the remote controller. Press once, then press again and hold for two seconds to power the remote controller on or off.
7. Turn on the aircraft. Press the power button on the Intelligent Flight Battery once, then press and hold again for two seconds until the drone turns on. The drone will automatically connect to the controller if it has previously been linked.

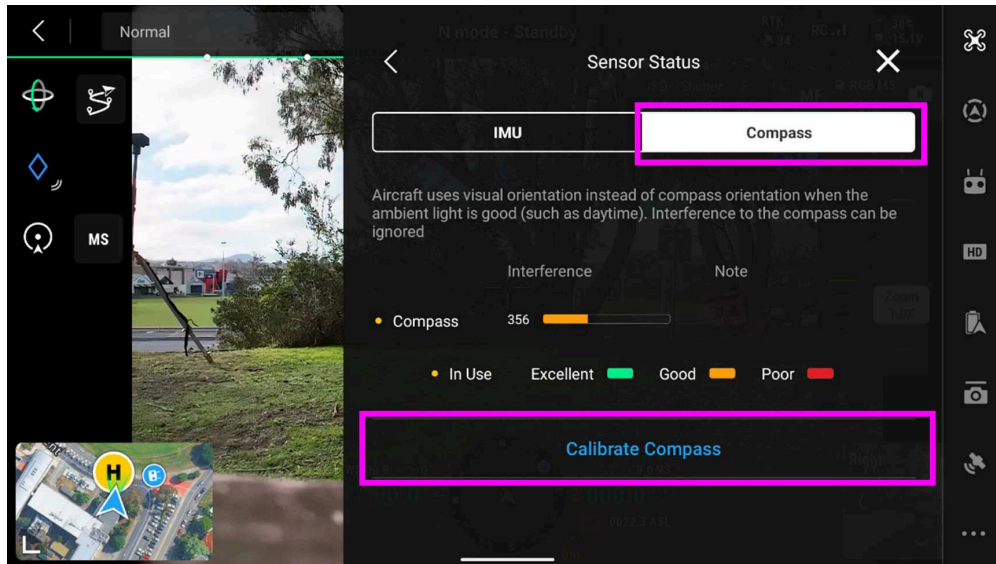
14 Compass calibration

A compass calibration should be performed at all sites following significant travel.

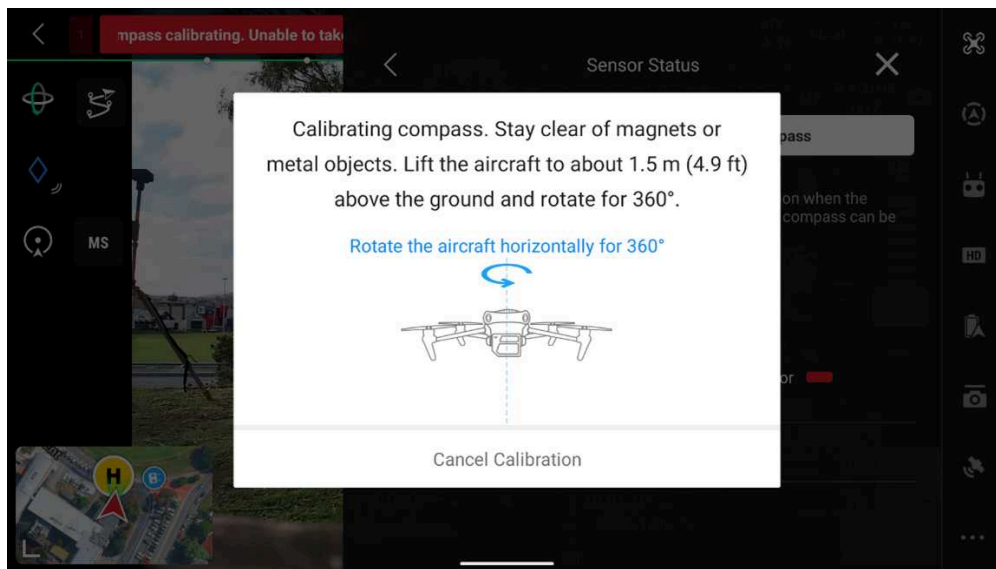
- 14.1 Click on the "... " icon on the right-hand side of the main screen.
Click on the drone icon to open Flight Settings and select "Sensor Status"



