

Drone Data Collection Protocol using DJI Matrice 300 RTK: Imagery and Lidar

Authors: Poornima Sivanandam, Dr Darren Turner, Prof Arko Lucieer

Contact details:

poornima.sivanandam@utas.edu.au, darren.turner@utas.edu.au, arko.lucieer@utas.edu.au

Revision: 3.0

Date: 3 November 2022

Acknowledgements: TERN Landscapes team, TERN Surveillance team, Ben Sparrow, Ramesh Raja Segaran, Dillon Ross Campbell, Jacob Virtue, Bethany Melville, Kimberly McCallum, TERN Data Services

Contents

Abbreviations.....	1
Scope.....	2
Pre-field tasks.....	3
Firmware updates.....	3
Mission Planning.....	6
Automated KML generation.....	6
Existing TERN sites.....	6
New TERN site or site KML unavailable.....	7
Submit Job Safety Assessments.....	8
Equipment checks.....	8
Notes on Battery maintenance.....	9
Pack list.....	10
Weather.....	11
In the field.....	12
D-RTK2 base station setup.....	12
Adjust D-RTK2 base station coordinates.....	14
Prepare the aircraft.....	16
Compass calibration.....	18
RGB and multispectral Mission	19
Install P1 and MicaSense sensors.....	19
RGB and multispectral Mission settings.....	20
Zenmuse P1 Camera settings.....	24
MicaSense settings.....	26
Pre-flight: MicaSense Panel capture.....	28
Lidar Mission	31
Install L1 sensor.....	31
Lidar Mission Settings.....	32
RGB Camera Settings.....	36
Pre-flight.....	37
Lidar Missions.....	37
M300 aircraft checks.....	38
Aircraft take-off and landing.....	38
During the flight.....	39
Lidar missions: Known issue in Zenmuse L1 Firmware V04.00.01.06 (May 2022).....	39
Post-flight.....	40

MicaSense Panel capture (RGB and multispectral missions only).....	40
Record metadata	40
Check equipment	40
Data quality.....	41
Data backup	42
Post-campaign	43
Data management	43
Data transfer to TERN Data Services.....	43
Drone equipment and Compliance.....	44
To do list.....	45
References	46
Appendix 1: Pre-field checklist.....	47
Appendix 2: Pack list	48
Appendix 3A: RGB and multispectral mission: pre-flight task list.....	49
Appendix 3B: Lidar mission: pre-flight task list.....	53
Appendix 4: Pre-flight checklist	57
Appendix 5: Post-flight checklist.....	58

Abbreviations

CASA	Civil Aviation Safety Authority
CRP	Calibrated Reflectance Panel
DJI	SZ DJI Technology Co., Ltd.
DLS	Downwelling Light Sensor
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMS	Health Management System
RGB	Red, Green, Blue
ReOC	Remotely Piloted Aircraft Operator's Certificate
RTK	Real Time Kinematic
UAS	Unoccupied Aircraft System

Scope

This document describes the data collection protocol for the DJI Matrice 300 RTK (M300) aircraft. The protocol includes flight planning and data collection procedures to cover a 100 x 100 m (1 ha) area using RGB, multispectral and lidar sensors. Procedures include recommended settings for imagery and lidar missions:

1. **RGB and multispectral imagery** capture using M300 with two sensors simultaneously: DJI Zenmuse P1 RGB mapping camera and MicaSense RedEdge-MX/Dual multispectral sensor.
2. **Lidar mapping** using DJI Zenmuse L1 sensor on M300. The aim is to achieve consistent and robust data collection of vegetation structure to facilitate ecosystem monitoring.

Georeferencing is done using the DJI D-RTK2 base station and onboard GNSS RTK (see M300 Data Processing protocol), and as a result, the use of Ground Control Points (GCPs) is not covered here. Approvals and procedures for UAS operations and compliance as per CASA regulations are outside the scope of this document. It is recommended to have two pilots qualified to fly the M300 on these missions. The protocol is best used with two staff: a pilot and a spotter. Suggested responsibilities for these roles are articulated in the task lists in Appendices 3A and 3B.

Pre-field tasks

Firmware updates

It is essential that the firmware is updated before departing for field work.

1. On the remote controller, open the DJI Pilot app. On the main screen of the app, press on the status displayed on the top-right to bring up the UAV Health Management System (HMS) (Figure 1).
2. Any available firmware updates will be indicated next to 'Firmware'. Press 'Update' (Figure 1) and follow on-screen instructions to complete installation.

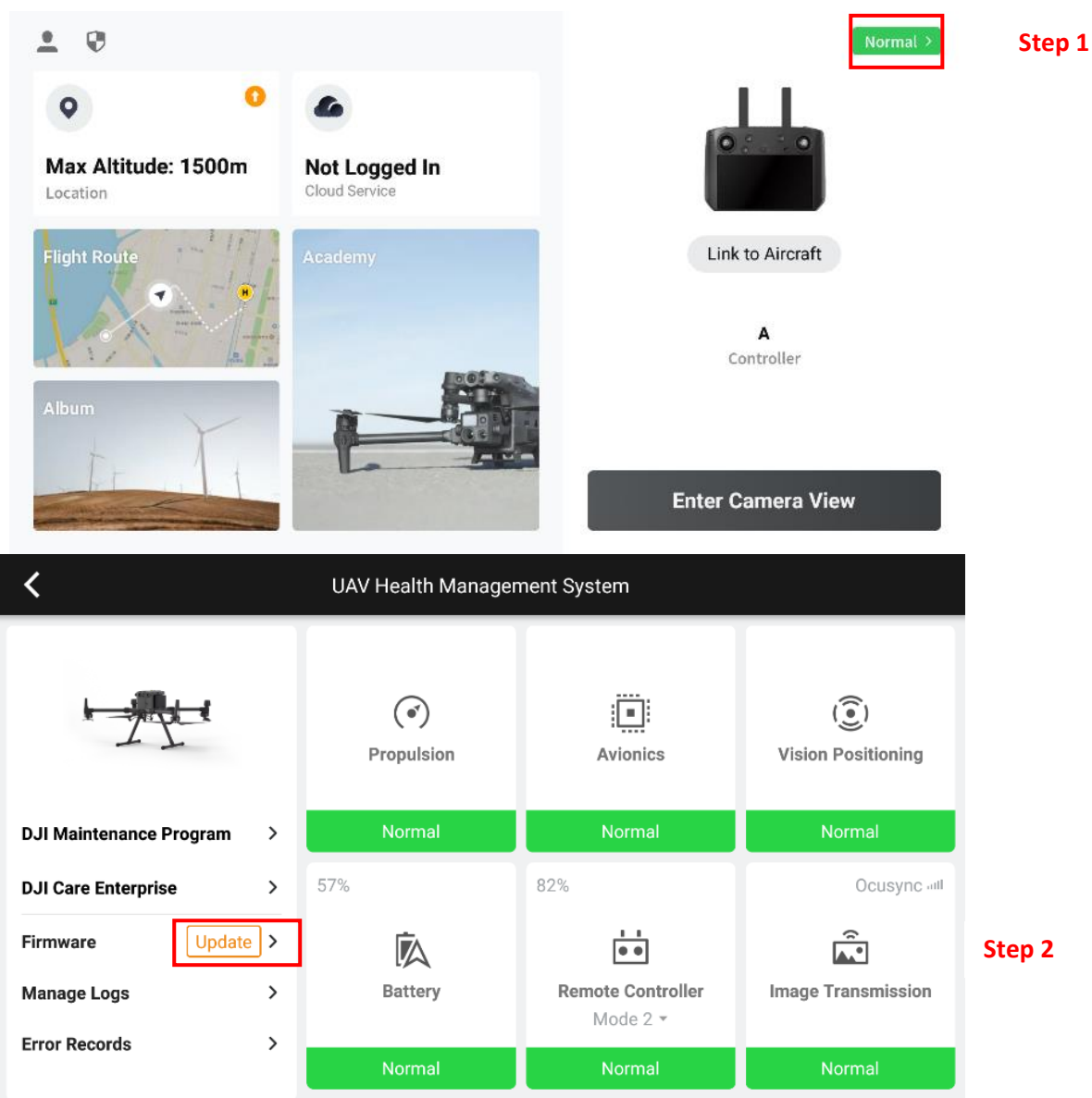


Figure 1: Access the UAV Health Management System to check for firmware updates to M300 equipment. Press 'Update' next to firmware to install firmware.

3. **Sensors:** To check for and install firmware updates to the DJI sensors, connect DJI Zenmuse P1 on Gimbal 1, and repeat the previous step. Repeat for DJI Zenmuse L1 sensor.

4. **Battery station/Batteries:**
 - Follow the steps used to charge the batteries: place the batteries in the battery station, connect the battery station to power and turn it on.
 - Connect the remote controller to the battery station using the USB-C cord.
 - Launch DJI Pilot2 app and follow on-screen prompts to start firmware update for the battery station and batteries.
 - Monitor progress using the app (Figure 2). Note that the battery station will stop charging while firmware update is in progress.
5. Check for MicaSense sensor firmware updates on the [MicaSense](#) website. Follow instructions provided on the website to download and install firmware updates.
6. Once all the firmware has been updated **flight and sensor settings must be checked**. It is necessary to check settings after any upgrades as default settings may change. Inspect all mission and sensor settings and update as required to ensure settings are as specified in the following sections.
7. Following any firmware updates, conduct a trial flight before packing equipment for the field trip.

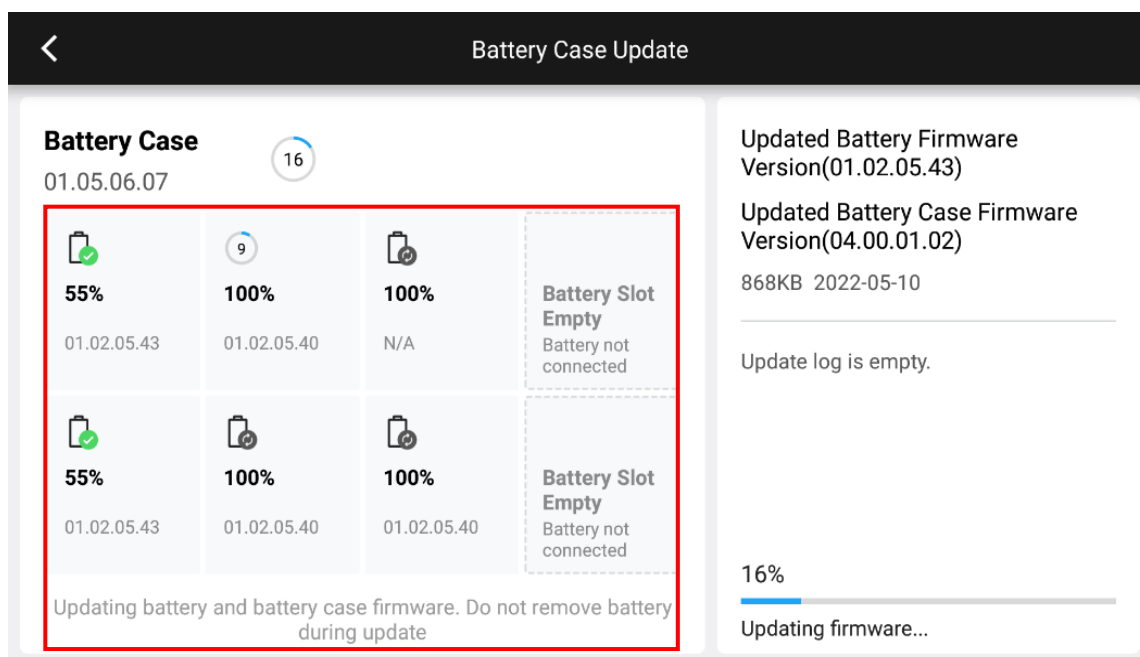


Figure 2: Connect the remote controller to the battery station to update firmware for the battery station and all the M300 batteries.

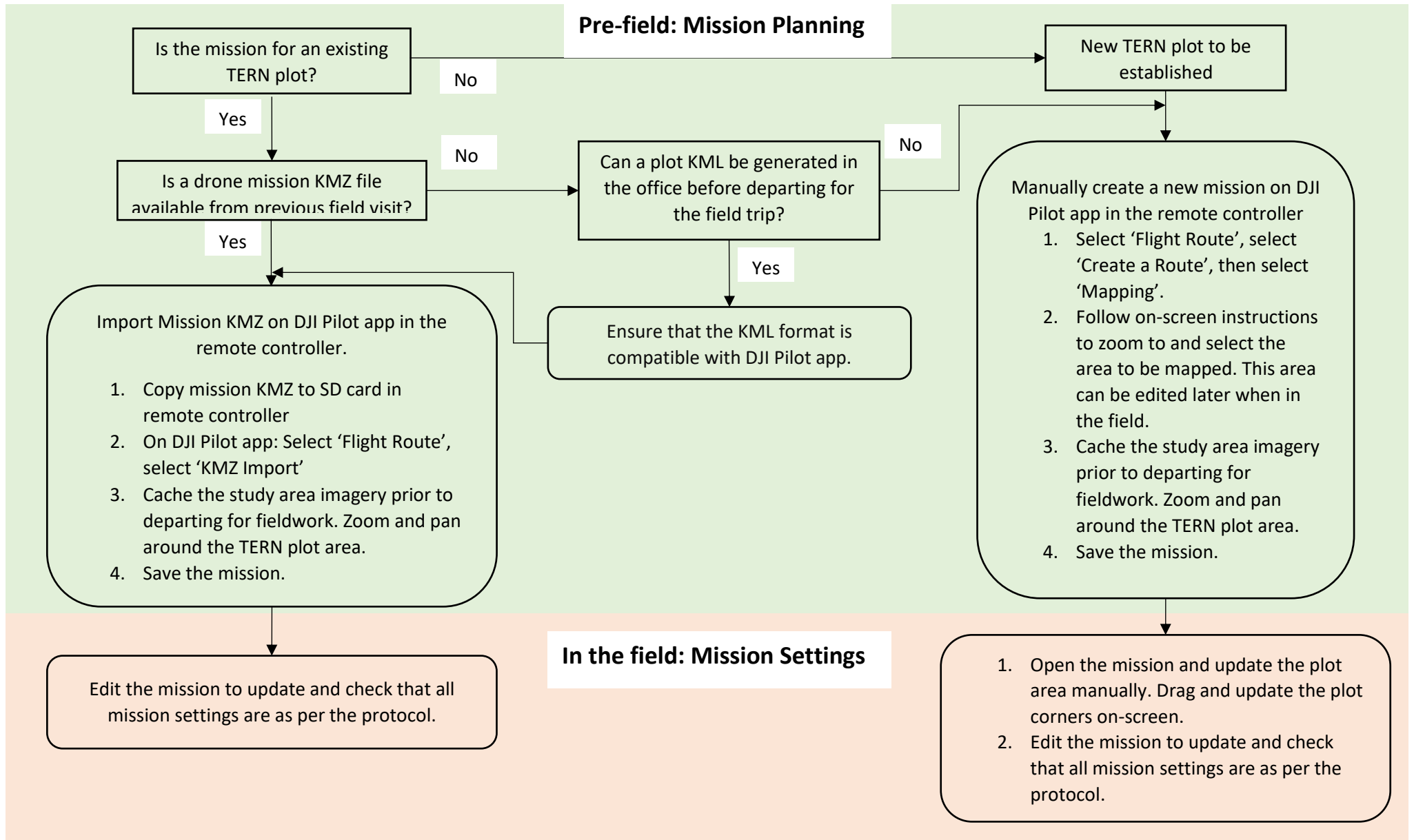


Figure 3: Suggested Mission Planning workflow prior to departing for fieldwork and when in the field.

Mission Planning

Automated KML generation

To create KMLs from existing TERN 1 ha plot corner coordinates, refer to TERN Surveillance documentation. Ensure that the KML format is compatible with DJI Pilot app requirements (Figure 3).

Existing TERN sites

If a site KML is unavailable, follow steps listed in 'New TERN site or site KML unavailable' instead. For existing TERN plots where a site KML is available, complete the following steps to import or create a flight mission. KML files must be imported on the remote controller prior to departing for field work. This is important to ensure that the KML format is compatible with the DJI Pilot app.

1. On the DJI Pilot app (Figure 4) select 'Flight Route'.
2. Select 'KMZ Import' to import the KMZ file.
3. Choose Storage (Internal Storage or external SD card) and select the KMZ file to be imported.
4. The imported mission will appear on the DJI Pilot interface. Open the mission and **cache study area imagery** (Figure 5). Imagery is cached by zooming and panning around the TERN plot area. It is important to wait for the imagery to be fully loaded. Repeat this step on any other tablet to be used for in the field. **It is essential that this step is performed in the office prior to departing for fieldwork.** If the study site imagery is not cached, background imagery of the plots will not be available on DJI Pilot during drone data collection in the field.
5. Check the flight settings in the mission and ensure that appropriate settings have been applied (see RGB and multispectral Mission settings).
6. For non-standard plots, (e.g., covering 2 plots located in close proximity), the mapping area may need to be manually edited using the remote controller screen.
7. If the KML that was imported is from a previous flight mission, mission settings would also be imported. Otherwise, the mission settings would be set to the default values. In either case:
 - a. Name the mission in the format 'TERNPlotName_YYYY'.
 - b. Update all flight and sensor settings as described in RGB and multispectral Mission settings.
8. Save the mission.

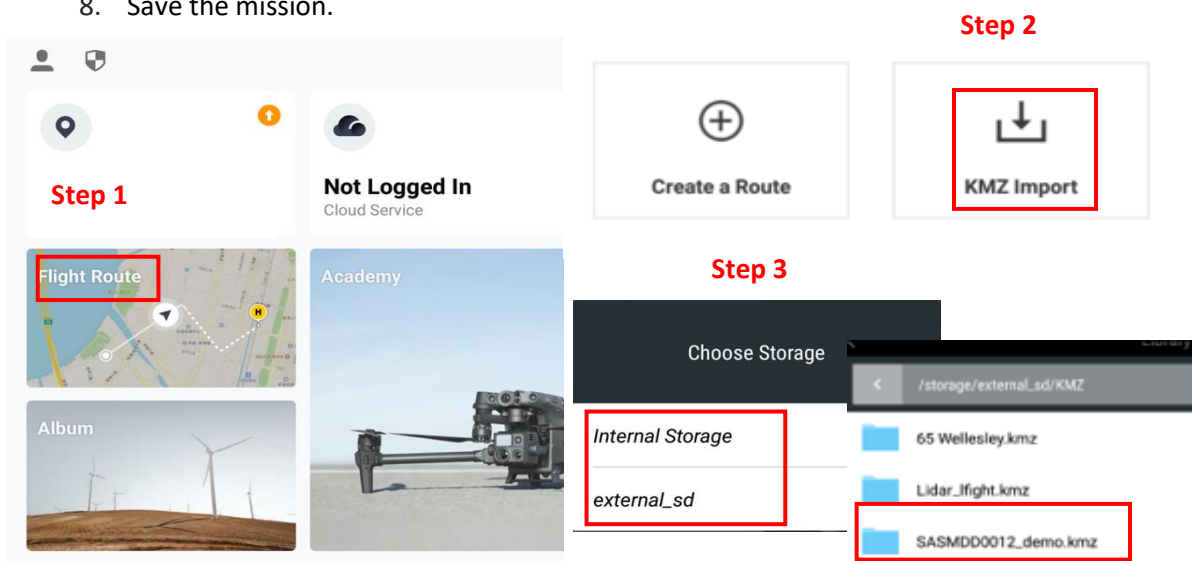


Figure 4: Access Flight Route on the main screen of DJI Pilot app to import KMZ file of TERN plot(s).

Step 4

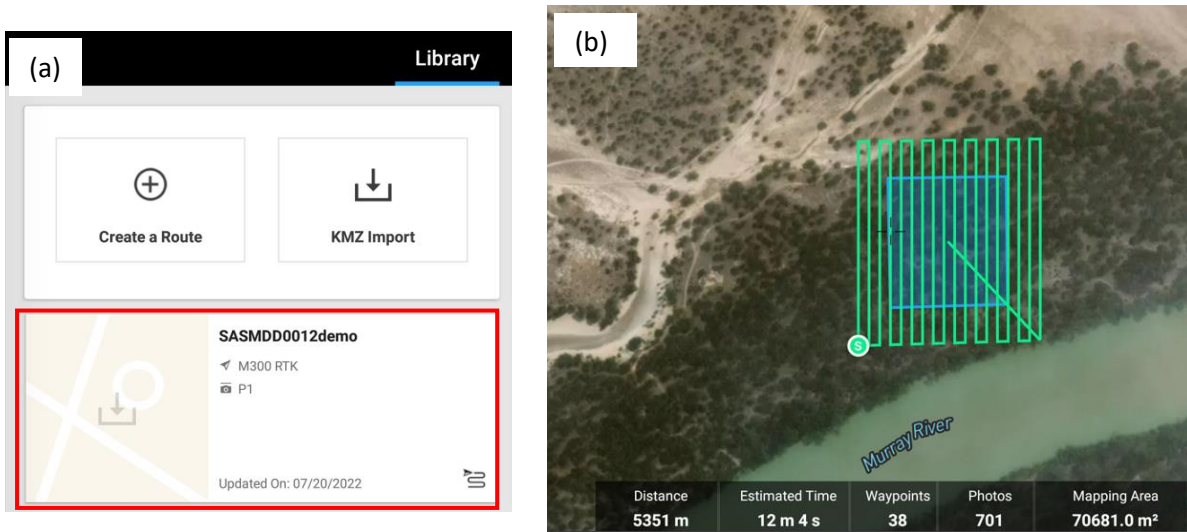


Figure 5: (a): The imported file appears in the list of missions. (b): Open the mission file and cache the study area map imagery. Zoom and pan around the TERN plot area (shown by the blue outline) and wait for the imagery to be fully loaded. Press the Save icon when done.

New TERN site or site KML unavailable

If a site KML is unavailable, manually create a new mission on DJI Pilot by completing the following steps:

1. Select '**Flight Route**' on the main screen. Then select 'Create a Route' and 'Mapping' (Figure 6).
2. Follow on-screen instructions to zoom to and select the area of TERN plot to be mapped.
3. Cache study area imagery as described in step 3 above.
4. Name the mission in the format 'TERNPlotName_YYYY'. Update all flight and sensor settings as described in RGB and multispectral Mission settings.
5. Save the mission.

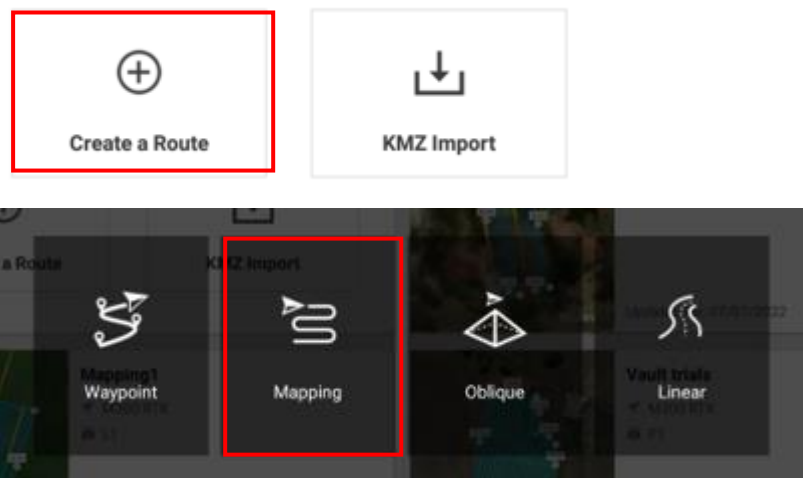


Figure 6: To manually create a mission on DJI Pilot, select Flight Route - 'Create a Route' – 'Mapping'. Follow on-screen instructions to zoom to and create the area to be mapped. Update mission settings as described later in this document. Cache study area map imagery as shown in the previous figure.

Submit Job Safety Assessments

Before drone surveys, flight missions must be assessed and approved by the Chief Remote Pilot. Follow organisation guidelines and contact the Chief Remote Pilot to submit Job Safety Assessments (JSAs).

Equipment checks

The following equipment checks must be undertaken before departing for field work and before conducting a flight.

1. Check the M300 airframe and propellers for any damage such as imperfections, cracks, etc.
2. Check that the dual gimbal mount is connected (Figure 7).
3. Inspect the gimbal dampeners and gimbal anti-drop rope for any cracks or damage. Replace if necessary.
4. Ensure that the Downwelling Light Sensor (DLS) is installed (Figure 7). Ensure that the cable is secured and unable to come in contact with the propellers.
5. Check M300 and DRTK-2 batteries for any damage (see Notes on Battery maintenance on following page).
6. Ensure that memory cards (P1/MicaSense: SD, L1: microSD) are formatted and installed on all sensors. **Note:** P1 and MicaSense SD cards are formatted differently and must be labelled so that they can be used appropriately (e.g., P1 A, P1 B, MICA A, etc.). If the plan is to maintain a set of memory cards for each TERN plot, include plot ID on Ziploc bag.
7. Charge the following equipment:
 - M300 batteries
 - DRTK-2 batteries
 - M300 remote controller – this refers to charging the M300 remote controller unit using the USB charger. This is in addition to charging the batteries used in the controller (same batteries that are used in the DRTK-2).
 - Tablet used for MicaSense sensor
8. Check that the following are installed on the field UAV laptop:
 - Format tool (e.g., [GUIFormat](#)): to format MicaSense SD card to FAT32. **Note:** Formatting is usually done through the MicaSense WiFi user interface. However, in case of issues with the SD card, the sensor will not be detected in the user interface and hence this alternate solution is necessary.
 - Folder comparison tool (e.g., [WinMerge](#)) to check data across SD card/SSD during data backup.
 - [DJI Assistant 2 \(Enterprise Series\)](#) app: useful to export flight logs in case of any errors.



Figure 7: Pre-field: check that the DLS is installed on the M300.

Notes on Battery maintenance

- Do not use batteries with any visible damage including swelling.
- Charge batteries using an approved Battery Station or charger.
- Only use paired batteries (M300 batteries are paired for redundancy. Label the batteries paired using DJI app).
- Store batteries at room temperature in a dry and ventilated place. Transport in a safe case, and do not leave batteries in vehicles except during transportation. Hence when leaving vehicles unattended during trips, arrangements will need to be made to leave UAV battery stations with collaborators, and to pick them up prior to the next trip.
- For detailed information on battery use and maintenance, please see the relevant equipment safety guidelines (DJI 2020).

Pack list

Prior to departing for field work it is recommended that Appendix 2: Pack list be used to check that all equipment is packed.

1. M300 case with the following:
 - a. M300 drone with DLS connected
 - b. Remote controller and charger
 - c. Spare propellers
 - d. MicaSense calibrated reflectance panel (CRP)
 - e. Tablet to be used for MicaSense user interface and charger
2. M300 battery charging station with the following:
 - a. M300 batteries (x8)
 - b. D-RTK2 batteries (x4)
 - c. Power cord
 - d. USB-C cable to connect to remote controller
3. D-RTK2 Mobile Station antenna, tripod, and extension rod.
4. P1 Sensor case with the sensor, SD card and spare SD cards.
5. RedEdge-MX/Dual case with the sensor, labelled MicaSense SD cards and spare SD cards.
6. For Lidar mapping: DJI Zenmuse L1 LiDAR sensor, microSD card and spare cards.
7. Sturdy rubber mat to launch/land drone (suggested minimum size 2 x 2 m to flatten vegetation and reduce dust)
8. DGPS unit
9. Star pickets, filing tool, battery-powered engraver, and flagging tape to mark the location of D-RTK2 base if site revisit is likely to occur in the future for monitoring purposes.
10. Laptop to be used in the field for data backup, format cards, etc.
11. SD and microSD card reader (dual SD card slots ideal to backup both P1 + RedEdge-MX cards at the same time.)
12. SSDs to backup data.
13. Case to secure and store memory cards. Ensure that all memory cards are labelled. If the plan is to maintain a set of SD cards for each TERN plot, labelled Ziploc bags for each plot.
14. Tool kit with spare parts: gimbal grommets, spare gimbal covers and lens caps, spare screws of types used; screwdrivers, cable ties. It is not appropriate to use power tools on drone equipment.
15. First aid kit with extra bandages/dressings.
16. DGPS unit
17. Radios and air band radio
18. Generator (if required to charge batteries in the field). Generators must have an inverter incorporated to them – this is identified as a “pure sine wave generator”. The Honda 2200i has been tested and works well and charges the batteries in a reasonable time and at least theoretically could charge two battery banks simultaneously (or batteries + run lights etc). It is worth using 15 A power cord to minimise voltage drop.

Weather

- Check local weather on [windy.com](https://www.windy.com) for wind and rain forecast (Figure 8). Prior to departing for field work in areas with unreliable or no internet connectivity, arrange a scheduled call procedure with a contact in the office to get a weather forecast update.
- Review conditions when aircraft is at target altitude (wind speed is likely to be higher).
- Preferred flight conditions are sunny and calm. Stable diffuse light under cloud cover is also fine but ensure the images are well exposed and fly slower to avoid motion blur. See RGB and multispectral Mission settings for recommended flight speed.
- Patchy cumulus clouds are acceptable if they are slow moving and hence unlikely to change the illumination conditions over the site during the acquisition period.
- **Note** that other type of clouds, especially high cirrus clouds, will significantly influence the radiometric quality of the collected data. Patchy cloud resulting in patches of shadow and sunspots are not suitable for imagery mapping missions (fine for lidar missions).
- Do not fly in the rain or in windy conditions with wind speeds over 30 km/h. Wind speed over 30 km/h on the ground will also compromise the quality of data due to moving canopies.

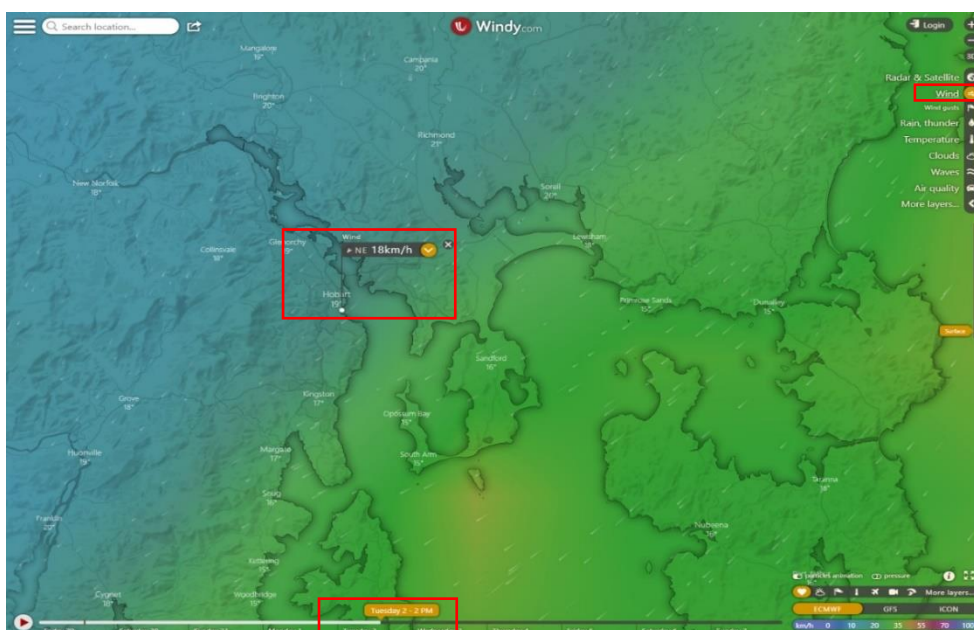
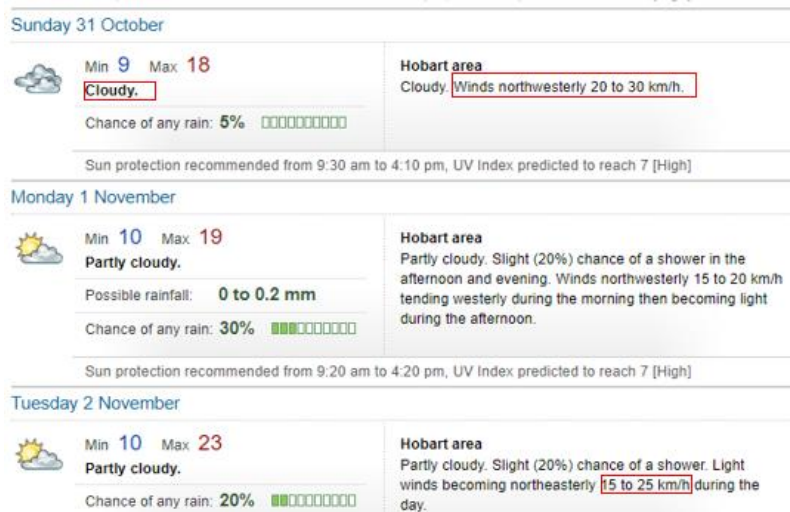


Figure 8: Check the local weather forecast for rain and wind conditions. Tag the study area on windy.com to check wind/rain forecast for the day of flight.

In the field

D-RTK2 base station setup

The dual frequency RTK GNSS in the M300 enables direct georeferencing of images. The D-RTK2 base station must be established at a plot corner easily accessible from the drone launch area. Note that the preference is to use the southwest star picket. The base station must be in an open area to prevent GNSS signals from being blocked.

Complete the following steps to establish the D-RTK2 base station:

- Carry pickets, tags, and battery-powered engraver or hand tool to file/mark the picket side where the base station was setup.
- If a drone survey was completed previously at this site refer to metadata for information on which plot corner was used, and how the tripod was set up at the star picket.
 - Note that the preference is to use the southwest star picket and position the D-RTK2 outside the plot.
- In plots where a picket cannot be left in place (e.g., national park), use a fixed and identifiable object in the terrain that is permanent and take a photo of the mark, and include that with a description in the metadata. (e.g., something that does not easily move or rot; for example, a large rock feature could be suitable).
- Move the top of star picket slightly to the side so that the antenna top of the D-RTK2 base station can be positioned on the outside corner of the star picket and levelled (Figure 10).
- Check the antenna bubble for levelling (not the tripod bubble).
- Take a photo of the base station and include this in the metadata folder with the raw data.
- Check that the battery in D-RTK2 antenna has adequate charge.
- Press and hold the Power button to power on the D-RTK2 antenna. Setup it to operate as a 'Mobile Base station (Broadcast Mode, M300 RTK)' which is Mode 5.
- Press the Mode button to change to Mode 5 (Figure 9). The indicator button will turn from green to yellow to indicate that the mode is being changed. The indicator will turn from yellow to green in a few seconds. **A blinking patten of 5 times indicates it is in Mode 5.** If the pattern is different, use the Mode button to switch modes.

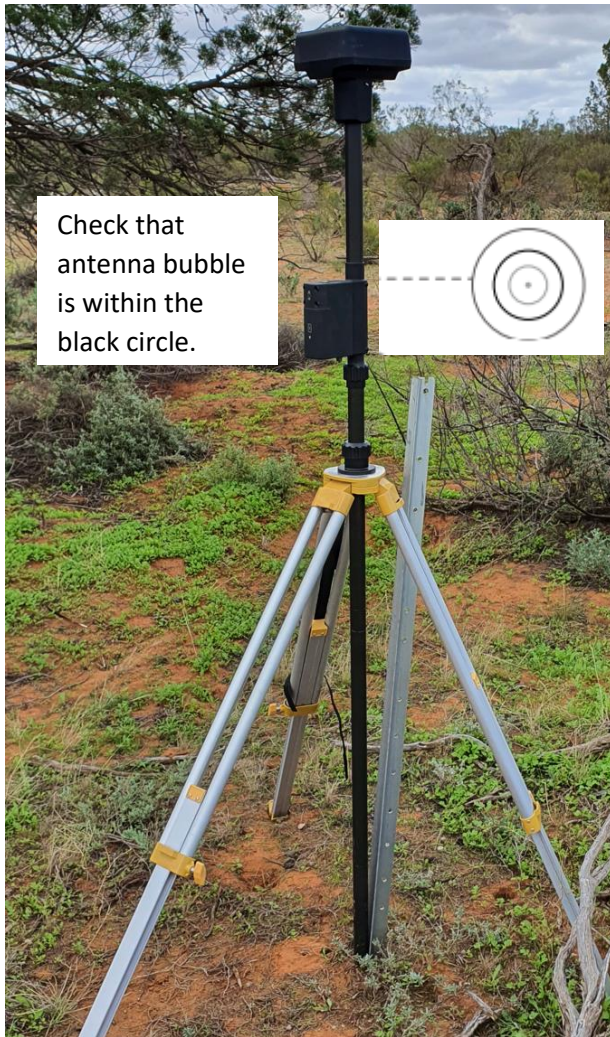


Figure 10: Setup D-RTK2 base station at plot corner easily accessible from drone launch area. Move the top of star picket slightly as shown so that the antenna can be positioned on the outside of the plot. Check the antenna bubble as shown for levelling.



Figure 9: Power up the antenna. Press the Mode button to operate in Mode 5 – indicated by a blinking pattern of 5 times.

Adjust D-RTK2 base station coordinates

1. Open the mission screen on DJI Pilot app on the remote controller. Press the '...' on the right-hand side of the main menu to access settings.
2. Select RTK and enable RTK Positioning using the toggle. Select RTK Service Type: D-RTK2 Mobile Station (Figure 11).
3. Select Advanced Settings (password: 123456) and enter the DGPS coordinates for the plot corner.
 - a. If Lat/Lon, and Altitude (at ground level) are available from DPGS: Enter Longitude and Latitude coordinates (8 decimal places). Under Altitude enter the value of the height at ground level collected from DGPS plus 1.8 m. The reason for the addition of 1.8 m to the height at ground level is that the Altitude value must include the rod height measured from ground to the phase center of the D-RTK2 antenna (which equals 1.8 m when using the extension rod that comes with the D-RTK2 base station). Hence the addition of 1.8 m.
 - b. If Lat/Lon are available but Altitude is not: Enter Longitude and Latitude coordinates (8 decimal places). Leave the Altitude value as it is. Do not update the Altitude value.

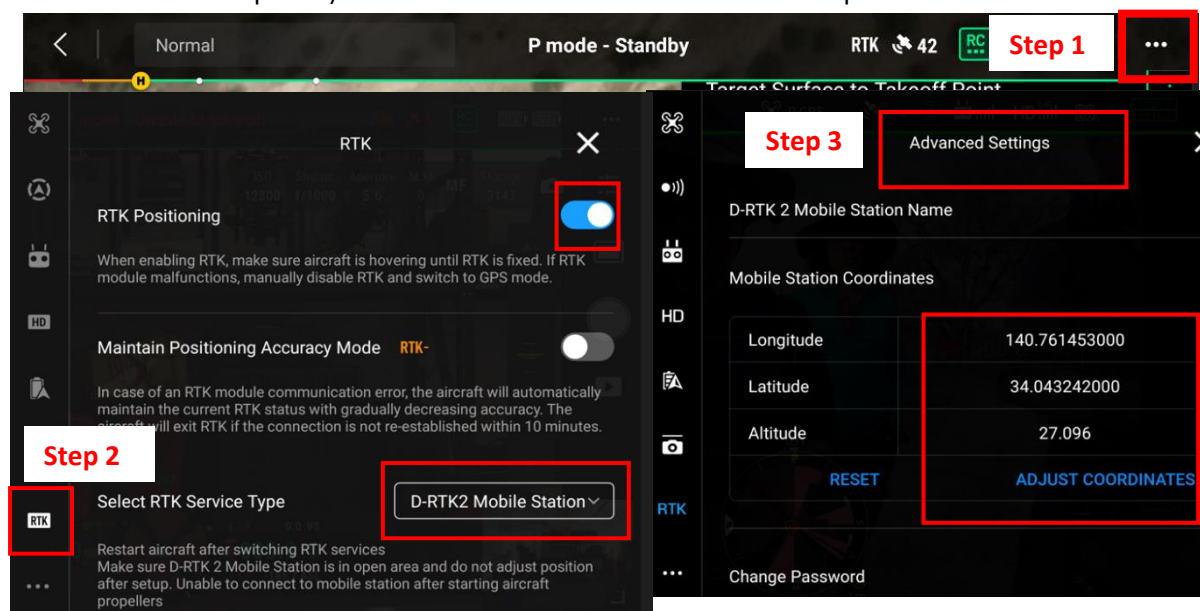


Figure 11: Enter DGPS coordinates for the plot corner following steps 1-3 as shown above. Enter the Longitude and Latitude of the plot corner. If Altitude at ground is available, enter ground height + 1.8 m. If Altitude value is unavailable, do not update it. Press Save when done.