- 14.2 Select the Compass tab and Calibrate Compass



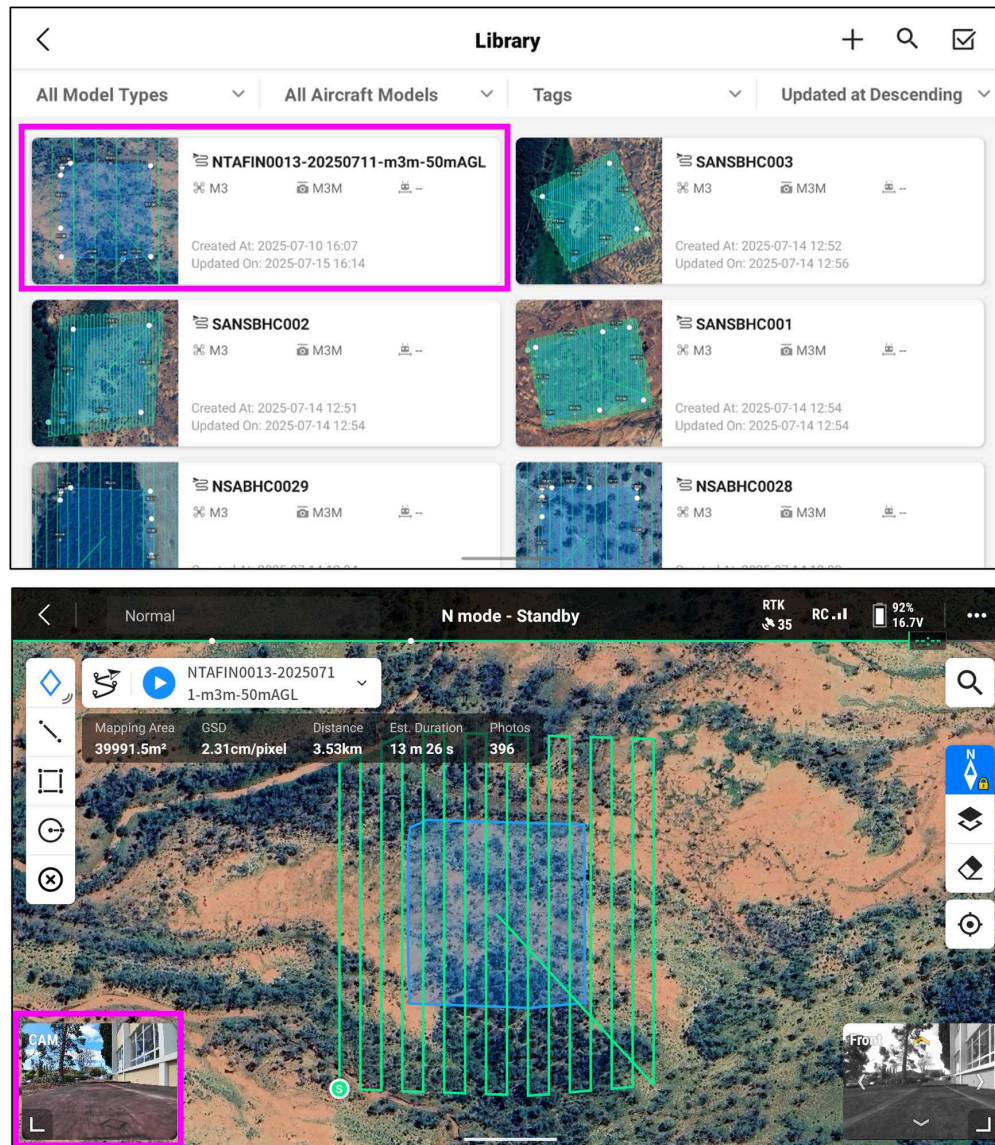
- 14.3 Follow on screen instructions to calibrate the compass. This process involves rotating the aircraft around the vertical and horizontal axes.