4. Press Save and then restart the aircraft.
5. **Note:** If an error related to the RTK base station still appears on the mission screen after restarting the aircraft, press anywhere on the screen and the error should disappear. (If it does not, restart the base station and check that the coordinates are as entered in step 3. Restart the aircraft.)
6. Open RTK settings again (Figure 12). Check that:
 - a. D-RTK2 Mobile Station Status is connected.
 - b. Base station coordinates have been updated.
 - c. Aircraft Orientation and Positioning have status FIX.

	aircraft	Station
Orientation:	FIX	
Positioning:	FIX	
Latitude:	34.044785499	34.043242000
Longitude:	140.761593271	140.761453000
Ellipsoidal Height	105.559	27.096
Course Angle:	89.4	

Figure 12: After aircraft has been restarted, access RTK settings as shown in the previous figure. Check that the D-RTK2 base station coordinates have been updated. Check that Aircraft Orientation and Positioning have status FIX.

Prepare the aircraft

1. With the M300 still in the pelican case, **install landing gear** on the aircraft. Slide the gear lock to the end of the landing gear and rotate it until the dot matches the alignment mark. Be sure to align the dots and not overtighten (that could damage the landing gear).

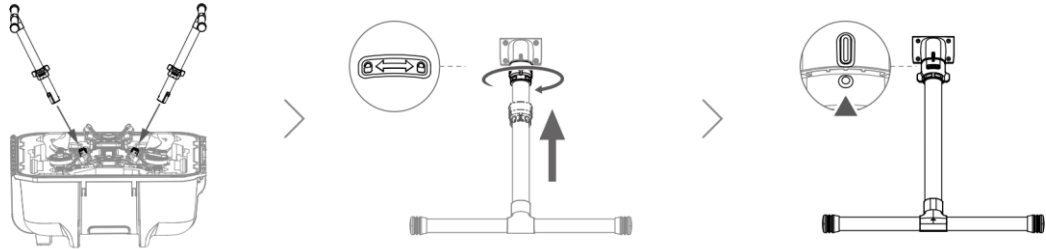


Figure 13: Install landing gear on the aircraft. Slide the lock to the end of the landing gear and rotate it until the dot matches the alignment mark (Image source: DJI 2022b)

2. Lift the drone using the landing gear and place the drone on the mat to be used for takeoff. **Remove both the propellor holders.**

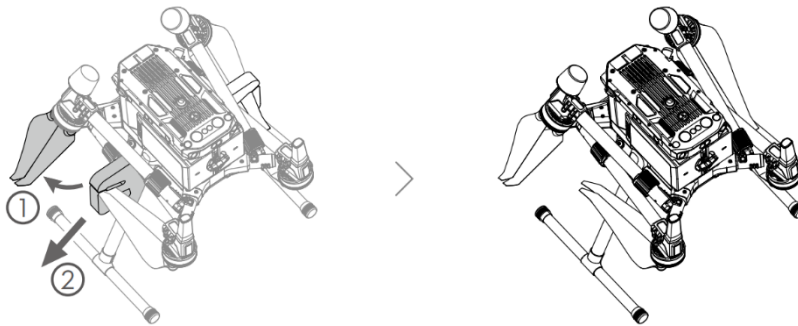


Figure 14: Use the landing gear to lift the aircraft from the case and place on launch mat. Remove both the propellor holders (Image source: DJI 2022b).

3. Unfold the frame arms on both sides.

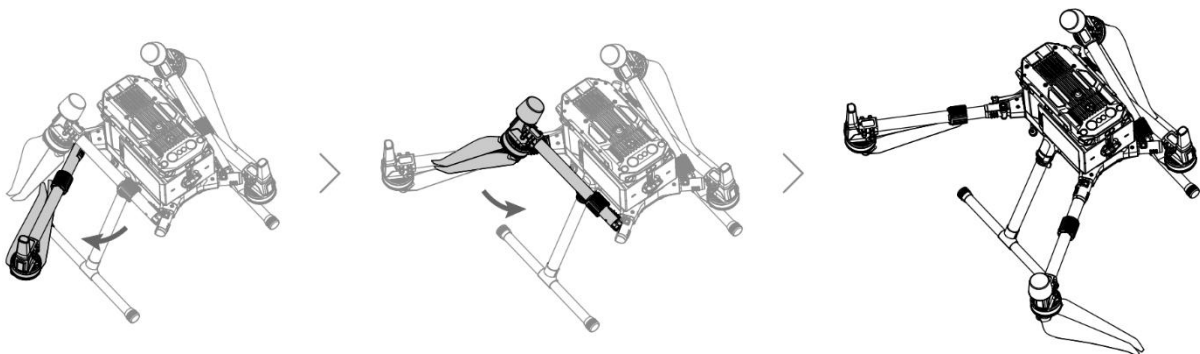


Figure 15: Unfold the frame arms as shown above. Repeat on the other side (Image source: DJI 2022b).

4. Lock the frame arms and unfold the propellers.

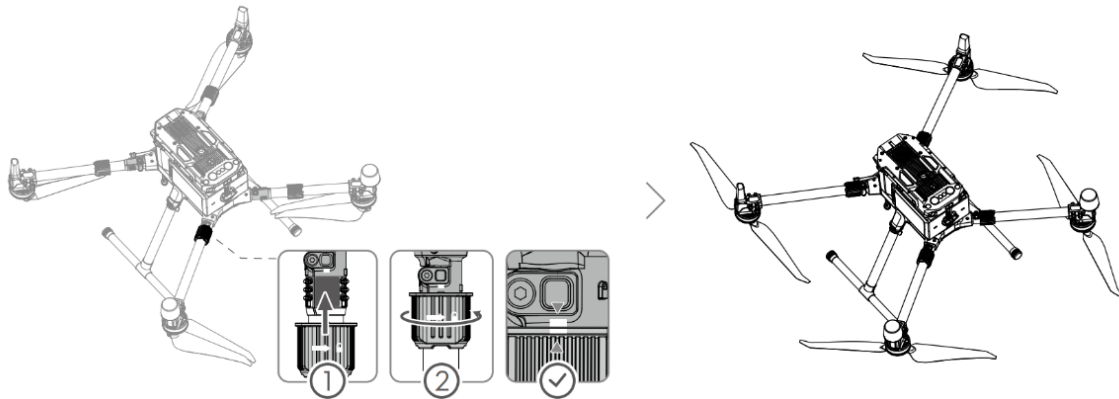


Figure 16: Lock the frame arms as shown in the inset above. Unfold the propellers. (Image source: DJI 2022b).

5. Install a pair of batteries (note which ones you are using). Press the battery level button once to check the level of charge.

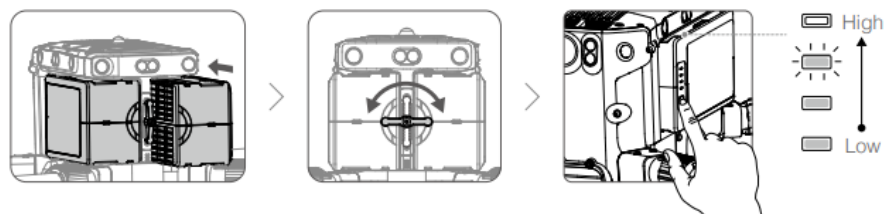


Figure 17: Install a pair of batteries and lock them in place as shown in the diagram above (Source: DJI 2022b).

6. **Turn on the aircraft and link to remote controller:** Press the power button on top of the aircraft, press and hold the button again. Press and hold the power button for at least five seconds to link aircraft and remote controller.

Compass calibration

Compass calibration must be performed at all sites following significant travel. It is recommended to do this step before the sensors are installed to avoid damaging the sensors or gimbal dampeners. To calibrate the compass, follow the steps below:

1. Click on the '...' on the right-hand side on the main screen
2. Click on the drone image in the following screen to access 'Flight Controller Settings'. Scroll down and select 'Sensor Status' (Figure 18).
3. Click on the Compass tab. Click on 'Calibrate Compass' and follow on-screen instructions to calibrate the compass. The process involves rotating the aircraft around the vertical and horizontal axes. As the aircraft is rotated, the earth's magnetic field appears to rotate while the aircraft field stays constant. This process thus provides a measurement of the aircraft's magnetic field at the location and aligns the aircraft flight system relative the magnetic north.

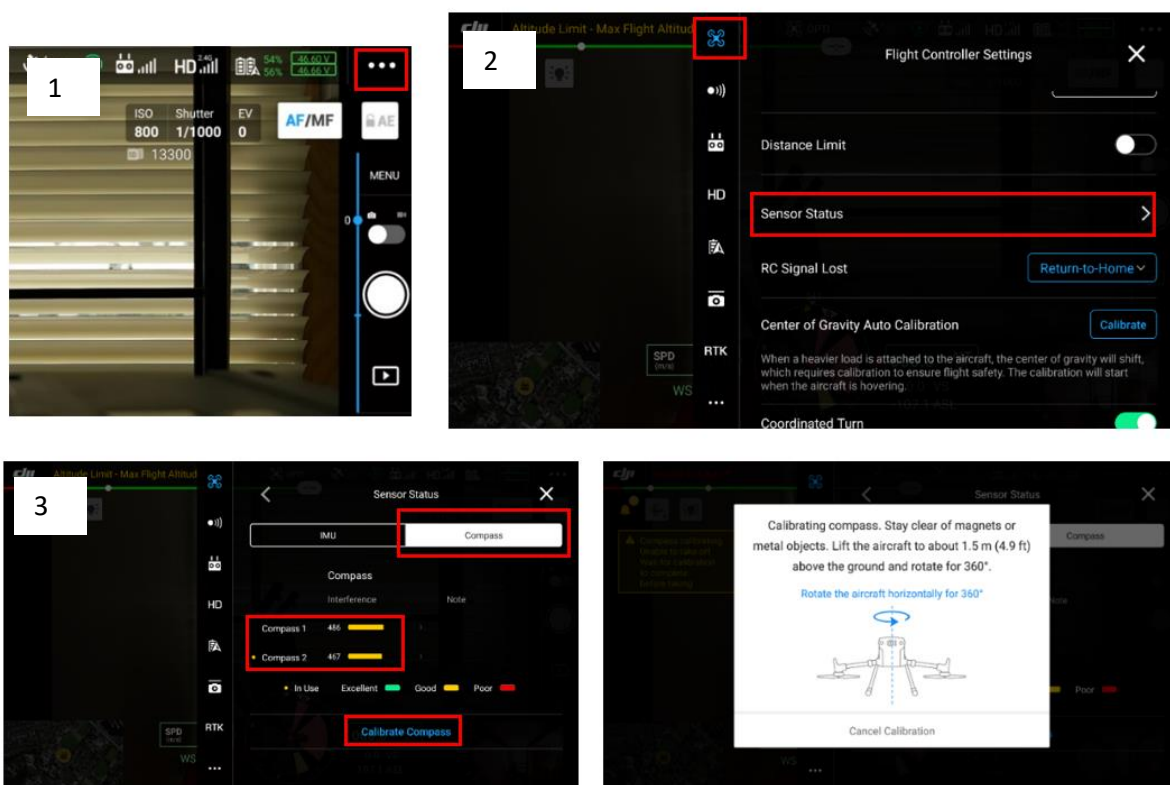


Figure 18: Compass calibration must be completed following significant travel. Follow steps 1-3 as shown above to access Flight Controller Settings – Sensor Status – Calibrate Compass. Then follow on-screen instructions to start calibration.

RGB and multispectral Mission

Install P1 and MicaSense sensors

1. Check that the P1 and MicaSense sensors have SD cards.
2. Connect P1 sensor on Gimbal 1 (Figure 19). Press the gimbal detachment button to remove the cover. Align the white and red dots and insert the P1 sensor. Rotate the gimbal lock to the locked position.
3. Repeat step to mount MicaSense sensor on Gimbal 2.
4. MicaSense: Connect the power cable. Connect Downwelling Light Sensor (DLS) to the DLS port (Figure 19(a)).
5. **Remove lens caps from all sensors.**
6. **Note: If the sensor does not fit in the gimbal socket check the connection inside the gimbal. Rotate the pin so that it aligns (Figure 19(b)).**

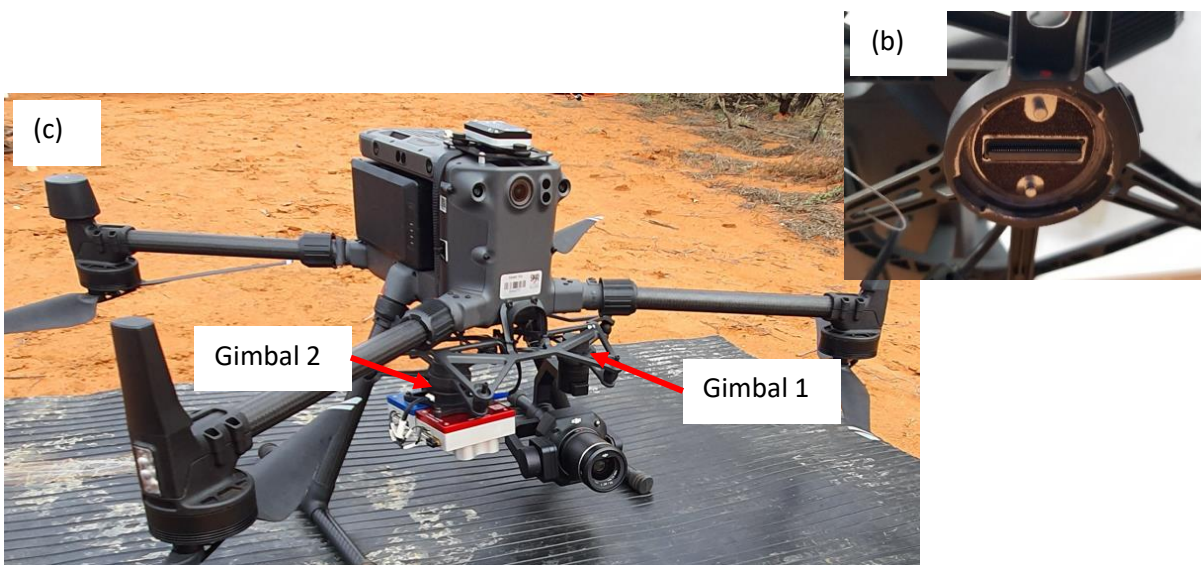
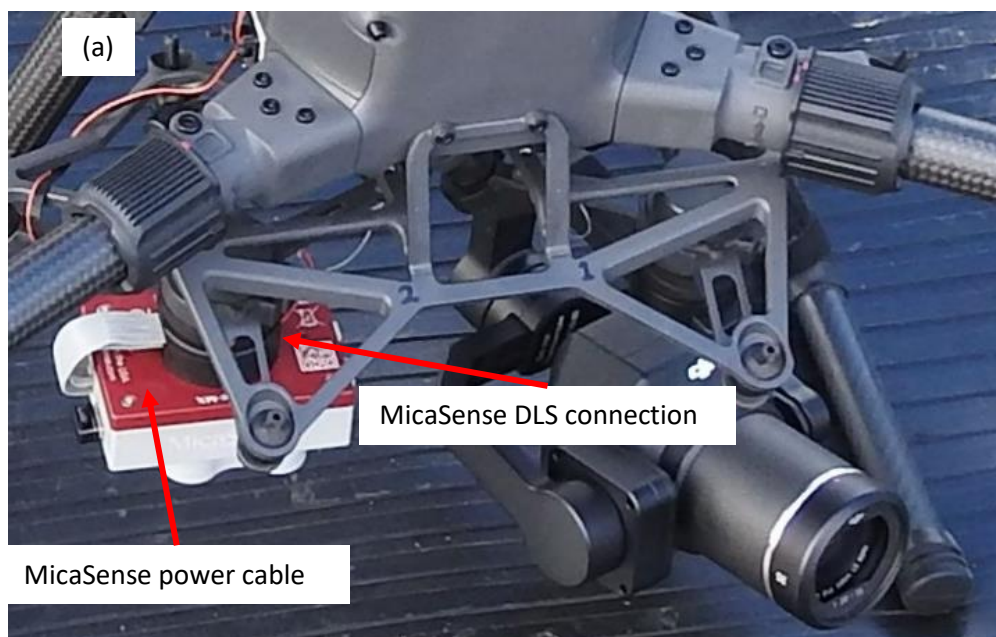


Figure 19: (a) Install P1 camera on Gimbal 1 and the MicaSense sensor on Gimbal 2 (RedEdge-MX sensor shown here). Connect the power cable and DLS on MicaSense sensor. (b) If the sensor does not fit in the gimbal socket, check the alignment of the socket, and rotate the pins. (c) shows M300 with P1 on Gimbal 1 and MicaSense RedEdge-MX Dual sensor on Gimbal 2.

RGB and multispectral Mission settings

Update or check the flight settings as per the following steps. See Figure 23 for a visual summary of all settings. Press the Edit icon (as highlighted in Figure 20) to update flight parameters.

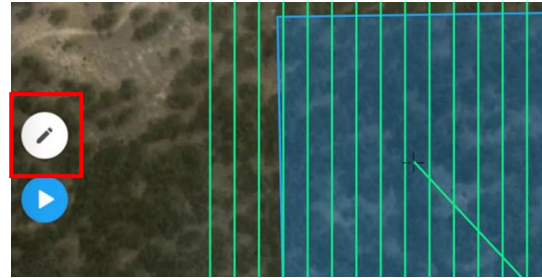


Figure 20: Edit the mission to update flight settings.

1. Expand the menu on the right to update the following settings

- a. Enter a name for the Mapping mission.
We recommend using the standard plot naming convention: E.g., PlotName_YYYY, for example, SASMDD0008_2022.
- b. Check that the area to be mapped (shown in blue polygon) is correct. Manually editing the plot outline might be required in new TERN plots established at the time of the drone mapping visit. To edit the area, drag and update the plot corners on-screen following instructions that appear on the remote controller screen.
- c. Select **Camera** -> **Zenmuse P1** -> **35 mm** lens which is the specification of the P1 camera that will be used for this mission.
- d. **Terrain Follow**: Disable.
This would be a useful feature in TERN plots where there is difference in terrain between site and takeoff area, or within site. In these scenarios there will be holes in the dataset which can be avoided using Terrain Follow. By importing a Digital Elevation Model (DEM) of the plot, the aircraft can follow differences terrain and ensure overlap requirements are met across the site. This feature is yet to be tested in TERN plots (see To do list).
- e. **ASL/ALT**: Relative to Takeoff Point (ALT). *With this setting the elevation is calculated from the takeoff point.*
- f. **Flight Route Altitude (m)**: 80.
The flight altitude affects the ground sample distance (GSD) or the distance on the ground covered in one pixel. With the P1 sensor specifications ($GSD = \text{pixel size} \times \text{flight height} / \text{focal length}$), a flight height of 80 m results in a GSD of 1 cm/pixel which is considered appropriate for the TERN missions. Note that in tall, forested sites to achieve the intended overlap at the top of canopies, the flight altitude and Target Surface to Takeoff Point (see below) must be increased. The settings are yet to be refined for these environments (see To do list).
- g. **Target Surface to Takeoff Point**: *Vegetation height and terrain complexity, as well as difference in terrain between plot and the drone takeoff area must be considered when setting a suitable target surface (Figure 21). This is essential to ensure that the overlap calculations are applied appropriately. When the terrain to map and the takeoff point differ in elevation, set this to the distance from the takeoff point to the target surface. **Note:** Flight settings in tall forests (> 30 m) and sites with steep terrain are yet to be tested (see To do list).*
 - In rangeland and grassland sites, use the default value of 0 when takeoff point is at same elevation as the site.
 - In forested environments, set this to the height of the representative crowns in the plot. See flowchart below (Figure 21 and Figure 22).

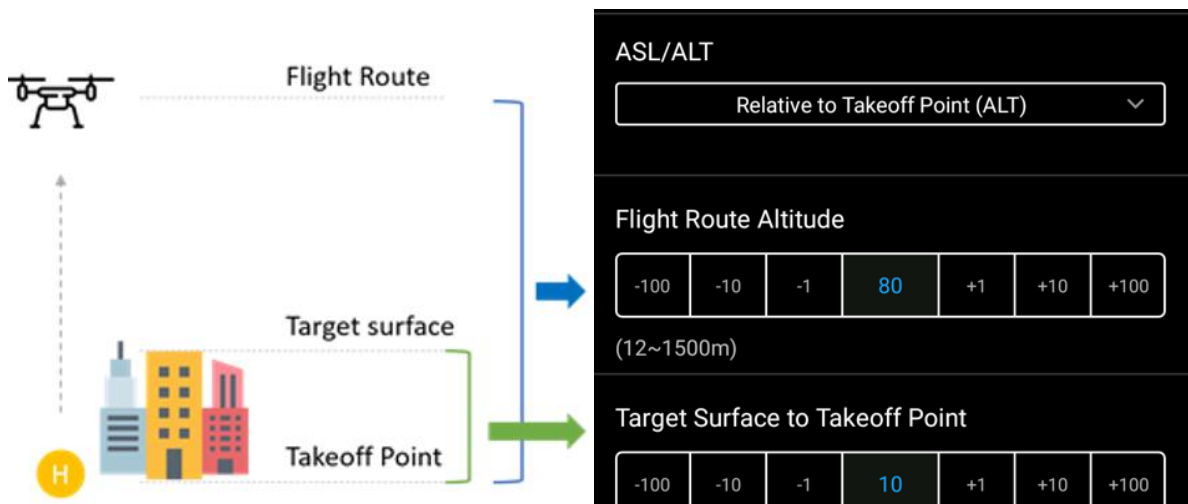


Figure 21: Target Surface to Takeoff Point must be set to ensure overlap calculations are applied to top of canopies. (Image source: DJI).

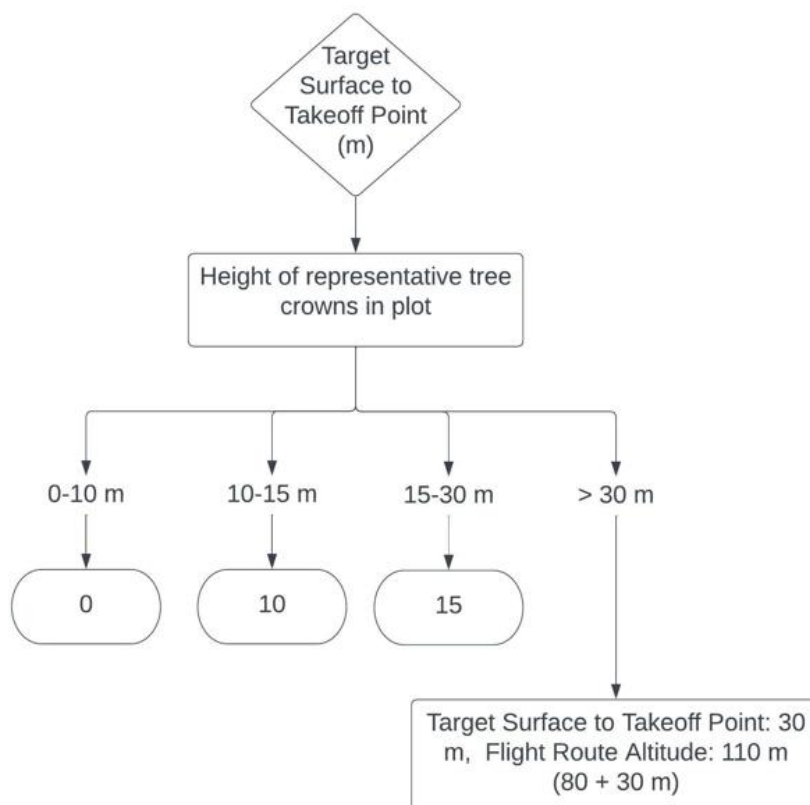


Figure 22: Consider the height of vegetation in the plot when setting Target Surface to Takeoff Point.

- h. **Takeoff Speed:** 15 m/s. This is the speed from the takeoff point to the first waypoint in the mission and can hence be faster than the flight speed.
- i. **Speed:** set this to be lower than the maximum possible speed for the mission. E.g., if the maximum is 10.8 m/s, set this to 10 m/s. The goal is to fly RGB and multispectral sensors simultaneously, the MicaSense trigger time (1 s) is slower than the P1 (0.7 s), which is why we do not recommend the default maximum speed for the mission.
- j. **Elevation Optimisation:** Enable. This is necessary to improve direct georeferencing accuracy. When enabled the aircraft will fly to the center of the flight area at the end of the survey mission and capture a series of oblique photos to improve elevation accuracy.

2. Under **Advanced Settings**, ensure the following have been set:

- a. **Side Overlap Ratio (%)**: 80. *Overlap between the flight lines.*
- b. **Frontal Overlap Ratio (%)**: 80. *Overlap along the flight line. The side and forward overlap ratios are important in the processing workflow where image matching is performed to align images based on matching points. Adequate overlap ratios ensure good image matching in the final orthomosaic data product.*
- c. **Course Angle**: 0. *North-South direction is chosen to minimise variation in reflectance data (BRDF effects) in multispectral data capture.*
- d. **Margin**: 50 m. *Includes a buffer around the flight area. It is suggested that the margin be set to 50 m to ensure a 200 x 200 m coverage in the orthomosaic. However, pilots can consider reducing the margin to 25 m for operational considerations (obstacles, proximity to roads, battery capacity, efficiency of multiple plots, etc).*
- e. Photo mode: default 'Timed interval shot'.

3. Under **Payload Settings**, ensure the following have been set (these should be the default settings):

- a. **Focus mode**: First Waypoint Autofocus recommended for mapping mission.
- b. **Dewarping**: Disabled. *Note that enabling dewarping to remove distortion in images requires P1 lens calibration. This process is yet to be tested. The default recommended setting is to disable Dewarping for images to be used to generate an orthomosaic. The auto calibration process in Agisoft Metashape is used to align imagery.*



Figure 23: Mission settings: Check and update all the settings. Note that the Flight Altitude and Target Surface to Takeoff Point must be updated for densely vegetated forest sites, and in sites with a large difference in terrain to ensure adequate overlap at top of canopy/high terrain. Speed must be set to a value slightly less than the maximum possible to ensure that P1 and MicaSense trigger at similar intervals. A margin of 50 m is recommended to ensure adequate coverage on the orthomosaic.

Zenmuse P1 Camera settings

When using any camera for data collection, ensuring the correct settings during image acquisition is an important step in the data collection workflow. Each camera has three main settings that can be independently controlled: aperture, shutter speed and ISO (sensitivity). Ensuring the correct combination of these settings is vital in reducing motion blur and exposure issues in the imagery.

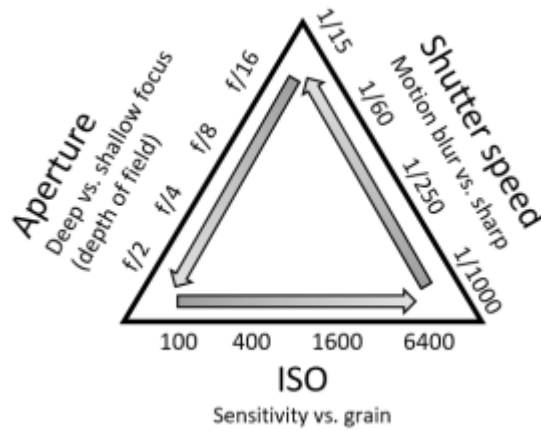


Figure 24: Exposure Triangle: relation between Aperture, Shutter speed and ISO.

Note that while the settings listed below must be checked initially, once set only the white balance needs to be changed based on site-specific illumination conditions.

1. The following steps outline the process of updating the camera settings as well as suggested values. Press the P1 camera view (highlighted in Figure 25) and update the camera settings as shown in Figure 26.

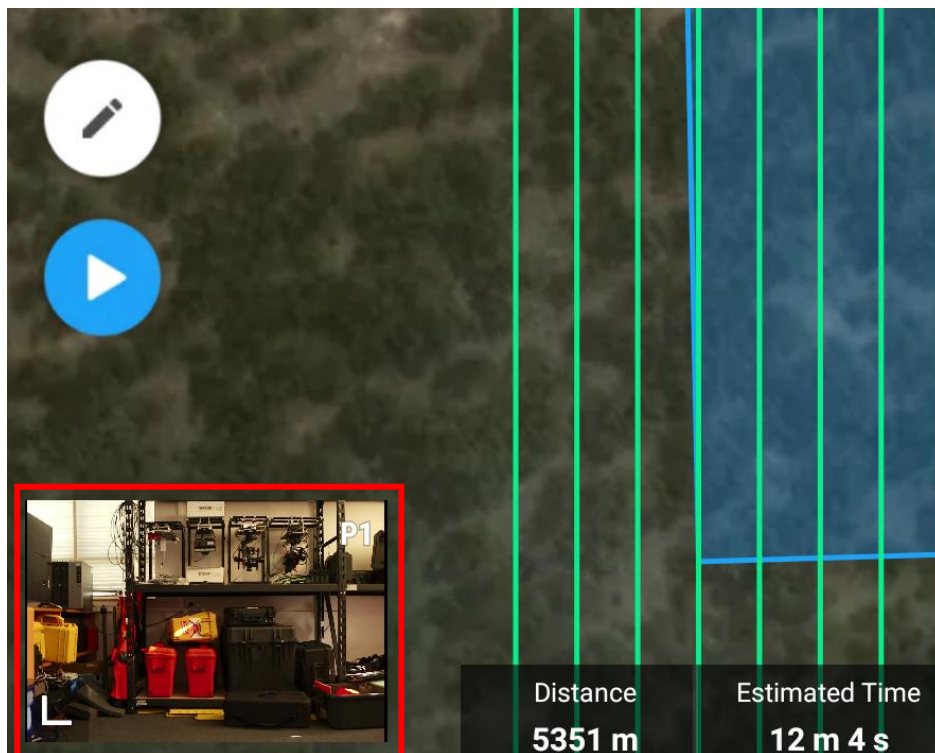


Figure 25: Press the 'P1' camera view and update camera settings.

2. Select **'M'** manual mode and select **Auto ISO**. The ISO will then be automatically set according to the surroundings. It is recommended to check this value during the flight to ensure it is as expected.
3. **Aperture:** f/5.6. *This is the size of the opening in the lens, controlling how much light it lets through to the camera sensor.*
4. **Shutter speed:** 1/1000 s. *This determines the length of time the camera shutter remains open when an image is being captured. Faster shutter speeds reduce the risk of motion blur but can also reduce the amount of radiation able to reach the sensor. This can lower the final radiometric quality of the data.*
7. Check that **Exposure Value (EV)** is 0. *This value is used to check if the imagery is over or under exposed.*
8. **White Balance:** Select the arrow next to 'White Balance' to edit it.
 - **Do not leave this setting as Auto otherwise you may get inconsistent colour balance between images.**
 - Note: select 'Sunny' when bright and overcast, and Cloudy only when dark and overcast.
9. Check that the defaults are unaltered for **Image Ratio (3:2)**, **Image Format (JPG)**.
10. Ensure the SD card has been backed up. Press Format SD card.
11. Save the mission.

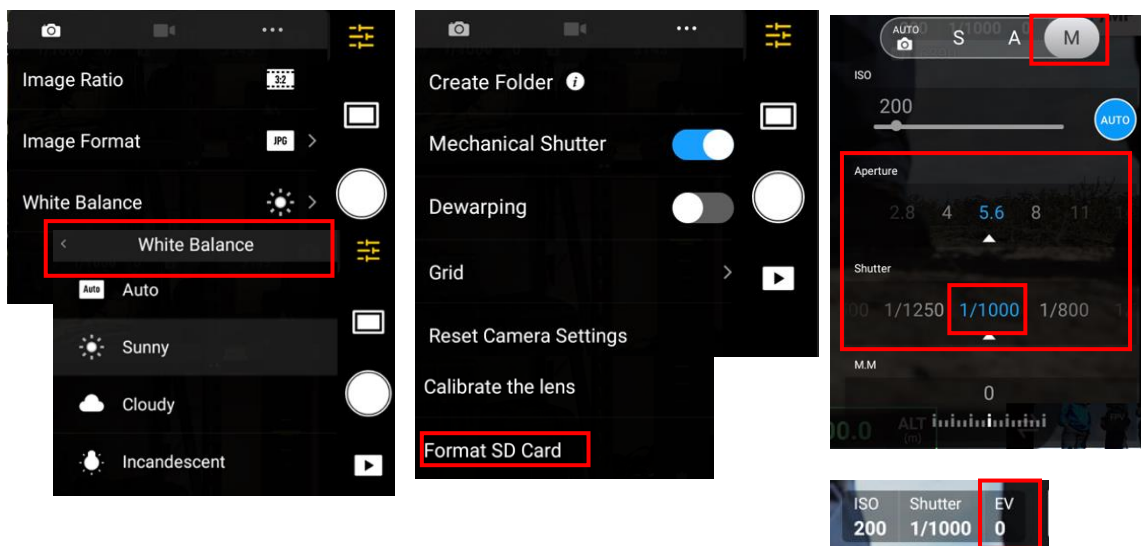


Figure 26: Update P1 camera settings as shown above. Note that while all settings must be checked to be as above, White Balance must be updated at each plot to either Sunny or Cloudy (when dark and overcast). Check that M mode, Auto ISO, Aperture f/5.6, Shutter speed 1/1000 s. Check that EV is 0. Format the SD card.

MicaSense settings

MicaSense settings must be updated/checked as follows:

1. Use the tablet to connect to the Micasense sensor WiFi hotspot (password: micasense). And access the camera's home page by typing or copying the device IP address 192.168.10.254 in the browser.
2. **Note on issues with MicaSense WiFi connection:** It can take a few moments to detect and connect to the sensor. Lowering the tablet or mobile phone closer to the MicaSense sensor has been found might reduce interference issues.
3. When there is an issue with MicaSense SD card, the sensor will not be detected in the user interface and so the SD card cannot be formatted through the interface. To overcome this, remove the SD card and reformat it to FAT32 using a laptop (e.g., use [GUIFormat](#)).
4. On the Home screen of the user interface (Figure 27), check that:
 - a. Downwelling Light Sensor (DLS) status is connected.
 - b. SD card is displayed under Storage. (Note that in Figure 27 two SD cards are displayed as the sensor used is MicaSense RedEdge-MX Dual. A single SD card would be displayed in the case of MicaSense RedEdge-MX.)
 - c. GPS is running and satellites are visible.

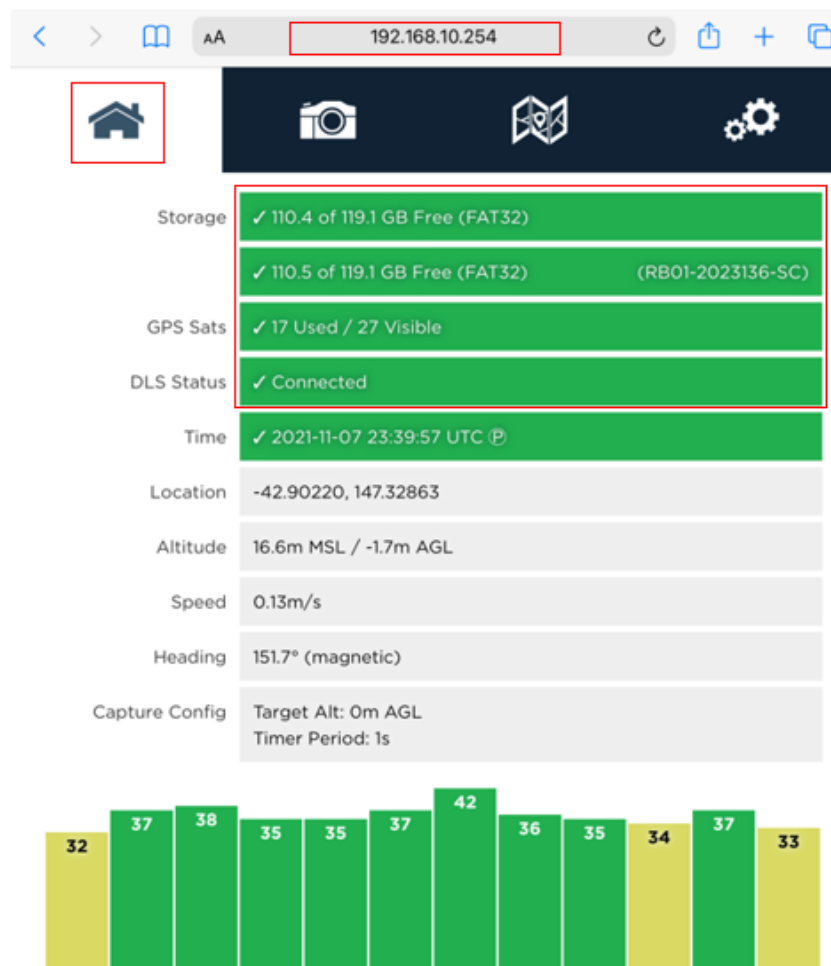


Figure 27: Connect to MicaSense sensor through the WiFi interface. Check that the DLS is connected and that GPS satellites are visible. In that this screenshot two SD cards rather than one are displayed under Storage as this is from MicaSense RedEdge-MX Dual sensor.

5. Format the SD card(s): Ensure that any data on the SD card(s) has been backed up. Select the Settings icon, under 'Storage and Firmware', select 'Reformat Storage'
6. Select the Settings icon and enter the following under 'Basic Configuration' (Figure 28):

The Timer mode, time period setting, and the flight speed ensure similar P1 and MicaSense trigger times which is necessary to co-register the multispectral images (georeferenced with navigation-grade accuracy) using P1 images that are accurately georeferenced using the onboard GNSS RTK. Target Alt and Tolerance ensure that capture begins when close to the flight height.

- a. Auto-Capture Mode: Timer
- b. Time period (sec): 1
- c. Target Alt (m): set to flight altitude e.g., 80
- d. Target Alt Tolerance (m): 20
- e. Manual Exposure: Do not Enable (button must not be checked). *Recommended by MicaSense, the ISO and exposure for each band is automatically optimised so that the image is properly exposed.*
- f. Press Save

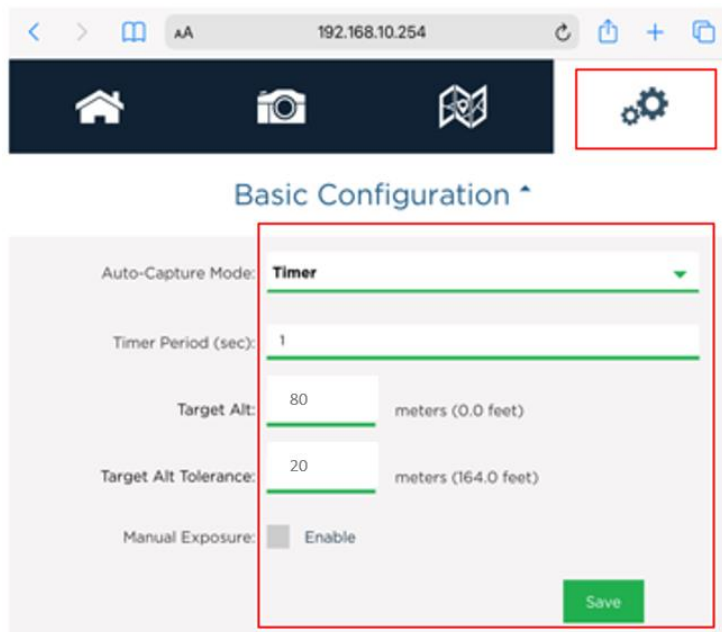


Figure 28: Under Basic Configuration in Settings: check that MicaSense capture mode is Timer, Time Period is 1 second. Target Altitude must be set to the flight altitude (Mission settings). Set Target Alt Tolerance to 20 m. Manual Exposure must be disabled. Press Save. **Not shown above:** Under 'Storage and Configuration', press 'Reformat storage' to format the card.