Data collection - RGB and multispectral sensor settings

- 15 The RGB and multispectral sensor settings should be checked before the first flight. If multiple flights are being completed, once the sensor settings are updated, only the image white balance needs to be changed based on illumination conditions.

- 15.1 Load the previously saved mission file from the Flight Route library and select the bottom left square (CAM) to access and update the sensor settings.



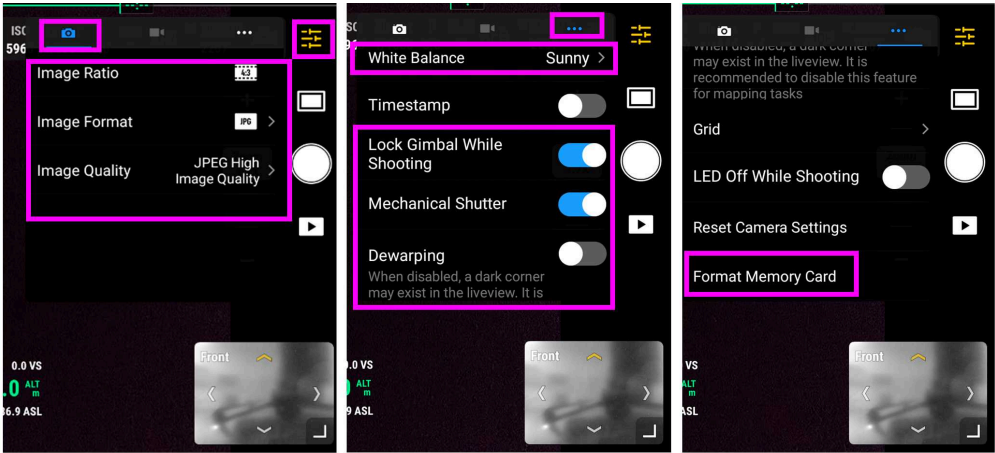
- 15.2 Update the camera settings as shown below

A	B
Setting	Parameter
ISO	AUTO
Shutter	1/1000

	A	B
	Aperture (F)	5.6
	Focus	AFC
	Camera Mode	M



- 15.3 Access and check the image and advanced settings are as shown below. Select the three adjustment lines icon and the "... " icon to access the advanced settings.
- **White balance:** Either Sunny or Cloudy should be selected based on the sky conditions. Do not leave this as auto or there may be inconsistent colour balances between images.



	A	B	C
		Settings	Parameter
	Image Settings	Image Ratio	4:3
		Image Format	JPG
		Image Quality	JPEG High Image Quality
	Advanced Settings	White Balance	Sunny or Cloudy
		Tiimestamp	Disable
		Lock Gimbal While Shooting	Enable
		Mechanical Shutter	Enable
		Dewarping	Disable

	A	B	C
	Code	Sky Condition	White Balance Setting
	0	Clear sky	Sunny
	1	Haze	Sunny
	2	Thin cirrus, sun not obscured	Sunny
	3	Thin cirrus, sun obscured	Sunny
	4	Scattered cumulus, sun not obscured	Sunny

	A	B	C
	5	Cumulus over most of sky, sun not obscured	Sunny
	6	Cumulus, sun obscured	Sunny
	7	Complete cumulus cover	Cloudy
	8	Stratus, sun obscured	Cloudy
	9	Drizzle	Cloudy

Citation

Assmann, J., Kerby, J., Cunliffe, A., Myers-Smith, I. (2018)
 . Vegetation monitoring using multispectral sensors .
 Journal of Unmanned Vehicle Systems.

<https://doi.org/10.1139/juvs-2018-0018>

LINK

- 15.4 **Format Memory Card:** ensure that any data has been backed up before formatting the SD card. It is recommended to use one SD card for a day of field work, swapping for a new SD card if one is filled to avoid deleting data. Back up data at the end of each day of fieldwork.



Field cheat sheet - DJI Mavic 3M mission settings

16

	A	B	C
	Parameter	Value	Note
	General Settings		
	Area Route	PlotID-YYYYMMDD-sensor-mAGL	e.g. NTAFIN0013-20250711-m3m-50mAGL
	Aircraft	M3E Series M3M RGB+MS	
	Ortho GSD	Default	
	Altitude Mode	Relative to Takeoff Point (ALT)	



A	B	C
Route Altitude (m)	Dependent on ecological feature	Pilot to assess (see ste 5)
Elevation Optimization	Enable	
Safe Takeoff Altitude (m)	20	Pilot to reassess on site.
Speed (m/s)	Default and maximum value	
Course Angle (°)	0	
Upon Completion	Return to Home	
Advanced Settings		
Target Surface to Takeoff Point (m)	0	Pilot to assess (see step 6)
Side Overlap Ratio (%)	80	
Frontal Overlap Ratio (%)	80	
Margin (m)	50	
Photo Mode	Timed Interval Shot	
Custom Camera Angle	Disable	
Rotue Start Point	-	Set to the farthest point from takeoff site.
Takeoff Speed	Default	
DJI Mavic 3M sensor settings		
ISO	AUTO	
Shutter	1/1000	
Aperture (F)	5.6	
Focus	M	
Camera Mode	M	
Image Ratio	4:3	
Image Format	JPG	
Image Quality	JPEG High Image Quality	

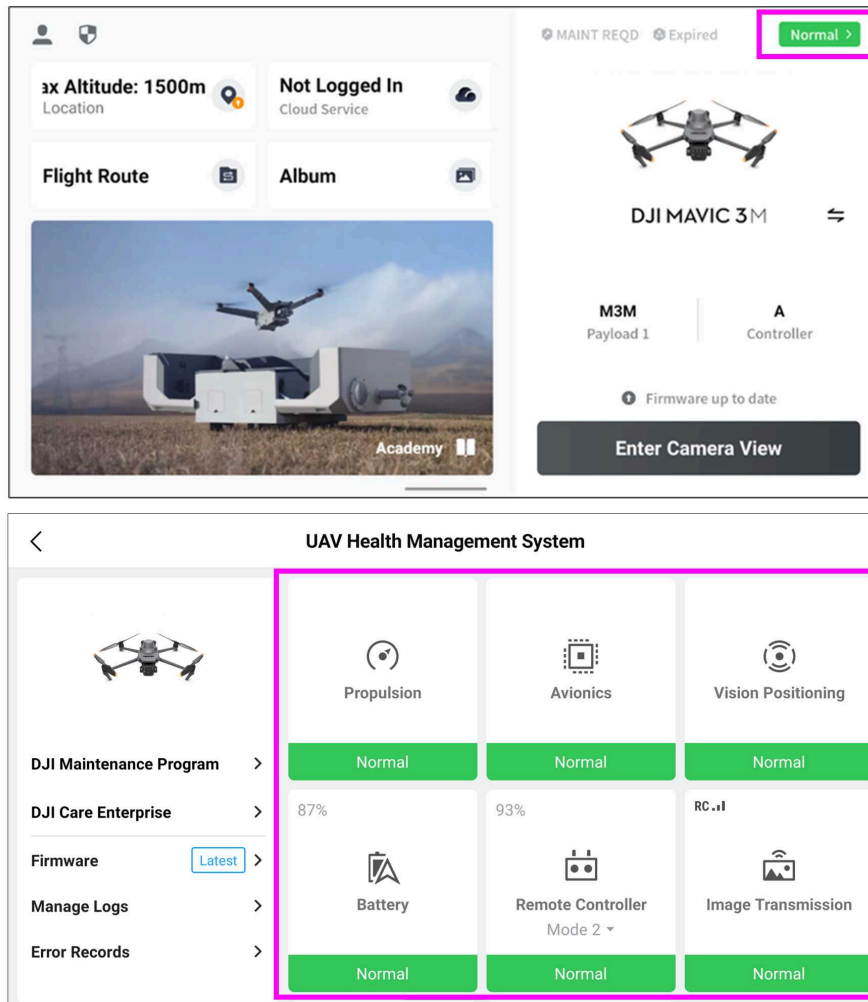
A	B	C
White Balance	Sunny or Cloudy	Refer to sky code table in step 15.3.
Timestamp	Disable	
Lock Gimbal While Shooting	Enable	
Mechanical Shutter	Enable	
Dewarping	Disable	

Flight mission and sensor settings for the Mavic 3M platform for use in the field.