Pre-flight: MicaSense Panel capture

The MicaSense sensor includes a grey plastic box containing a QR code (used in processing software e.g., Agisoft Metashape) and a large white square which is the 'panel' that can be used to calibrate the reflectance values of the sensor (Figure 29). Reflectance panels are an important tool used to ensure the radiometric quality of datasets. The panel acts as a reference value in the calibration process, as it has a well characterised and documented reflectance profile across the spectral range captured by the sensor. By having a target with a known and expected spectral response, the processing workflow is able to compensate for different illumination conditions between image acquisitions. It is important to capture images that are representative of light conditions at the time of flight.

CRP care instructions from MicaSense

- The CRP is hence like a scientific instrument and must be handled with care. When in the field, MicaSense recommend only having the panel case open when panel images are being captured and keeping it closed at all other times.
- It is important to not touch the panel area with your bare hands, as dirt, oil, or grease on your hands may lead to degradation of the panel.
- MicaSense recommend that the panel be cleaned using a photo brush to lightly brush off any soil, dust, or dirt.



Figure 29: MicaSense sensors include a grey plastic box containing a QR code and a large white square which is the panel used to calibrate reflectance.

To make best use of the CRP, it is important to ensure the following:

- For both CRP and mission capture, if there is moving cloud cover, wait for a few minutes. The aim is to collect CRP that is representative of flight conditions.
- Capture images both before and after flight, and in the metadata indicate which set of images represent flight conditions. Also include information on cloud cover during the flight.

The Micasense sensors have a manual capture mode that can be used to collect pictures of the panels. Alternatively, the QR mode can be used for automatic panel detection. Use of one of these modes (rather than a normal capture mode that is used during the mission) is important to avoid over exposure of panel images (MicaSense 2020).

1. To capture images of the panels: On the MicaSense user interface select the camera icon (Figure 30). Leave the default setting at 'All Bands'.

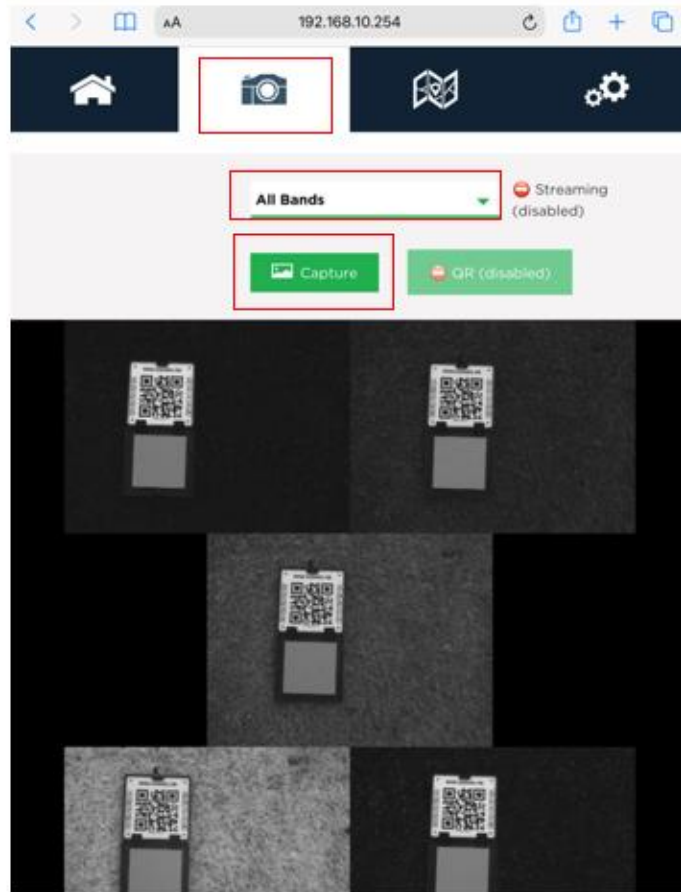


Figure 30: On the Camera page use the Capture button to capture images of the calibration panel in all bands. Check the images that appear on the screen; the panel must take up at least one third of the image. Capture three sets of images for redundancy.

2. Facing into the sun hold the UAS over the CRP. Ensure there are no shadows cast on the CRP or the DLS on the UAS (Figure 31). Avoid bright coloured clothing to mitigate any reflected light contamination.



Figure 31: MicaSense panel capture: ensure there are no shadows cast on the panel or the DLS on the drone.

3. Ensure that the panel takes up at least one third of the image width, and that the QR code and serial number label are visible in the image.
4. Press the **Capture** button to capture images of the panel. Images will be displayed on the screen (Figure 30).
5. Repeat these steps to capture three sets of images for redundancy.

Lidar Mission

This section describes mission settings for a lidar mapping mission using DJI Zenmuse L1 sensor on DJI Matrice 300 (M300) RTK UAS.

Install L1 sensor

- Check that the L1 has a microSD card installed.
- Connect L1 on Gimbal 1 (Figure 32). Press the gimbal detachment button to remove the cover. Align the white and red dots and insert the L1 sensor. Rotate the gimbal lock to the locked position.

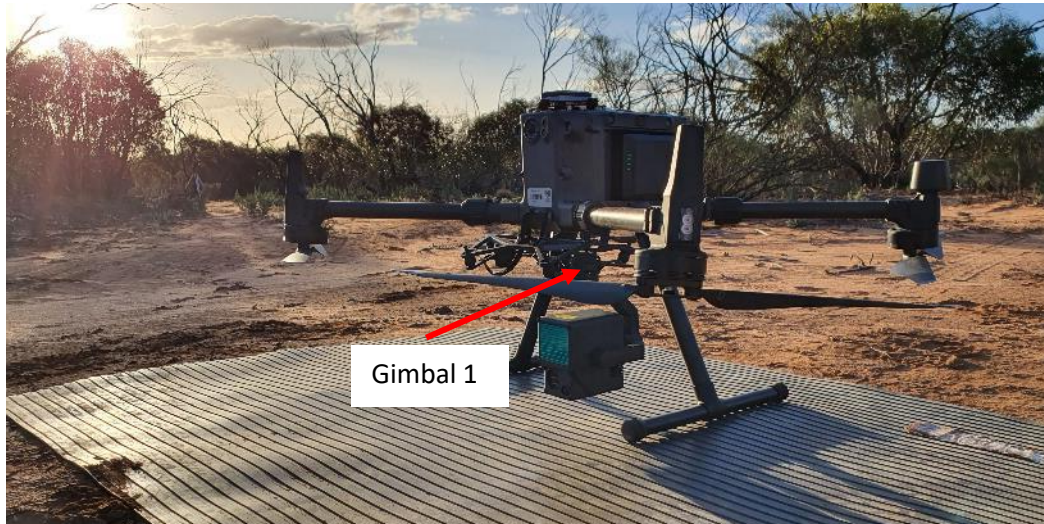


Figure 32: M300 with DJI Zenmuse L1 installed in gimbal 1.

Lidar Mission Settings

Update or check the flight settings as per the following steps. See Figure 36 for a visual summary of all settings. Press the Edit icon (as highlighted in Figure 33) to update flight parameters.

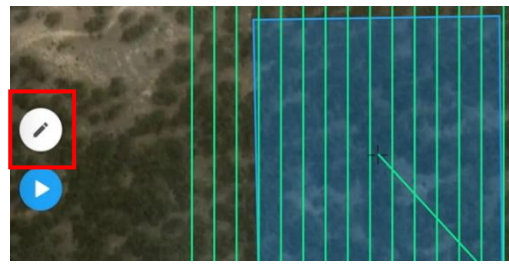


Figure 33: Press the edit button to update flight mission settings.

1. Expand the menu on the right to update the settings below
 - a. Enter a name for the Mapping mission in the format PlotName-L1-YYYY. E.g., SASMDD0001-L1-2022
 - b. Check that the area to be mapped (shown in blue polygon) is correct. Manually editing the plot outline might be required in new TERN plots established at the time of the drone mapping visit. To edit the area, drag and update the plot corners on-screen following instructions that appear on the remote controller screen.
 - c. Check that Camera-> Zenmuse L1->**LiDAR Mapping** is selected for the lidar mapping mission.
 - d. **IMU Calibration:** Enable
This performs IMU calibration before and after flight, and approximately every 100 s (end of flight lines). IMU calibration is necessary to ensure reconstruction accuracy of the point cloud. During the flight, calibration is performed in backwards/forwards flights at the start of the flight and end of each flight line.
 - e. **Terrain Follow:** Disable
This would be a useful feature in TERN plots where there is difference in terrain between site and takeoff area, or within site. In these scenarios there will be holes in the dataset which can be avoided using Terrain Follow. By importing a Digital Elevation Model (DEM) of the plot, the aircraft can follow differences terrain and ensure overlap requirements are met across the site. This feature is yet to be tested in TERN plots (To do list).
 - f. **ASL/ALT:** Relative to takeoff point (ALT). *With this setting the elevation is calculated from the takeoff point.*
 - g. **Flight Route Altitude:** 50 m appropriate for Calperum plots and for similar vegetation communities in other areas. Between 50-100 m recommended. Other values and the impact on point densities yet to be tested in tall, forested sites (To do list).
 - h. **Target Surface to Takeoff Point:**
 - *Vegetation height and terrain complexity, as well as difference in terrain between plot and the drone takeoff area must be considered when setting a suitable target surface (Figure 34). This is essential to ensure that the overlap calculations are applied appropriately. When the terrain to map and the takeoff point differ in elevation, set this to the distance from the takeoff point to the target surface. **Note:** Flight settings in tall forests (> 30 m) and sites with steep terrain are yet to be tested.*
 - *In rangeland and grassland sites, use the default value of 0 when takeoff point is at same elevation as the site.*
 - *In forested environments, set this to the height of the representative crowns in the plot. See flowchart below (Figure 35).*
 - i. **Takeoff Speed (m/s):** 15
This is the speed from the takeoff point to the first waypoint in the mission and can hence be faster than the flight speed.

- j. **Speed** (m/s): 5. Other values yet to be tested for lidar mapping mission.
- k. **Elevation Optimization**: Disable
 When enabled the aircraft will fly to the center of the flight area and capture a series of oblique photos to improve elevation accuracy. This is not relevant for the lidar mapping mission.

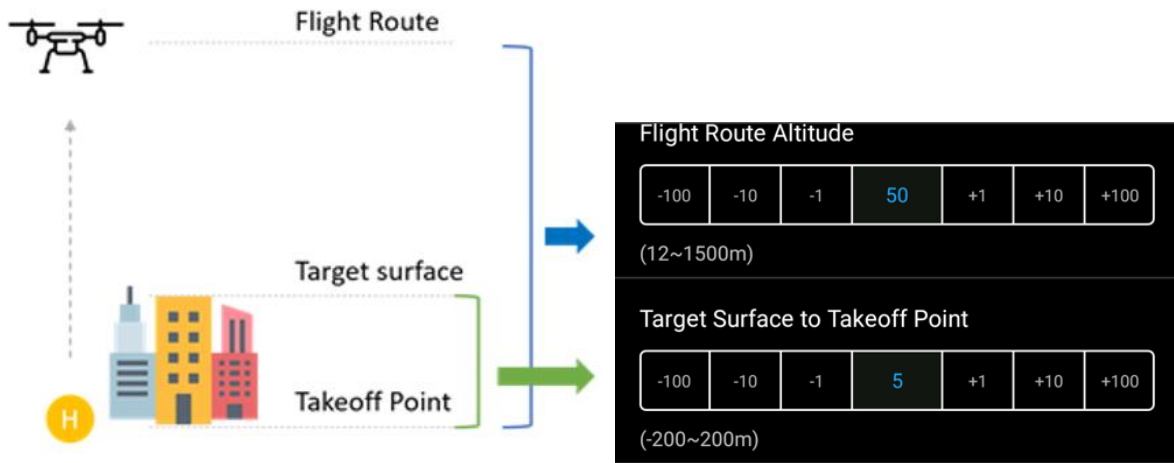


Figure 34: Target Surface to Takeoff Point must be set to ensure overlap calculations are applied to top of canopies. (Image source: DJI).

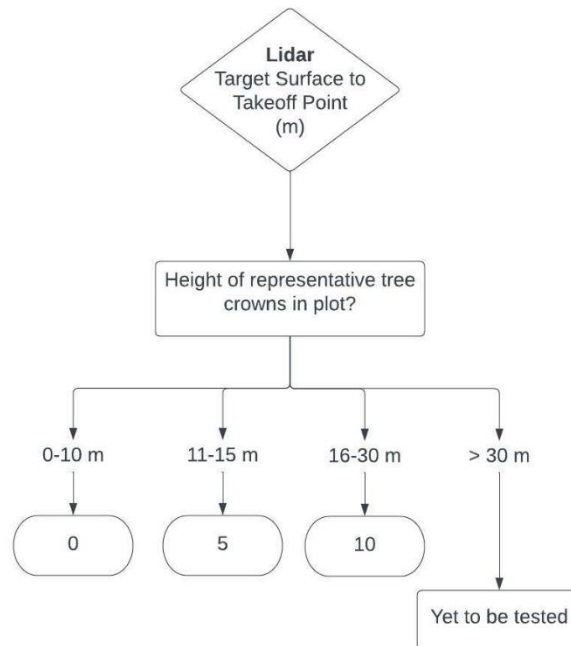


Figure 35: Consider the height of vegetation in the plot when setting Target Surface to Takeoff Point.

2. Under **Advanced settings** ensure the following have been set:
 - a. **Side Overlap (LiDAR) (%)**: 50. Overlap between the flight lines. An overlap of 50 % has been found to be sufficient to reconstruct the point cloud from raw lidar data in the sites mapped.
 - b. *Side Overlap (Visible): automatically calculated based on above.*
 - c. **Forward Overlap (Visible) (%)**: use the default value calculated based on LiDAR Side Overlap. **Reduce this value if it slows flight speed to below 5 m/s.** The priority here is the lidar mapping (rather than overlap in images).
 - d. **Course Angle**: 0. *Maintain North-South direction consistent with the RGB + multispectral flights.*
 - e. **Margin**: 50 (include a 50 m buffer). *Includes a buffer around the flight area. It is suggested that the margin be set to 50 m to ensure a 200 x 200 m coverage in the orthomosaic. However, pilots can consider reducing the margin to 25 m for operational considerations (obstacles, proximity to roads, battery capacity, efficiency of multiple plots, etc).*
 - f. **Photo mode**: 'Timed interval shot'

3. Update **Payload settings** as follows:
 - a. **Return Mode and Sampling Rate**: *Laser pulses emitted from a lidar sensor are reflected by objects on and above the ground surface. The time taken for the emitted pulse to be reflected back is used to calculate the distance traveled and hence the elevation. The L1 supports up to 3 returns from a laser pulse. The first return is usually associated with the tallest feature (e.g., tree canopy). The intermediate return is useful to capture vegetation surface. The last return would be from the ground or thick low-lying vegetation.*
 - **If unsure, choose Triple and 160 KHz.**
 - Forested sites: choose **Return Mode: Triple, Sampling Rate: 160 KHz** to capture the vegetation structure.
 - For low-lying vegetation sites **where only 2 returns would be expected**, choose Return Mode: Dual, Sampling Rate: 240 KHz.
 - b. **Scanning Mode: Repetitive**. *Lidar mapping mission needs repetitive scanning which provides a flat field of view. (Whereas non-repetitive scanning results in near-circular field of view and is denser in the center).*
 - c. **RGB Coloring**: Enable. *Generates a colourised point cloud.*

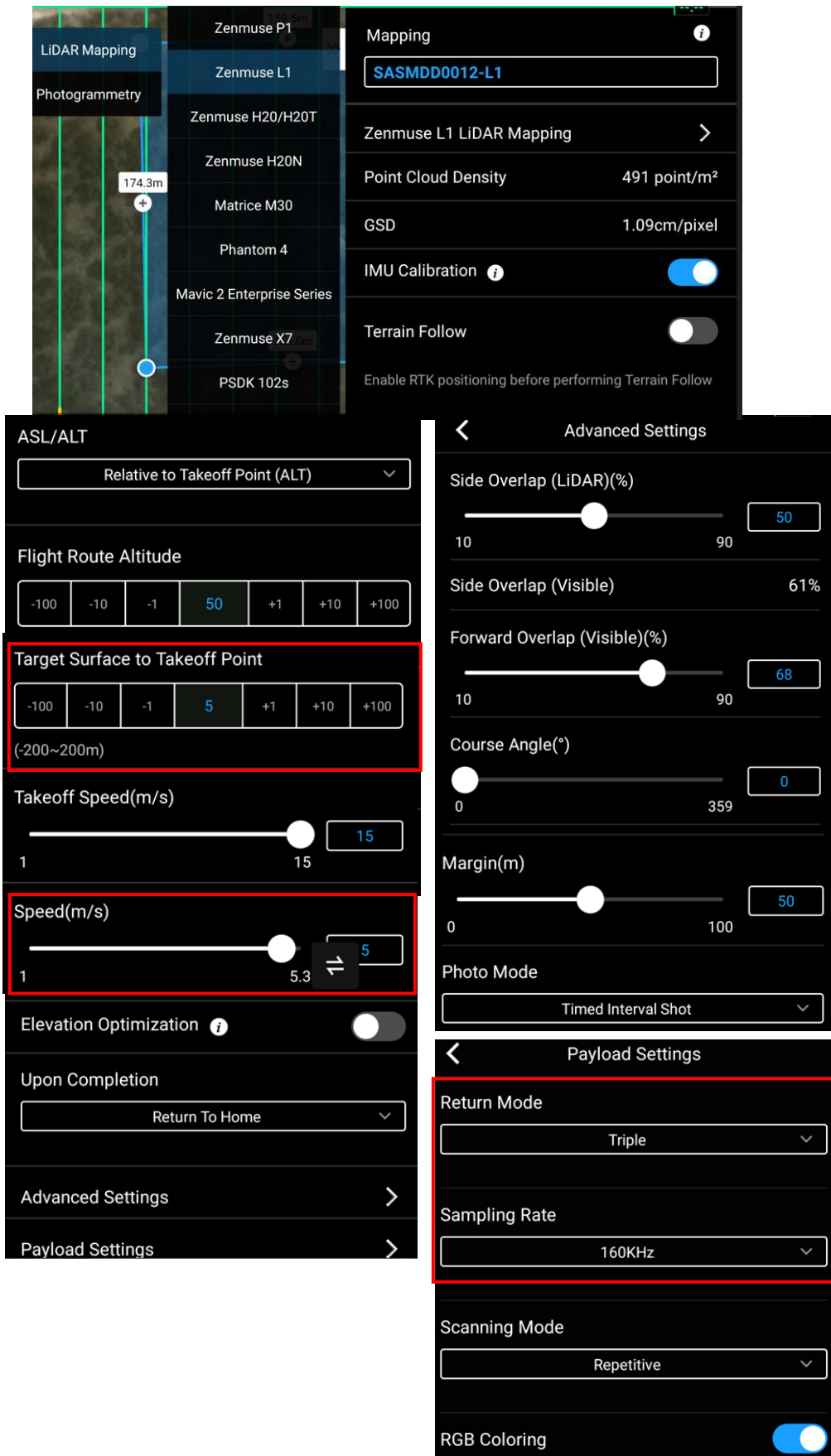


Figure 36: Overview of lidar mapping mission settings. Note that all settings must be checked and updated.

RGB Camera Settings

The following settings are recommended to reduce motion blur. Note that while the settings listed below must be checked initially, once set only the white balance needs to be changed based on site-specific illumination conditions.

1. In the L1 view, press 'CAMERA' to update the RGB camera settings (Figure 37).
2. Select S mode (Shutter priority) Shutter speed: 1/1000 s. Aperture and Iso are set automatically. Check that EV is 0.
3. White Balance: Select the arrow next to 'White Balance' to edit it.
 - **Do not leave this setting as Auto. Otherwise, you may have inconsistent colour balance between images.**
 - Select 'Sunny' when bright and overcast, and Cloudy only when dark and overcast.
4. Check that the defaults are unaltered for Image Ratio (3:2), Image Format (JPG).
5. Enable Mechanical shutter and Dewarping.
6. Update the Lidar settings (sampling Rate, Scanning Mode, Return Mode and RGB coloring) as entered in the Payload Settings (previous section).
7. Ensure the SD card has been backed up. Press Format SD card.

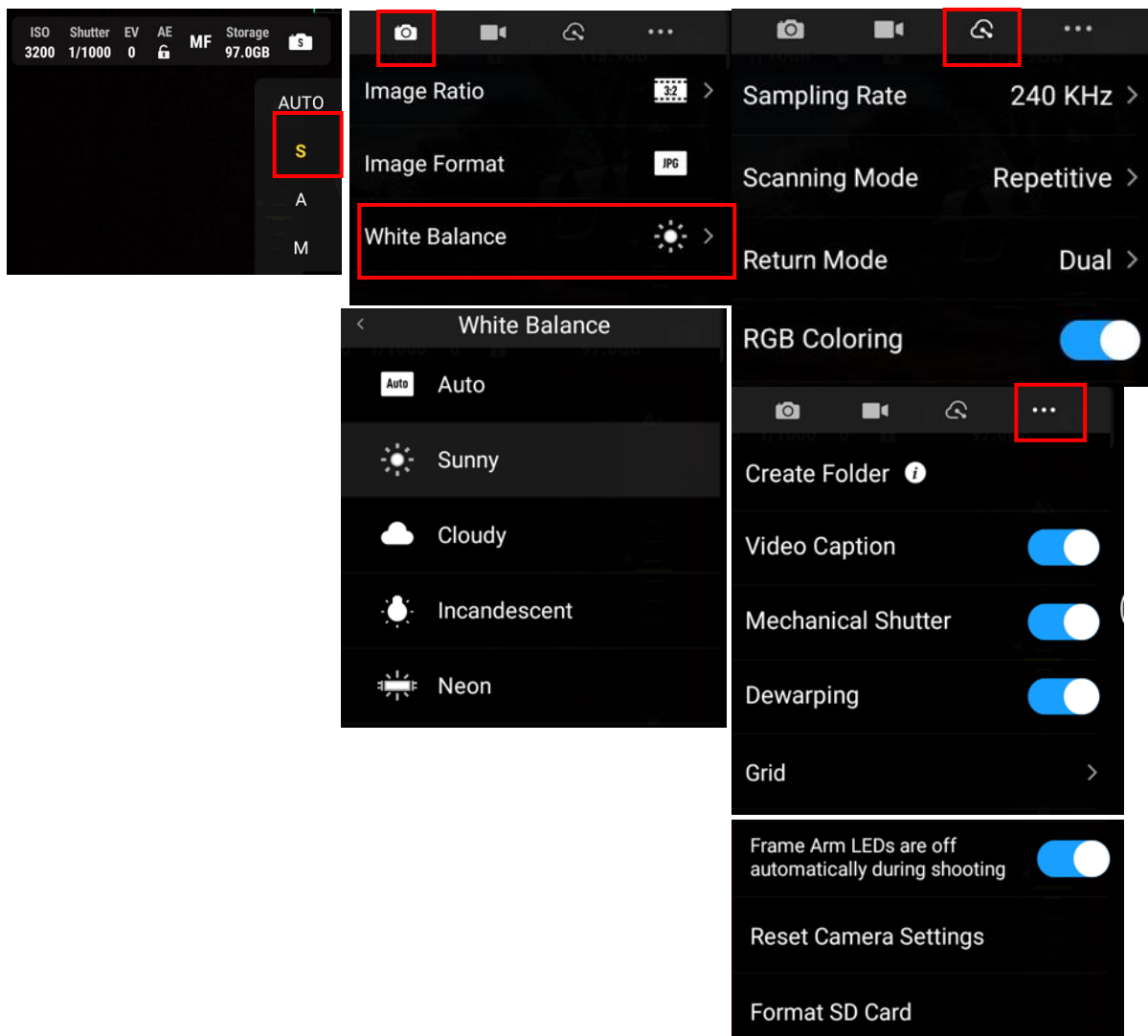


Figure 37: RGB camera settings for a lidar mapping mission. Check all settings. White Balance must be updated at each site.

Pre-flight

Lidar Missions

1. **Wait until the message 'Payload IMU warmed up' appears on the screen.** Figure 38 shows message that appears while IMU is still warming up. Note that this can take 5 – 6 mins from turning on the M300. Do not fly before the Zenmuse L1 payload is ready.
2. Also see 'During the flight' section for information on a known issue see at random in some lidar missions.

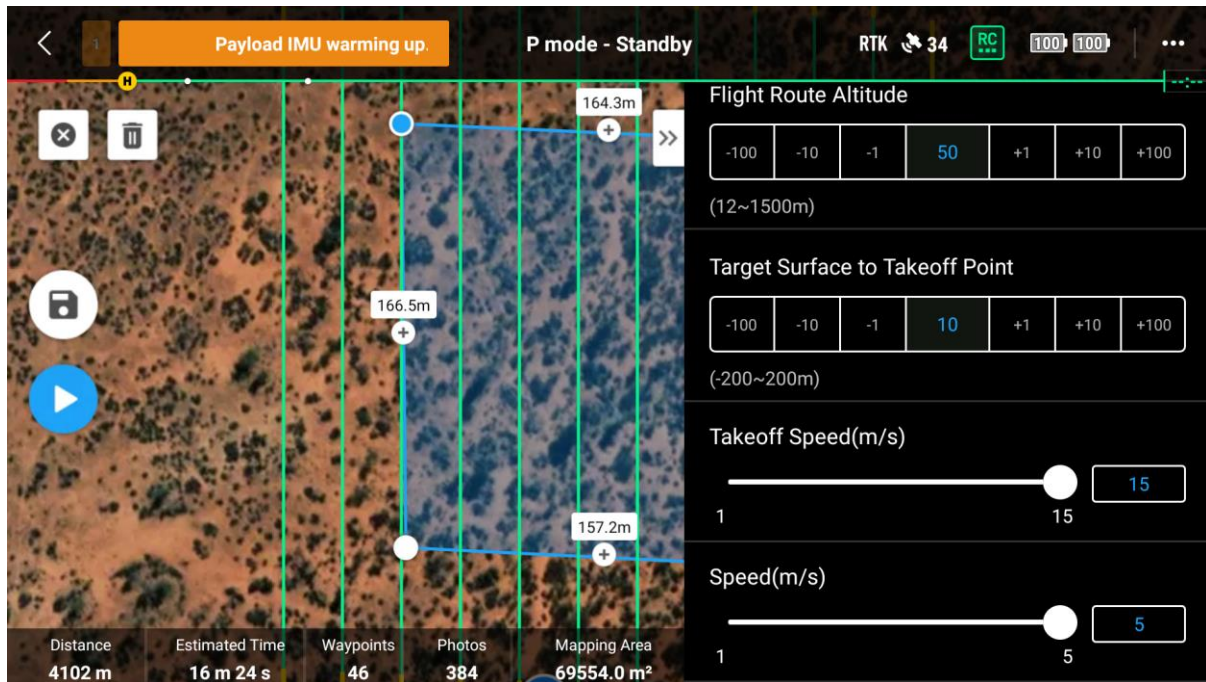


Figure 38: This screenshot shows the 'Payload IMU warming up' message. Wait until this is complete.

M300 aircraft checks

1. Check the aircraft setup (propellers, frame arms, landing gear, DLS) and ensure the sensors are connected properly. **Note:** while either the pilot or spotter might prepare the aircraft, the pilot must check the equipment before takeoff and maintains ultimate responsibility for the aircraft.
2. From the main screen of DJI Pilot, press the status message ('Warning' in Figure 39) for UAV Health Management System.
3. Scroll down the screen and resolve any Warnings or errors. Check that all systems are Normal (Figure 39). If any module has a Caution or Warning, tap the message for more information and troubleshooting.
4. Check that the M300 batteries, D-RTK2 battery and the remote controller have adequate charge.
5. Check that the satellite count is more than 10.
6. Check the DJI app for any other alerts/errors.

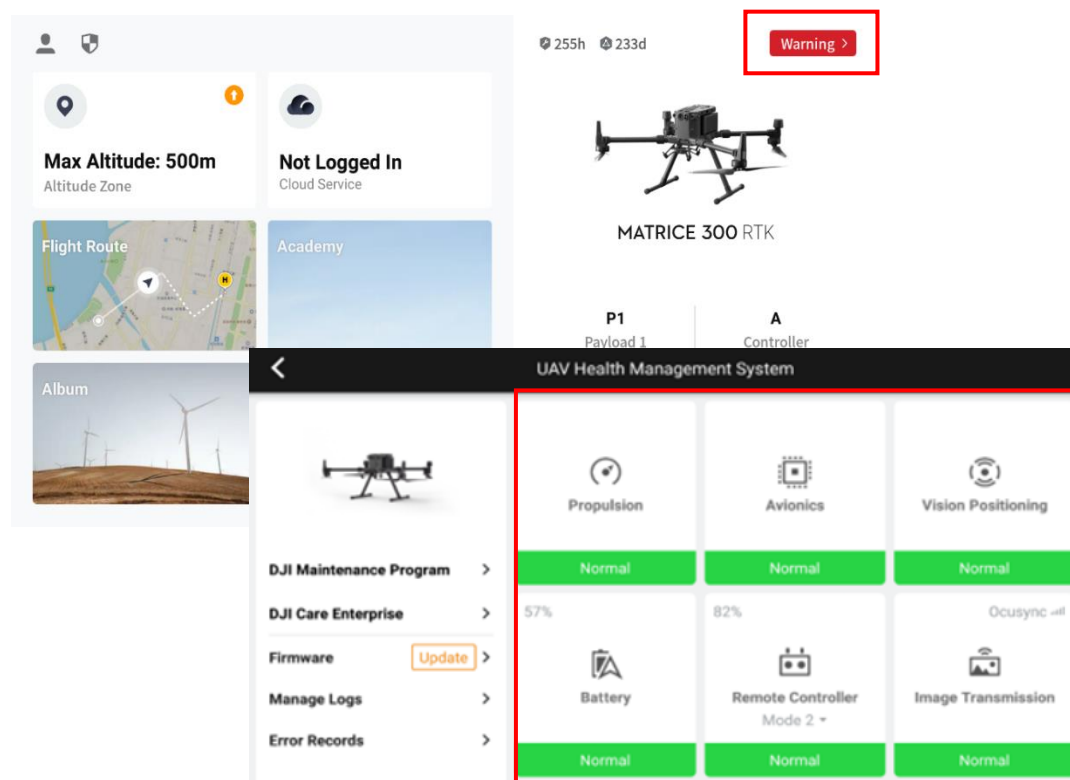


Figure 39: Before takeoff access the UAV HMS using the main screen. Scroll through the list to ensure that the status of all systems under Health Management System is Normal.

Aircraft take-off and landing

Undertake the following checks:

1. The launch area must be outside the plot.
2. The plot must be cleared before take-off and checks undertaken for any potential safety hazards. During the flight people must not be in the plot. Recommended that people stay close to the vehicles.
3. Manual take-off and landing are recommended. Use the remote controller to start the motors and take off manually. When ready start the mission (press the 'Play' button on the mission).

During the flight

1. Monitor UAS status to check that the mission is being flown at the correct speed and flying height. Ensure that batteries have enough power to complete the mission safely.
2. Monitor the surrounding area for any obstacles and changes in weather.
3. For an emergency landing, abort the mission as per Remote Pilot License training.
4. In TERN plots located close to roads, as the drone approaches the road a spotter with a radio must confirm that there is no traffic. If traffic is present, the pilot must pause the mission until traffic passes. The mission can be resumed once the spotter has radioed to confirm the road is clear. If this happens, make sure to include a note in metadata.

To land the aircraft pause the mission when returning home and then take over manually. With auto-landing, the pilot would have no control over the route.

Lidar missions: Known issue in Zenmuse L1 Firmware V04.00.01.06 (May 2022)

- With the L1 firmware update in May 2022, the following **error appears at random in some of the L1 flights**. Communications with DJI Support has indicated that a fix will be released in the next firmware version.
- When the aircraft enters the flight area at the end of the first IMU calibration, the following error **'Payload data connection failed. Unable to get point cloud data. Restart payload.'** appears on the screen (Figure 40).
- The point cloud display on the screen turns blank as well (Figure 40). However preliminary testing has shown that the point cloud data is still being collected. So, the recommendation is to complete the flight despite this message.
- **Note that the data must be checked post-flight to ensure that the raw data volume is as expected, as in this case there is no way to confirm point cloud data collection during the flight.**

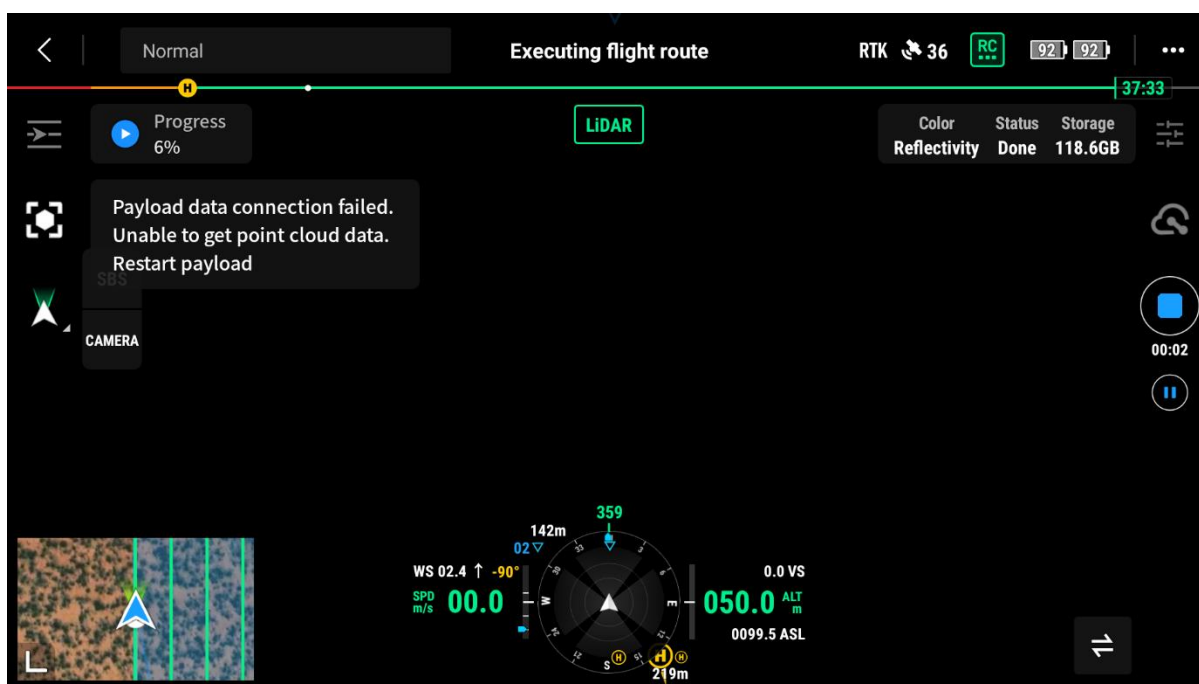


Figure 40: Screenshot shows the error message that randomly appears on some lidar mapping missions since the firmware update in May 2022. Note that the point cloud display has gone blank (main screen). However, testing has shown that data is still being collected.

Post-flight

Once the UAS has landed, ensure that the following steps are taken:

MicaSense Panel capture (RGB and multispectral missions only)

- Repeat steps to capture CRP images post-flight. In the metadata note which set of images (pre- or post-flight) are most representative of flight conditions

Record metadata

- Check that all metadata has been recorded on the TERN Surveillance UAS field app.

Check equipment

- Check that the propellers, aircraft and sensors are intact and there is no sign of any damage.

If continuing other flights at the plot:

- Hot swap M300 batteries if necessary: leave the drone powered on and swap one battery at a time.
- Charge the batteries.
- If the D-RTK2 base station battery is replaced at a plot, ensure that the Station coordinates are correct under RTK Settings (refer to Adjust D-RTK2 base station coordinates). Include a note in the metadata if a battery was replaced between missions at a plot.

At the end of flights at the plot:

- Turn off the D-RTK2 Mobile station and pack the antenna, tripod + rod.
- Pack the M300 (the reverse of aircraft setup steps)
 - Turn off the M300. Remove batteries and store in the battery station.
 - Remove and pack the sensors.
 - Remove SD cards for backup to SSD (see below).
 - Replace gimbal covers.
 - Fold the propellers.
 - Unlock the frame arms and fold both sets the same way. Replace propeller holders. Refer to the diagrams in 'Prepare the aircraft' for details.
 - Carry the drone using the landing gear (upright) and place it in the drone case (upside down as packed).
 - Unlock and remove the landing gear. **Note:** watch for the propellers while removing the landing gear - move the lock on the gear so it does not impact the propellers.
 - Replace the landing gear in the slots on the case.
 - Power down and store the remote controller in the case.

End of day: Charge all equipment (M300 + DRTK2 batteries, remote controller, radio, etc.). It is recommended that the batteries are left on charge until required to pack-up.

Data quality

It is important to check the quality of the collected imagery after flight. The following steps can be taken to ensure that the data is of sufficient quality to proceed to the processing stage:

1. Data volume

Note that the information on expected data volume below is for a 150 m x 150 m plot with a 50 m margin - this is provided as an indication of volume in the absence of data from a standard plot with 50 m margin. **The recommendation is a 50 m margin with a 100 x 100 m plot resulting in a 200 x 200 m mission area.**

Table 1: Expected data volume for RGB and multispectral images for a 150 x 150 m TERN plot with a 50 m margin which is a larger plot area than usual. Note the increased image count with a non-zero value for Target Surface to Takeoff Point.

Sensor	Target Surface to TakeOff Point (m)	Approximate image count	Data volume (GB)
P1	0	600	12
	10	693	15
MicaSense RedEdge-MX	0	600 x 5-bands	8

Table 2: Expected data volume for a lidar mapping mission using DJI Zenmuse L1. As above, note that this data is from a larger plot area.

Target Surface to TakeOff Point (m)	Return Mode	L1 mission folder size (GB) (the largest file in the folder is file with .ldr extension)	RGB image count
0	Dual	5	273
10	Triple	6.3	374

2. Image quality

P1:

- a. Check at least 3 photos from the start of mission, middle and end of flight. Check that the images are not blurry.
- b. Check that the Shutter Speed, White Balance (Manual), Aperture and Auto ISO settings are correct

MicaSense:

- a. Check the CRP pre- and post-flight images. There must be at least 2 images pre- and post-flight. The entire panel must be covered in the image and the panel should take up around one-third of the image. Note that there will be one image tiff per band (image suffix is the band number). There must hence be two sets of good CRP images pre- and post- flight.
- b. As with the P1, check the shutter speed in at least 3 images (suggest checking the Blue band which are images ending in _1.tif in 5-band data and _6.tif in 10-band).

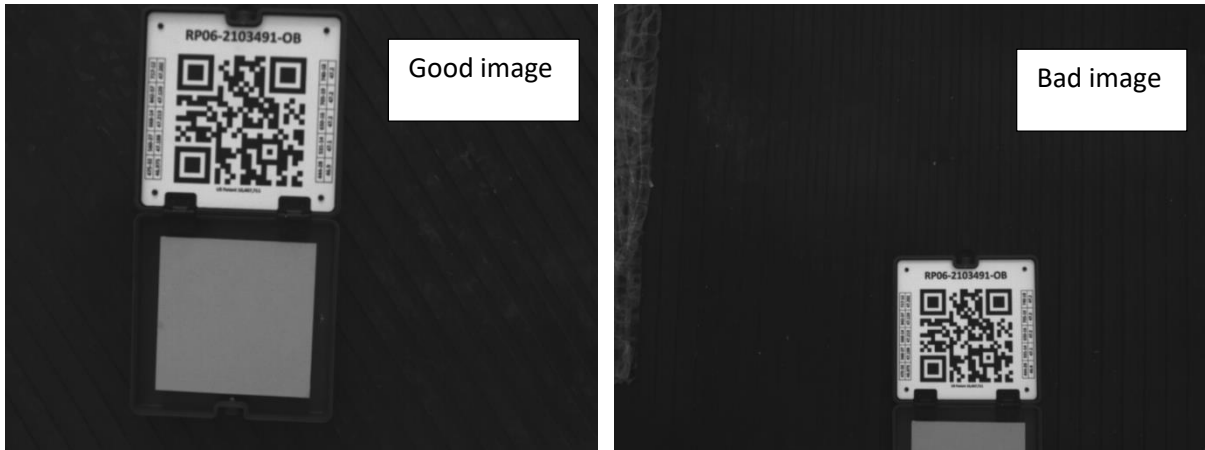


Figure 41: The entire panel must be covered in the image and the panel should take up around one-third of the image.