Data collection - Flight before, during and after

17 Flight operational safety

1. Before takeoff, the pilot should complete one last check of the aircraft including resolving any warnings or errors in the UAV Health Management System.
2. Check that the remote controller and aircraft batteries have adequate charge for the flight.
3. Ensure the status LED on the remote controller and the battery level indicator on the drone are solid green – this indicates that the drone and controller are linked.
4. Before takeoff, review the flight area for obstacles and adjust the mapping mission accordingly to ensure the mission is safe.
5. Use a manual takeoff and landing to maintain control, particularly in areas with uneven terrain or obstructions.
6. Maintain constant communication between the pilot and spotter, particularly near roads or other potential hazards.
7. The UAV's speed, altitude and battery levels should be continuously monitored during the flight.



18 Takeoff, mapping mission and landing

Before takeoff, check the sky and weather conditions. It is best to align the flight with consistent lighting conditions for quality data collection.

- Sunny and clear skies or consistent cloud cover is ideal.
- If there are fast moving or patchy clouds, consider waiting for more consistent lighting conditions.
- Abrupt changes in light conditions (such as a cloud moving in front of the sun halfway through a mission) will impact data quality.





Examples of ideal and non-ideal lighting conditions for drone data collection. It is best practice to have consistent sky conditions for the duration of the flight, but this is not always possible due to logistics and time constraints.



Changing light conditions during a flight mission can have an impact on the data products. Shown above is the impact of a cloud moving in front of the sun during a mapping mission, highlighting the importance of uniform light conditions for data collection.

- 18.1
1. Use the controller to initiate a manual takeoff and navigate to a safe altitude.
 2. Perform a pre-flight check to ensure that the drone is functioning correctly:
 - Move the drone up and down.
 - Pivot the drone left and right.
 - Slide the drone forward, back, left and right.



18.2 Press the "Play" icon to start mission.



18.3 This will prompt a Preflight Check and Mapping Checklist. Review and ensure all flight mission setting are correct.

✕

Normal

HMS >

N mode

90% 16.7V

72%

Controller A

Set

RTK Connected

118.8G

⚠ Note: Make sure aircraft arms are completely unfolded. Ignore this message if aircraft arms are unfolded

RTH	(20~1500m)	-100	-10	50	+10	+100	Signal Lost Action	Return To Home
Altitude								
Max	(20~1500m)	-100	-10	100	+10	+100	Max Flight Distance	☐
Altitude								
Home Point							Control Stick Mode	Mode 2
Customize Battery Warning	Critically Low: 20% Low: 40%							
Obstacle Avoidance	Brake Avoid Off							
Horizontal Sensing			Brake: 1.0m		Alert: 16.0m			
Upward Sensing			Brake: 1.0m		Alert: 10.0m			

✕

90% 16.6V
RTK Connected
72%
118.75 G

3527 m Distance	13 m 26 s Est. Duration	34 Waypoints	2.31 cm/pixel Reconstruction GSD	396 times Payload 1 Photos
--	--	---------------------------------------	---	---

Safe Takeoff Altitude: -100 -10 20 +10 +100

Flight Route Complete Action: Return To Home ▼

Create Folder: NTAFIN0013-20250711-m3m-50mAGL

Dewarping: ☐

White Balance: Sunny ▼

Save Photo: DJI Mavic 3M - RGB+MS

Signal Lost Action: Return To Home ▼

Camera Mode: Auto S A **M**

Shutter: 1/1000 ▼

Back
Upload flight mission

18.4 Select “Upload flight mission” to start the automated mapping mission.

✕

90% 16.6V
RTK Connected
72%
118.75 G

3527 m Distance	13 m 26 s Est. Duration	34 Waypoints	2.31 cm/pixel Reconstruction GSD	396 times Payload 1 Photos
--	--	---------------------------------------	---	---

Safe Takeoff Altitude: -100 -10 20 +10 +100

Flight Route Complete Action: Return To Home ▼

Create Folder: NTAFIN0013-20250711-m3m-50mAGL

Dewarping: ☐

White Balance: Sunny ▼

Save Photo: DJI Mavic 3M - RGB+MS

Signal Lost Action: Return To Home ▼

Camera Mode: Auto S A **M**

Shutter: 1/1000 ▼

Back
Upload flight mission

18.5 During the flight:

1. Monitor the mission progress, ensure line-of-sight with the drone and follow all applicable airspace regulations.
2. Monitor battery levels. If the drone battery reaches 30%, pause the mission, manually land and swap batteries as required. The drone should be powered down completely

prior to a battery being changed. The mission can be resumed from breakpoint after a battery swap.

3. The spotter should monitor the surroundings for any obstacles, changes in weather or potential raptor encounters.



18.6 Metadata

Record the following flight and site environmental metadata:

1. Wind speed
2. Sky condition
3. Any changes in in sky condition or wind speed, noting at what percentage of the mission the change occurred (*e.g. at 70% of mission, a cloud moved in front of the sun changing light conditions*).
4. White Balance setting: if Sunny or Cloudy was selected.
5. If any flight parameters were altered from the mission settings suggested in RGB and multispectral mission settings.

- 18.7 At the end of the mission, manually land the drone.

19 Post flight

1. Check that all relevant metadata has been recorded, including changes in wind speed or light conditions.

2. After landing the drone, check the system for any signs of damage.
3. Turn off and pack down field equipment.
4. Charge any equipment as required at the end of day.
5. Follow any organisational requirements relating to:
 - Uploading flight logs and finalising job safety assessments for flight missions.
 - Inspection and servicing of equipment, including maintaining a log of any issues.

19.1 **Before turning off and packing down the DJI D-RTK 2 base station, ensure it has been logging for longer than 1 hour** if you intend to post-process the raw GNSS log to refine the base station coordinates for on-going monitoring. See Step 23 for further information.



Data backup and metadata scheme

20 It is important to back up the raw drone data, the D-RTK 2 GNSS log and all other relevant metadata as soon as possible, ideally at the end of day (or at the end of each day if collecting drone data as part of an extended trip). The following data backup workflow and flight metadata standards has been defined to enable the comparison of drone surveys through time.

The following data needs to be exported and backed up:

1. Raw data for the mission off the drone microSD
2. Flight mission KMZ from the controller
3. .DAT GNSS log from the D-RTK 2 base station antenna

Flight environmental conditions and site metadata

A .CSV file should be completed for the site to capture flight environmental conditions and site metadata including white balance setting, cloud cover, wind speed, base station location (and coordinates as required) and any additional comments (e.g. if drtk battery was changed or if light conditions changed during flight).

An example of this is shown below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
	Site	Sensor	Flight_height (m)	Flight_speed (m/s)	Forward_overlap %	Side_overlap %	Target_surface_take of f(	Margin(m)	White_balance	Terrain_follow	Cloudy	Wind	Base_station_established	Base_station_lat_WGS84	Base_station_long_WGS84	Ellipsoidal_height_WGS84	Comments

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
							m)										
	N T A F I N O 0 1 3	M 3 M	5 0	4. 4	80	80	0	5 0	Su nn y	No	Su nn y	No wi nd	N E pi ck et of A us Pl ot	N A	N A	N A	

21 Recommended directory structure for data and metadata backup

PlotID/ (Unique Plot ID)

└─ YYYYMMDD/ (Collection date in year-month-day format)

└─ drtk/

└─ .DAT

└─ m3m/

└─ xmAGL/

└─ level0_raw/

└─ metadata/

└─ SiteName_YYYYMMDD_sensor_xmAGL.csv

└─ SiteName_YYYYMMDD_sensor_xmAGL.kmz

└─ .jpg

22 Mavic 3M data

1. Remove the microSD card from the drone and insert into a SD card slot or use a SD card reader to view and export the mission folder containing JPG and TIF images.
2. If the battery was changed during the flight, there will be multiple mission folders – make sure to export all folders for the mission.
3. Export mission folder(s) into the level0_raw folder within the m3m directory.
4. Check the file size and quantity of JPG and TIF files is as expected. Shown below is the average data quantity and file count for the Mavic 3M at the 1 hectare scale for 50 and 100 metres above ground level with a 50 metre buffer around the flight area.