Data backup

1. Check that the SD cards (or microSD card for L1) did not fill up – might indicate missed captures. If so, redo flight mission.
2. Backup memory cards to SSD.
3. Folder structure: Imagery and lidar data will be published in two separate collections (named imagery and lidar) on the TERN portal. Hence for ease of data upload, the following directory structure must be used (Table 3).
 - a. Folder structure in SSD for **lidar** raw data is <plot>/ YYYYMMDD/lidar/level0_raw/ where
 - YYYYMMDD: Date of mission
 - plot: TERN plot name
 - b. Folder structure in SSD for **RGB and multispectral imagery raw data** is <plot>/ YYYYMMDD/imagery/<sensor>/level0_raw/ where
 - sensor: 'rgb' or 'multispec'
4. Use a folder comparison tool (e.g., [WinMerge](#)) to check that all data was backed up.
5. Maintain a set of SD and microSD cards for each TERN plot.

Table 3: Folder structure for transfer to Data Services

Data	Path	Example
RGB	<plot>/YYYYMMDD/imagery/rgb/level0_raw/	SASMDD0001/20220519/imagery/rgb/level0_raw/
Multispectral	<plot>/YYYYMMDD/imagery/multispec/level0_raw/	SASMDD0001/20220519/imagery/multispec/level0_raw/
Lidar	<plot>/YYYYMMDD/lidar/level0_raw/	SASMDD0001/20220519/lidar/level0_raw/
Metadata	<plot>/YYYYMMDD/imagery/metadata/ <plot>/YYYYMMDD/lidar/metadata/	
DRTK logs	plot/YYYYMMDD/drtk/	

Post-campaign

Data management

1. Export mission KMZs and save in a separate folder labelled kmz/ onto an external SSD.
2. Connect the D-RTK2 base station antenna to the laptop and copy all logs from the campaign to drtk/ folder on the external SSD. At a minimum the relevant DAT file from rtcraw/ folder must be saved with the raw data (Table 3). This would enable post-processing D-RTK2 base station coordinates.
3. Copy all other campaign data on the external SSD.
4. Export and save all metadata from the TERN field app with the raw data. Follow a standard naming format as per TERN Surveillance procedure. Mission-level metadata such as picture of base station setup in the plot, kmz file, metadata must be reorganised in metadata/ under imagery/ and lidar/ (Table 3).

Data transfer to TERN Data Services

1. Prior to starting the data transfer, organise raw data as per the format shown in Table 3.
2. If not done already, for each plot create a metadata/ folder within both the imagery/ and lidar/ folders. Ensure that mission-specific metadata such as kmz files, photo of the D-RTK2 base station setup at a plot, are copied to the metadata/ folder.
3. Transfer the contents of the external SSD (with data and metadata and other files) to TERN Data Services for data upload to TERN portal.
 - Refer to documentation provided by the TERN Data Services team on 'Getting Started with Globus Connect Personal'.
 - Plot-level data will be stored in the QRIScloud location /Q4647/surveillance/drone/<plotName>/...
 - Transfer data to the above location as per directory structure shown in Table 3.

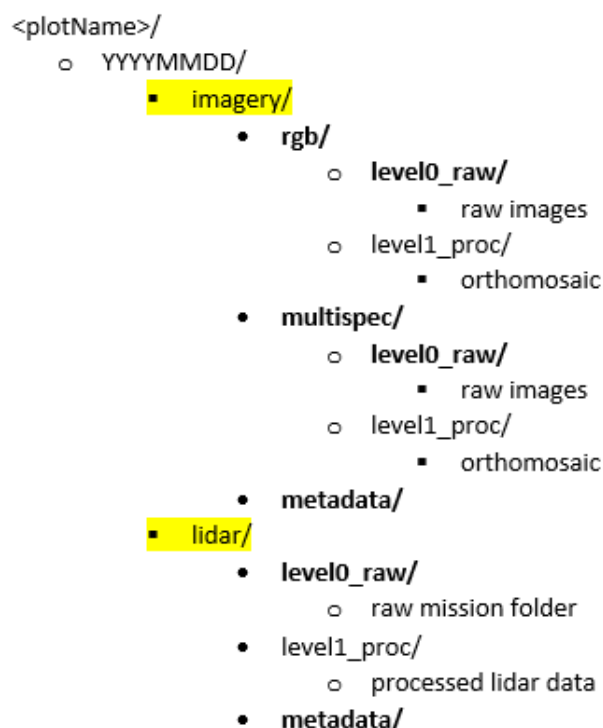


Figure 42: Folder structure for transfer to QRIS Cloud storage

Drone equipment and Compliance

1. Follow ReOC processes to upload flight logs and finalise JSAs for the flight missions.
2. In case of any errors during flight missions, export M300 aircraft logs using the [DJI Assistant 2 \(Enterprise Series\)](#) app.
3. Inspect and service the equipment as required. See DJI Maintenance Manual for details on recommended routine and regular inspection (DJI 2022a)
4. Maintain log of any issues for follow-up.

To do list

1. Optimal flying height, target surface to takeoff point and flight speed for tall, dense forested sites to be determined.
2. When to enable terrain follow, look into slope/aspect captured for TERN plots.
3. Annual refresher drone flying training recommended with a focus on using the remote controller buttons (rather than the DJI Pilot interface). Familiarity with the remote controller required in case of any issues with the app interface during flights.
4. TERN plot KMLs: Provide a reference to automated KML generation based on TERN plot corners in 'Mission Planning'. TERN app Locus generated KML not compatible with DJI Pilot (NG, Oct 2022). Can a process be created where we can input (manually, or preferably automatically) corner coordinates for a plot if the plot is established at the same time (a few hours before) the imagery is flown? (BS)
5. Include examples of bad images (Data quality).

References

DJI 2020, *Matrice 300 RTK Intelligent Battery Safety Guidelines*, DJI, Australia, viewed 8 February 2022, <[https://dl.djicdn.com/downloads/matrice-300/20200507/M300 RTK Intelligent Flight Battery Safety Guidelines.pdf](https://dl.djicdn.com/downloads/matrice-300/20200507/M300%20RTK%20Intelligent%20Flight%20Battery%20Safety%20Guidelines.pdf)>

DJI 2022a, *Matrice 300 RTK Maintenance Manual v1.2*, DJI, Australia, viewed 28 July 2022, <[https://dl.djicdn.com/downloads/matrice-300/20220620/M300 RTK Maintenance Manual v1.2 EN .pdf](https://dl.djicdn.com/downloads/matrice-300/20220620/M300%20RTK%20Maintenance%20Manual%20v1.2%20EN%20.pdf)>ss

DJI 2022b, *Matrice 300 RTK – user Manual v3.2.1*, DJI, Australia, viewed 25 July 2022, <[https://dl.djicdn.com/downloads/matrice-300/20220509/M300 RTK User Manual EN v3.2 1.pdf](https://dl.djicdn.com/downloads/matrice-300/20220509/M300%20RTK%20User%20Manual%20EN%20v3.2%201.pdf)>

DJI Download Center 2021, *D-RTK2 User Guide 2.0*, DJI, Australia, viewed 1 November 2021, <<https://www.dji.com/au/downloads/products/d-rtk-2>>

MicaSense 2020, *What is the difference between a “panel capture” and a “normal capture”?*, MicaSense, viewed 18 November 2021, <<https://support.micasense.com/hc/en-us/articles/360020204833-What-is-the-difference-between-a-panel-capture-and-a-normal-capture->>

White, A., Sparrow, B., Leitch, E., Foulkes, J., Flitton, R., Lowe, A. & Caddy-Retalic, S. 2012. *AusPlots Rangelands Survey Protocols Manual v. 1.2.9*.

Appendix 1: Pre-field checklist

Task	Description	Check
Update Firmware	M300 equipment (aircraft, remote controller, battery station, batteries, DJI sensors, etc.) DJI Pilot – UAV HMS	
	MicaSense sensor MicaSense Firmware updates	
	Check and update flight settings after firmware update DJI Pilot – Settings	
	Check and update sensor settings on firmware update DJI Pilot and MicaSense WiFi user interface	
	Conduct a trial flight	
Flight Planning	Import or create KMZ for all TERN plots DJI Pilot - Flight Route – KMZ Import or Create a Route	
	Cache plot area imagery for all plots	
Equipment Checks	Check for damage to M300 airframe and propellers.	
	Check that the dual gimbal mount is connected. Replace gimbal dampeners if damaged.	
	Check that the Downwelling Light Sensor is installed	
	Check M300 and D-RTK2 batteries for any visible damage	
	Charge equipment: <ul style="list-style-type: none"> • M300 batteries • D-RTK2 batteries • M300 remote controller • Tablet used for MicaSense sensor 	
	Software installed on field laptop: <ol style="list-style-type: none"> 1. Tool to format MicaSense SD cards to FAT32 (e.g., GUIFormat) 2. Folder comparison tool to check data backup (e.g., WinMerge) 3. DJI Assistant 2 (Enterprise Series) app 	
Pack list	See Appendix 2: Pack list	

Appendix 2: Pack list

#	Equipment		Check
1	M300 case	<ul style="list-style-type: none"> i. M300 drone with DLS connected ii. Remote Controller and charger unit iii. Spare propellers iv. MicaSense calibrated reflectance panel (CRP) v. Tablet to be used for MicaSense user interface and charger 	
2	M300 battery station	<ul style="list-style-type: none"> i. M300 batteries (x8) ii. D-RTK2 batteries (x4) iii. Power chord iv. USB-C cable to connect to remote controller 	
3	D-RTK2 Mobile Station antenna, tripod, and extension rod		
4	P1 Sensor case with the sensor, SD card and spare SD cards		
5	RedEdge-MX/Dual case with the sensor, labelled MicaSense SD cards and spare SD cards.		
6	DJI Zenmuse L1 LiDAR sensor, microSD card and spare cards.		
7	Sturdy rubber mat to launch/land drone		
8	DGPS unit		
9	Star pickets, filing tool and flagging tape to mark the location of D-RTK2 base if site revisit is likely to occur in the future for monitoring purposes.		
10	Laptop to be used in the field for data backup, format cards, etc.		
11	SD/Micro SD card reader (dual SD card slots ideal to backup both P1 + RedEdge-MX cards at the same time.)		
12	SSDs to backup data		
13	Case to secure and store memory cards		
14	Tool kit with spare parts: gimbal grommets, spare gimbal covers and lens caps, spare screws of types used; screwdrivers, cable ties		
15	First aid kit		
16	DGPS unit		
17	Radios and air band radio		
18	Generator (if required to charge batteries on field)		

Appendix 3A: RGB and multispectral mission: pre-flight task list

#	Task	Description	Suggested responsibility
1	D-RTK2 Base Station setup	<ul style="list-style-type: none"> • Setup base station in plot corner easily accessible from drone launch area. Preference is to use the southwest star picket and position the D-RTK2 outside the plot. • Move the top of the star picket slightly to the so that antenna top of D-RTK2 base station can be positioned on the outside corner of the plot and levelled. • Check antenna bubble for levelling (not tripod bubble) • Check that DRTK battery has adequate charge. • Power up and press the Mode button to operate in Mode 5. Look for a blinking pattern of 5 times in the indicator button. 	Spotter
2	Adjust D-RTK2 base station coordinates	<p>DJI Pilot – ‘...’ – RTK</p> <ul style="list-style-type: none"> - RTK Positioning – Enable - RTK Service Type: D-RTK2 Mobile Station - Advanced Settings (password: 123456) - Enter DGPS coordinates for plot corner in Lat//Lon (8 decimal places). - If Altitude value unavailable, leave Altitude as it is. - If Altitude at ground level available, enter ground height + 1.8 m in Altitude. - Save. - Restart aircraft. <p>DJI Pilot – ‘...’ – RTK.</p> <ul style="list-style-type: none"> - Station coordinates updated as entered above. - Aircraft Orientation and Positioning are FIX. 	Pilot and Spotter
3	Prepare the aircraft	<ul style="list-style-type: none"> - Install landing gear - Unfold frame arms and lock - Unfold propellers - Install a pair of batteries 	Pilot Note: Pilot must check aircraft before launch if others complete this step.
4	Compass calibration	<p>Recommended at all sites: DJI Pilot – ‘...’ – Flight Controller Settings – Sensor Status. And follow on-screen instructions.</p>	
5	Connect DJI Zenmuse P1 camera in gimbal 1.	<ul style="list-style-type: none"> • Press the gimbal detachment button to remove the cover. • Align the white and red dots and insert the P1 sensor. • Rotate the gimbal lock to the locked position. 	
6	Connect MicaSense sensor in gimbal 2	<ul style="list-style-type: none"> • Repeat above step. • Connect the power cable. • Connect DLS connection to port. 	

#	Task	Description	Suggested responsibility
7	Mission Settings	<p>Recommended naming for RGB + multispectral mission: PlotName-YYYY</p> <p>Review and update settings as per Figure 43. The following must be updated for each plot.</p> <ul style="list-style-type: none"> • Target Surface to Takeoff Point: See flowchart (Figure 44) on how to set this value. • Margin: 50 m. Consider reducing to 25 m in plots close to major roads. Increase margin in plots used for Cal/Val. • Speed: set it to be lower than the maximum possible for the mission. • When the site terrain is higher than at takeoff point increase the Flight Route Altitude which is usually 80 m. This is yet to be tested. 	Pilot
8	P1 Settings	<p>Note that all settings must be checked as per Figure 45. Once they are set, the only setting to be changed at each plot is the White Balance.</p> <ul style="list-style-type: none"> • Do not leave this setting as Auto otherwise you may get inconsistent colour balance between images. • Select 'Sunny' when bright and overcast, and Cloudy only when dark and overcast. <p>Format SD card (ensure has been backed up).</p>	Pilot
9	MicaSense Settings	<p>MicaSense sensor WiFi hotspot (password: micasense). 192.168.10.254 in the browser.</p> <ul style="list-style-type: none"> • Check that DLS is connected, and GPS is running (satellites are visible): Home page • Format SD card (ensure has been backed up): Settings icon – Storage and Firmware – Reformat Storage • Check settings are as below: Settings icon – Basic Configuration <ul style="list-style-type: none"> ○ Auto-Capture Mode: Timer ○ Time period (sec): 1 ○ Target Alt (m): set to flight altitude e.g., 80 ○ Target Alt Tolerance (m): 20 ○ Uncheck Manual Exposure ○ Press Save 	Spotter

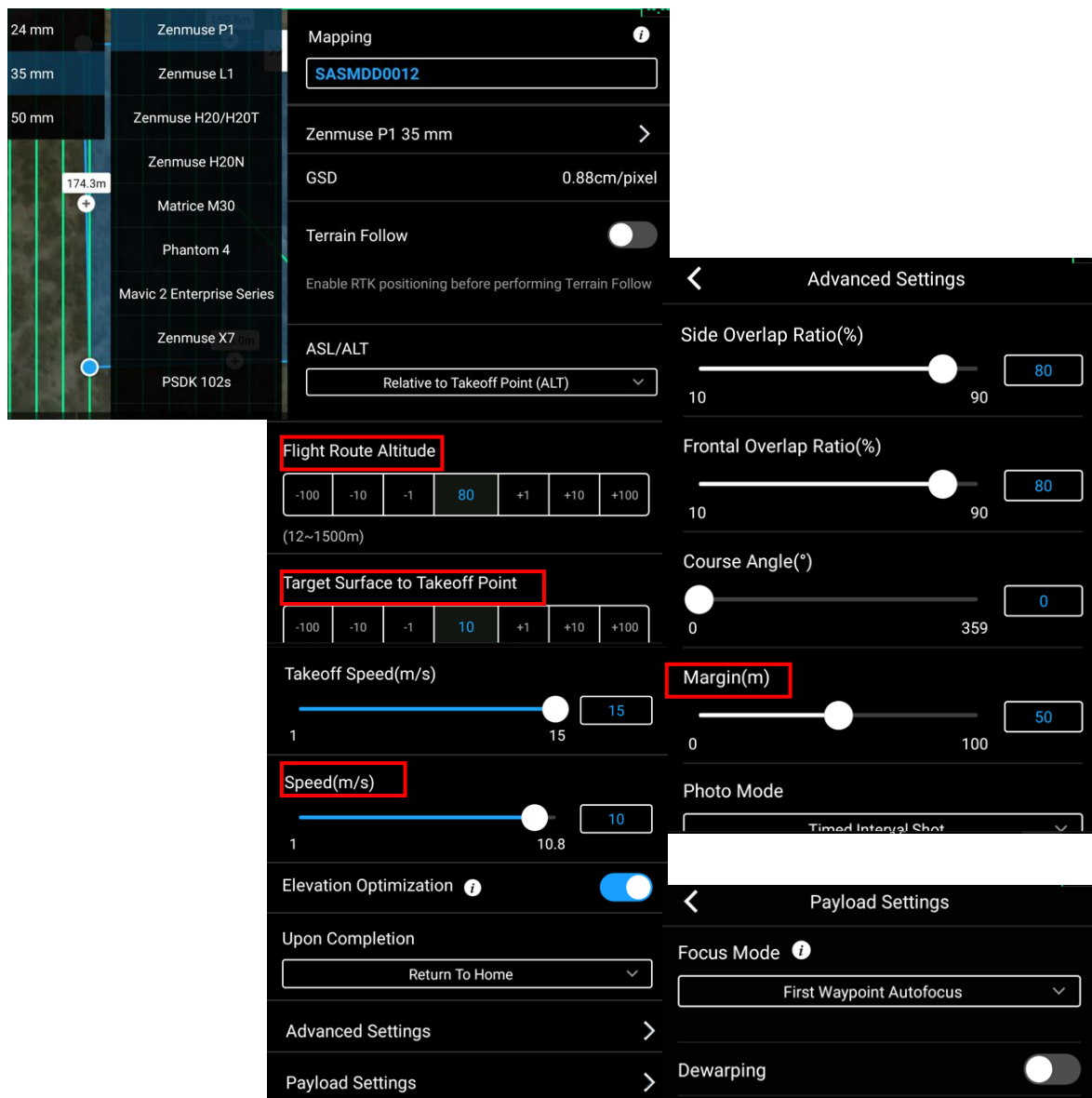


Figure 43: RGB and multispectral mission: check that Flight settings are as above. Settings that must be updated for each plot are highlighted.

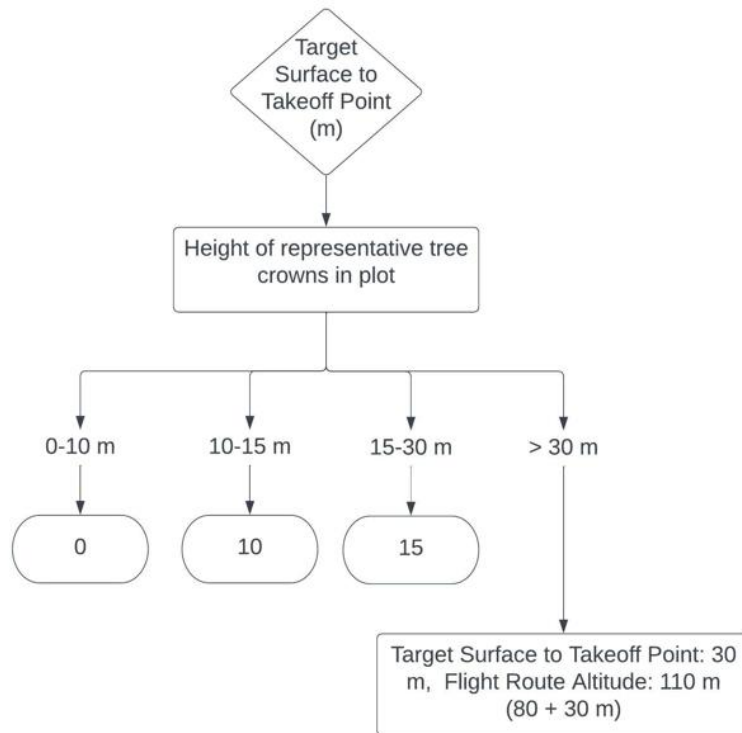


Figure 44: RGB and multispectral mission: consider the height of vegetation in the plot when setting Target Surface to Takeoff Point.