	A	B	C	D	E	F
	Area (ha)	Route altitude (m)	Data quantity (GB)	File number (total)	JPG files (count)	TIF files (Count)
	1	50	17.8	1990	397	1588
	1	100	5.29	594	118	472

Note: quantity and file number will vary if a Target Surface to Takeoff value is set.

The flight mission folder(s) will contain the following:

- JPG and TIF files
- A .NAV file, .OBS file, .BIN file and .MRK file which contain information about the positional accuracy, raw GNSS observations, binary GNSS data and camera trigger timestamps of the drone for subsequent processing.

Expected result

... 50mAGL > level0_raw > DJI_202409250949_001_20240925-NTAFIN0013-50mAGL

Name	Date modified	Type
DJI_202409250949_001_20240925-NTAFIN0013-50mAGL_PPKNAV.nav	25/09/2024 11:31 AM	NAV File
DJI_202409250949_001_20240925-NTAFIN0013-50mAGL_PPKOBS.obs	25/09/2024 11:31 AM	OBS File
DJI_202409250949_001_20240925-NTAFIN0013-50mAGL_PPKRAW.bin	25/09/2024 11:31 AM	BIN File
DJI_202409250949_001_20240925-NTAFIN0013-50mAGL_Timestamp.MRK	25/09/2024 11:29 AM	MRK File
DJI_20240925100729_0001_D.JPG	25/09/2024 11:07 AM	JPG File
DJI_20240925100729_0001_MS_G.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100729_0001_MS_NIR.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100729_0001_MS_R.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100729_0001_MS_RE.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100731_0002_D.JPG	25/09/2024 11:07 AM	JPG File
DJI_20240925100731_0002_MS_G.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100731_0002_MS_NIR.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100731_0002_MS_R.TIF	25/09/2024 11:07 AM	TIF File
DJI_20240925100731_0002_MS_RE.TIF	25/09/2024 11:07 AM	TIF File

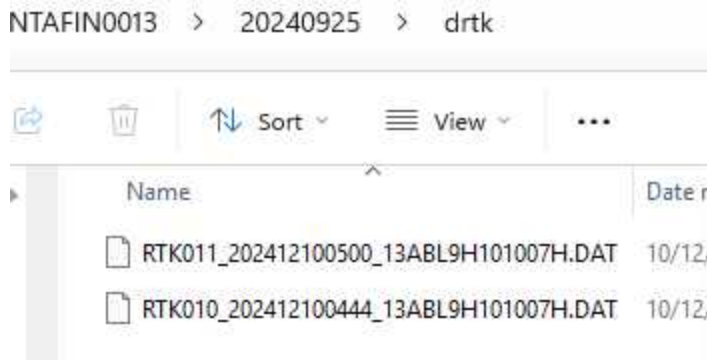
Expected files that will be present in the flight mission folder(s) following RGB and multispectral data collection.

23 DJI D-RTK 2 base station

1. Connect the D-RTK 2 base station antenna to the laptop and copy the raw GNSS data to the campaign drtk folder.
2. At a minimum, the relevant .DAT file from the rtmraw folder should be saved. This is the raw GNSS log that can be post-processed to refine the D-RTK 2 base station coordinates.

3. The .DAT file is in UTC time - if multiple flights have been completed in one day, it can be confusing determining which log belongs to which mission. To prevent confusion, it is recommended the time the D-RTK 2 base station is turned on and off is recorded for each site.

Expected result



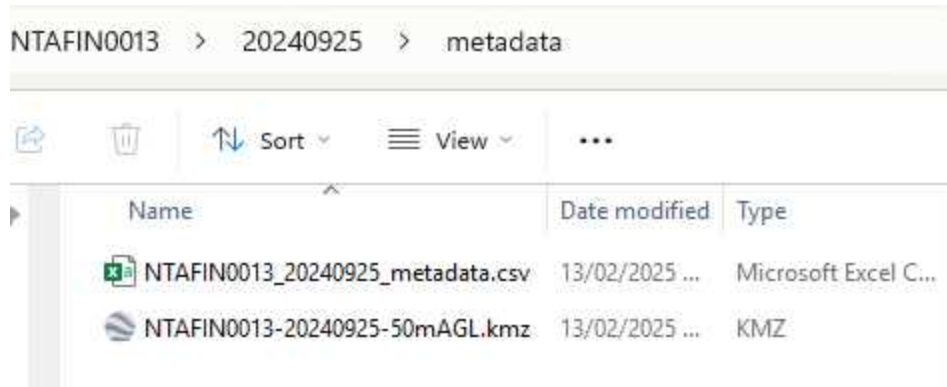
An example of the .DAT files that should be exported from the rtcraw folder of the D-RTK 2 antenna.