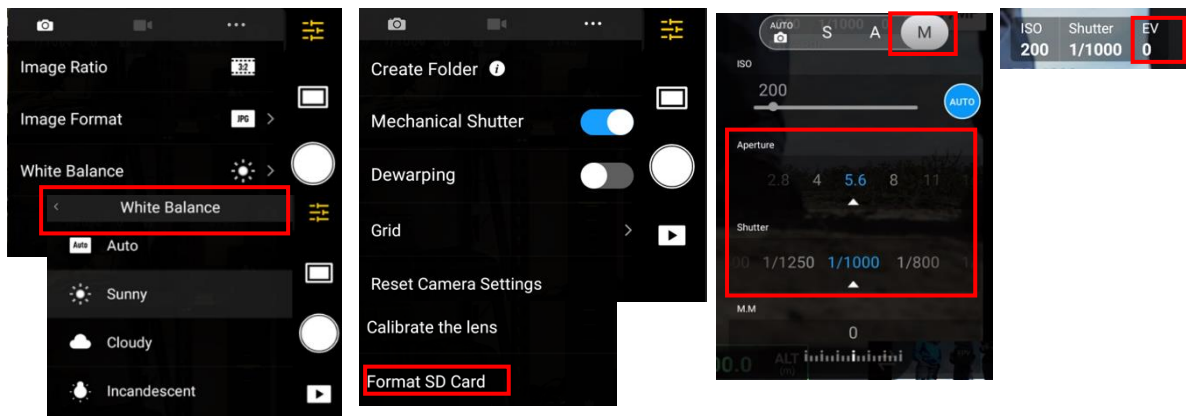


Figure 45: Update P1 camera settings as shown above. Note that while all settings must be checked to be as above, White Balance must be updated at each plot to either Sunny or Cloudy (when dark and overcast). Check that M mode, Auto ISO, Aperture f/5.6, Shutter speed 1/1000 s. Check that EV is 0. Format the SD card.

Appendix 3B: Lidar mission: pre-flight task list

#	Task	Description	Suggested responsibility
1	D-RTK2 Base Station setup	<ul style="list-style-type: none"> • Setup base station in plot corner easily accessible from drone launch area. Preference is to use the southwest star picket and position the D-RTK2 outside the plot. • Move the top of the star picket slightly to the so that antenna top of D-RTK2 base station can be positioned on the outside corner of the plot and levelled. • Check antenna bubble for levelling (not tripod bubble) • Check that DRTK battery has adequate charge. • Power up and press the Mode button to operate in Mode 5. Look for a blinking pattern of 5 times in the indicator button. 	Spotter
2	Adjust D-RTK2 base station coordinates	<p>DJI Pilot – ‘...’ – RTK</p> <ul style="list-style-type: none"> • RTK Positioning – Enable • RTK Service Type: D-RTK2 Mobile Station • Advanced Settings (password: 123456) • Enter DGPS coordinates for plot corner in Lat//Lon (8 decimal places). • If Altitude value unavailable, leave Altitude as it is. • If Altitude at ground level available, enter ground height + 1.8 m in Altitude. • Save. • Restart aircraft. <p>DJI Pilot – ‘...’ – RTK.</p> <ul style="list-style-type: none"> • Station coordinates updated as entered above. • Aircraft Orientation and Positioning are FIX. 	Pilot and Spotter
3	Prepare the aircraft	<ul style="list-style-type: none"> • Install landing gear • Unfold frame arms and lock • Unfold propellers • Install a pair of batteries 	Pilot
4	Compass calibration	<p>Recommended following significant travel: DJI Pilot – ‘...’ – Flight Controller Settings – Sensor Status. Follow on-screen instructions.</p>	<p>Note: Pilot must check aircraft before launch if others complete this step.</p>
5	Connect DJI Zenmuse L1 sensor in gimbal 1	<p>Press the gimbal detachment button to remove the cover. Align the white and red dots and insert the L1 sensor. Rotate the gimbal lock to the locked position.</p>	

#	Task	Description	Suggested responsibility
6	Mission Settings	<p>Suggested naming for lidar mission: PlotName-l1-YYYY</p> <p>Review and update all settings as per Figure 46. See Figure 47 on how to set Target Surface to Takeoff Point.</p> <p>Return Mode/Sampling Rate</p> <ul style="list-style-type: none"> • Forested sites: choose Return Mode: Triple, Sampling Rate: 160 KHz to capture the vegetation structure. • For low-lying vegetation (shrublands, rangelands, mallee): sites where only 2 returns would be expected, choose Return Mode: Dual, Sampling Rate: 240 KHz. • If unsure, choose Triple and 160 KHz 	Pilot
7	L1 RGB Camera Settings	<p>Note that all the settings must be checked as per Figure 48. Once they are set, the only setting to be changed at each plot is the White Balance.</p> <ul style="list-style-type: none"> • Do not leave this setting as Auto otherwise you may get inconsistent colour balance between images. • Select 'Sunny' when bright and overcast, and Cloudy only when dark and overcast. <p>Format SD card (ensure has been backed up).</p>	Pilot

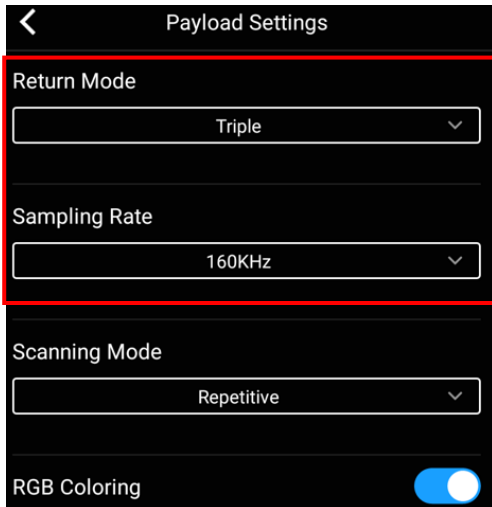
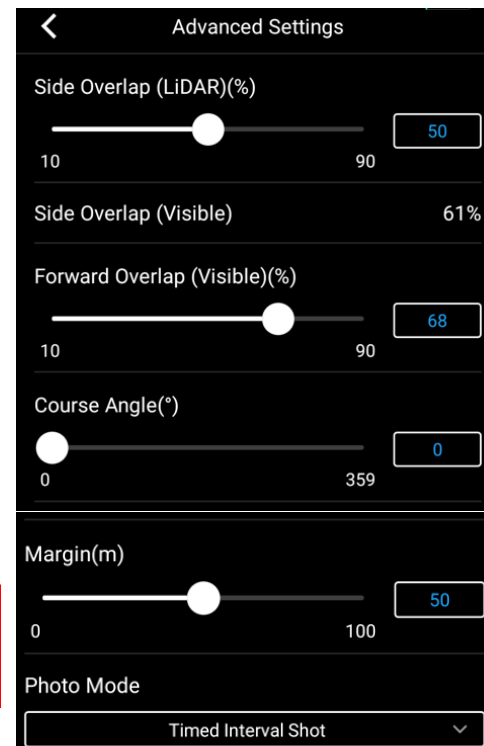
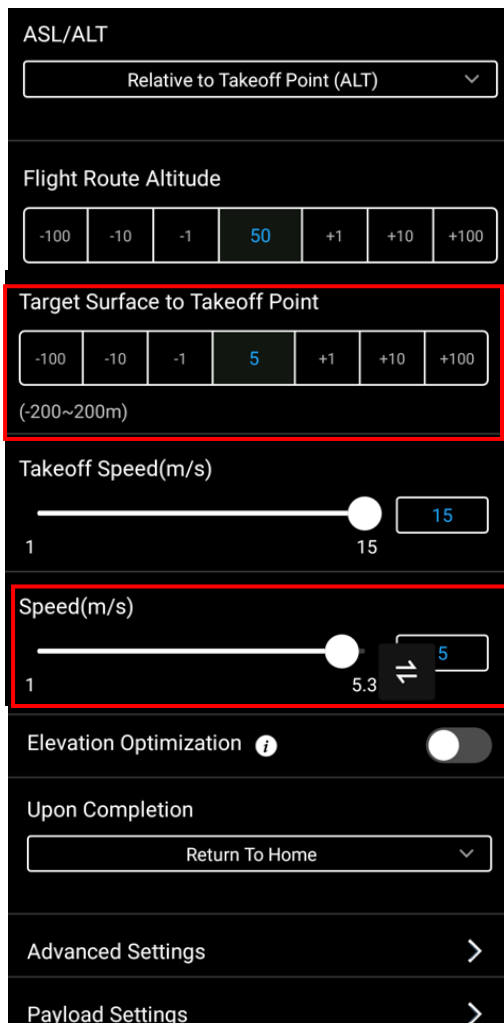
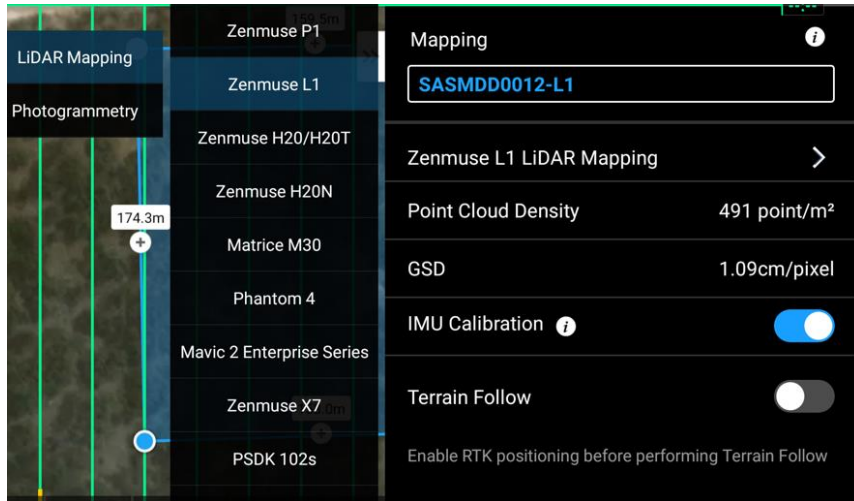


Figure 46: Lidar mission: Check and update all settings.

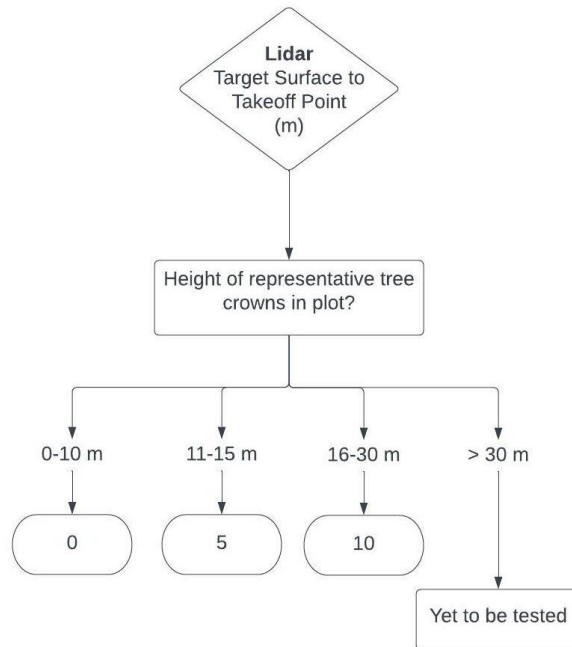


Figure 47: Lidar mission: consider the height of vegetation in the plot when setting Target Surface to Takeoff Point.

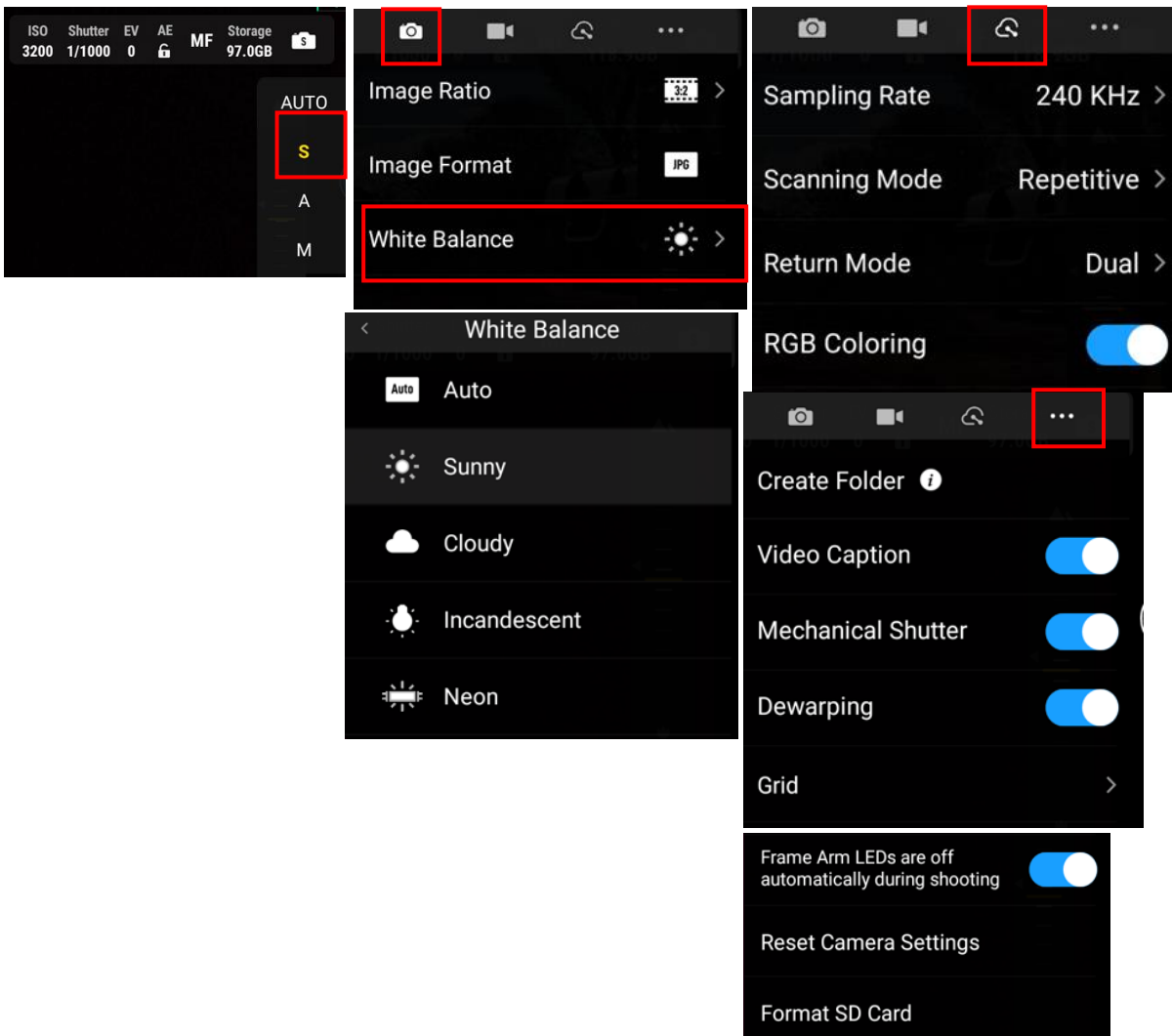


Figure 48: Lidar mission: RGB camera settings for a lidar mapping mission. Check all settings. White Balance must be updated at each site.

Appendix 4: Pre-flight checklist

Task	Description	Suggested responsibility
MicaSense CRP capture (for RGB + Multispectral flight)	<ul style="list-style-type: none"> For both CRP and mission capture, if there is moving cloud cover, wait for a few minutes. The aim is to collect CRP that is representative of flight conditions. Panel capture using MicaSense user interface – Camera icon <ul style="list-style-type: none"> Facing into the sun hold the aircraft over the CRP (at about 1 m height). Ensure there are no shadows cast on the CRP or the DLS on the UAS. Avoid bright coloured clothing to mitigate any contamination. Panel must take up at least one third of the image width. QR code and serial number label must be visible in the image. Press the Capture button. Images will be displayed on the screen. Repeat the Capture step thrice for redundancy. 	Pilot (aircraft) and Spotter (capture and check CRP images)
M300 aircraft checks	Aircraft setup (propellors, frame arms, landing gear, DLS). Sensors installed properly. UAV HMS – DJI Pilot - Main screen - status on top right must be 'Normal'. Press the status message to check all systems. M300 batteries, DRTK-2 battery and remote controller have adequate charge. Check DJI app for any other alerts. L1 Lidar mapping flight: wait until Payload IMU has warmed up.	Pilot

Note:

- Manual take-off and landing are recommended. Use the remote controller to start the motors and take off manually prior to starting the mission.
- Monitor UAS status to check that flying desired mission at correct speed, flying height. Ensure the batteries have power.
- Monitor surrounds for any obstacles, changes in weather. For an emergency landing, abort mission as per Remote Pilot License training.
- To land the aircraft pause the mission when returning home and then take over manually.

Appendix 5: Post-flight checklist

Task	Description	Suggested responsibility
MicaSense CRP capture (P1 + MicaSense flight)	<p>Panel capture using MicaSense user interface – Camera icon</p> <ul style="list-style-type: none"> • Facing into the sun hold the aircraft over the CRP (at about 1 m height). Ensure there are no shadows cast on the CRP or the DLS on the UAS. Avoid bright coloured clothing to mitigate any contamination. • Panel must take up at least one third of the image width. • QR code and serial number label must be visible in the image. • Press the Capture button. Images will be displayed on the screen. • Repeat the Capture step thrice for redundancy. 	Pilot (aircraft) and Spotter (capture and check CRP images)
Record Metadata	Record mission specific metadata on TERN app. Include notes on cloud cover, any issues during mission, if DRTK battery was changed between missions in a plot, etc.	Spotter
D-RTK2 base station	Turn off the D-RTK2 Mobile station and pack the antenna, tripod + rod.	Spotter
M300	<ul style="list-style-type: none"> • Turn off the M300. Replace batteries in battery station. • Remove and pack the sensors. • Remove SD cards for backup. • Replace gimbal covers. • Fold the propellers. <p>Unlock the frame arms and fold both sets the same way. Replace propellor holders. Refer to the diagrams in</p> <ul style="list-style-type: none"> • Prepare the aircraft for details. • Carry the drone using the landing gear and place it in the drone case. • Unlock and remove the landing gear. Note: watch for the propellers while removing the landing gear - move the gear so it does not impact the propellers. Replace the landing gear in the slots on the case. • Power down and store the remote controller in the case. 	Pilot
Data QA/QC	<p>P1:</p> <ul style="list-style-type: none"> • Open three images from the start, middle and end of mission. Check that there is no blurring. • Right click on each image to check that White Balance is 'Manual', shutter speed is 1/1000 s, aperture is f/5.6 <p>L1: Check that the DJI lidar mapping mission folder size is as expected for the mission.</p>	Spotter
Data backup	<ul style="list-style-type: none"> • Check that SD cards (or microSD for L1) did not fill up – might indicate missed captures. • Backup memory cards to SSD. Folder structure in SSD: date/plot/sensor/level_0/ • Use a folder comparison tool (e.g., WinMerge) to check that all data was backed up. 	Spotter

Revision History

Date	Revision	Changes
24/09/2021	1.0	Initial version
27/10/2021	1.1	Updated after review by Darren
15/11/2021	1.2	Updated after Oval trial flight
19/11/2021	1.3	Review by Darren and formatting updates
13/12/2021	1.4	Review by Arko
09/02/2022	1.5	Updated following review by Shaun Levick
21/04/2022	1.6	Updated on review by Ramesh Raja Segaran
09/05/2022	1.7	Added screenshots and notes for field testing
11/05/2022	1.8	Update prep/pack list with additional checks and equipment
02/08/2022	2.0	Updates from Calperum field campaign with TERN Surveillance in May 2022
27/09/2022	2.1	Consolidated imagery and lidar data collection protocol to one document.
3/11/2022	3.0	Incorporated updates based on several reviews from team.