- The .DAT file can be post-processed using **AUSPOS** to refine the positional accuracy of the data during subsequent processing, and to derive highly accurate base station coordinates for on-going monitoring. Refer to the **TERN Drone RGB and Multispectral Data Processing Protocol** for steps on how to handle and process the .DAT file.

24 Metadata

1. Export the completed mission KMZ file from the Mavic 3M controller and save in the metadata folder.
2. Complete the site CSV file to record environmental conditions, base station location, and sensor and mission settings for the flight.
3. Save a photo of the base station set up for the site (if applicable).

Expected result



The metadata folder should contain a .CSV of flight mission settings and environmental conditions, and the completed flight mission KMZ exported off the Mavic 3M controller. This ensures that the same flight path can be used for future monitoring, and environmental conditions that may impact data quality are recorded.

25 Data management in the field

1. If data backup is occurring in the field onto an external SSD, it is recommended to copy all mission data and metadata to a second SSD.
 2. Once transferred, use a folder comparison tool to check that all data was backed up.
- We recommend using Solid State Drives (SSDs) for data backup, with original data cables and adequate data transfer speeds (above 500 mb/s).

Citation

26 If this protocol was used or helpful, please cite as:

Robbins, A., Montes-Herrera, J.C., Sparrow, B., & Lucieer, A. 2025. NatureScan: RGB and Multispectral Drone Data Collection for Ecological Monitoring. **protocols.io**
DOI: dx.doi.org/10.17504/protocols.io.3byl463q2go5/v1

Protocol references

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Figures

The images in the Target Surface to Takeoff Value figure in Step 6 are sourced from the University of Maryland Centre for Environmental Science Media Library: **Media Library | Integration and Application Network**

- Acacia spp. (Acacia): Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network (ian.umces.edu/media-library)
- Eucalyptus camaldulensis (River Red Gum): Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network (ian.umces.edu/media-library)
- Eucalyptus spp. (Eucalypt) 1: Lana Heydon, QLD Department of Environment and Resource Management (ian.umces.edu/media-library)
- Corymbia spp. (Ghost Gum): Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library)
- Lepironia articulata (Blue Rush): Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library)
- Spartina spp. (Salt Marsh Grass): Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library)
- Tecticornia flabelliformis (Bead Samphire): Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network (ian.umces.edu/media-library)
- Triodia spp. (Spinifex) - Dieter Tracey, Terrestrial Ecosystem Research Network Australia (ian.umces.edu/media-library)

Citations

Step 15.3

Assmann, J., Kerby, J., Cunliffe, A., Myers-Smith, I.. Vegetation monitoring using multispectral sensors
<https://doi.org/10.1139/juvs-2018-0018>



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The **NatureScan project** aims to advance biodiversity monitoring in Australia by leveraging consumer-grade drones, expertise in field ecology, artificial intelligence and advanced remote sensing techniques. All outcomes of the project will be made publicly available to lower the knowledge barrier for a cost-effective drone set up to encourage uptake of drones for ecosystem and biodiversity monitoring. This protocol establishes a standardised method for robust and quality data collection, which can be used to accurately represent ecosystem condition over time.

All screenshots in this protocol were generated using DJI Pilot 2 Version 14.1.0.45. The reader is advised that the authors have made their best efforts to ensure instructions are comprehensive enough to fulfil the tasks required to the standards required at the time of publication.

Photographs and figures are provided by the authors unless otherwise indicated.

Enquiries about this protocol should be direct to Alice Robbins: alice.robbsins@utas.edu.au