

DJI L1 Operation Guidebook

V1.1 (June-2022)



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1. Supported Firmware and Software Versions

Before you proceed, please confirm that your device's firmware/software version is the latest by checking the Release Notes on DJI website:

<https://www.dji.com/zenmuse-l1/downloads>

<https://www.dji.com/matrice-300/downloads>

The latest firmware versions as of June, 2022 are shown in the table below and are used as the basis for the information within this guidebook. This guidebook will be updated to reflect changes from future firmware updates.

M300 RTK Aircraft	V04.00.03.00
M300 RTK Remote Controller	V04.00.03.00
Pilot App	V4.0.1.21
Zenmuse L1	V04.00.01.06
DJI Terra	V3.1.4

Note: The parameters provided in this guidebook are for reference only and do not apply to all scenarios. Please adjust them as appropriate to suit the actual conditions.

2. Parameter Overview

2.1 Introduction to DJI L1

The Zenmuse L1 integrates a Livox LiDAR module, a high-accuracy IMU, and a camera with a 1-inch CMOS on a 3-axis stabilized gimbal. When used with Matrice 300 RTK and DJI Terra, the L1 forms a complete solution that gives you real-time 3D data throughout the day, efficiently capturing the details of complex structures and delivering highly accurate reconstructed models.

1. Gimbal Connector
2. Pan Motor
3. LiDAR Sensor
4. RGB Mapping Camera
5. Auxiliary Positioning Vision Sensor
6. microSD Card Slot
7. Tilt Motor
8. Roll Motor

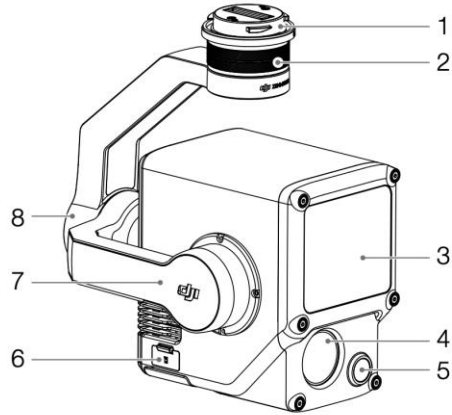


Figure: L1 components

2.2 Specifications

General	
Product name	ZENMUSE L1
Dimensions	152×110×169 mm
Weight	930±10 g
Power	Typical: 30 W; Max: 60 W
IP Rating	IP54
Supported Aircraft	Matrice 300 RTK
Operating Temperature Range	-20° to 50° C (-4° to 122° F) when using RGB mapping camera: 0° to 50° C (32° to 122° F)
Storage Temperature Range	-20° to 60° C (-4° to 140° F)
System Performance	
Detection Range	450 m @ 80% reflectivity, 0 klx 190 m @ 10% reflectivity, 100 klx
Point Rate	Single return: max. 240,000 pts/s Multiple return: max. 480,000 pts/s
System Accuracy (RMS 1σ)*	Horizontal: 10 cm @ 50 m Vertical: 5 cm @ 50 m
Real-Time Point Cloud Coloring Coding	Reflectivity, Height, Distance, RGB
LiDAR	
Laser Wavelength	905 nm
Beam Divergence	0.03° (Horizontal) × 0.28° (Vertical)
Ranging Accuracy (RMS 1σ)**	3 cm @ 100 m
Maximum Returns Supported	3
Scan Modes	Non-repetitive scanning pattern, Repetitive scanning pattern
FOV	Non-repetitive scanning pattern: 70.4° (horizontal) × 77.2° (vertical) Repetitive scanning pattern: 70.4° (horizontal) × 4.5° (vertical)
Laser Safety	Class 1 (IEC 60825-1:2014) (Eye Safety)

Inertial Navigation System	
IMU Update Frequency	200 Hz
Accelerometer Range	±8 g
Angular Velocity Meter Range	±2000 dps
Yaw Accuracy (RMS 1σ)*	Real-time: 0.3°, Post-processing: 0.15°
Pitch/Roll Accuracy (RMS 1σ)*	Real-time: 0.05°, Post-processing: 0.025°
Auxiliary Positioning Vision Sensor	
Resolution	1280×960
FOV	95°
RGB Mapping Camera	
Sensor Size	1 in
Effective Pixels	20 MP
Photo Size	5472×3078 (16:9), 4864×3648 (4:3), 5472×3648 (3:2)
Focal Length	8.8/24 mm (equivalent)
Shutter Speed	Mechanical shutter speed: 1/2000-8 s Electronic shutter speed: 1/8000-8 s
ISO	Video: 100-3200 (auto), 100-6400 (manual) Photo: 100-3200 (auto), 100-12800 (manual)
Aperture Range	f/2.8 - f/11
Supported File System	FAT (≤32 GB); exFAT (>32 GB)
Photo Format	JPEG
Video Format	MOV, MP4
Video Resolution	H.264, 4K: 3840×2160 30p
Gimbal	
Stabilized System	3-axis (tilt, roll, pan)
Angular Vibration Range	±0.01°
Mount	Detachable DJI SKYPORT
Controllable Range	Tilt: -120° to +30°, Pan: ±320°
Operation Modes	Follow/Free/Re-center
Data Storage	
Raw Data Storage	Photo/IMU/Point cloud/GNSS/Calibration files
Supported microSD Cards	microSD: Sequential writing speed 50 MB/s or above and UHS-I Speed Grade 3 rating or above; Max capacity: 256 GB
Recommended microSD Cards***	SanDisk Extreme 128GB UHS-I Speed Grade 3 SanDisk Extreme 64GB UHS-I Speed Grade 3 SanDisk Extreme 32GB UHS-I Speed Grade 3 SanDisk Extreme 16GB UHS-I Speed Grade 3 Lexar 1066x 128GB U3 Samsung EVO Plus 128GB
Post-Processing Software	
Supported Software	DJI Terra
Data Format	DJI Terra supports exporting standard format point cloud models: Point cloud format: PNTS/LAS/PLY/PCD/S3MB

* The accuracy was measured under the following conditions in a DJI laboratory environment: after a 5-minute warm up, using Mapping Mission with IMU Calibration enabled in DJI Pilot, and with the RTK in FIX status. The relative altitude was set to 50 m, flight speed to 10 m/s, gimbal pitch to -90°, and each straight segment of the flight route was less than 1000 m. DJI Terra was used for post-processing.

** Measured in an environment of 25° C (77° F) with a target of 80% reflectivity at a distance of 100 meters. Results may vary depending on test conditions.

*** The recommended microSD cards may be updated in future. Visit the DJI official website for the latest information.

2.3 Key Parameters

2.3.1 Detection Range

This refers to the farthest measurable distance of the LiDAR. This parameter varies greatly based on the actual environmental conditions. Main influencing factors include the target's surface reflectivity, the target's shape, and ambient light interference. Manufacturers generally indicate the LiDAR's measurable distance under different illumination and reflectivity. In the case of DJI L1, its LiDAR supports a measurable range of 450 meters under 0 klx when the measured target's reflectivity is 80%, and 190 meters under 100 klx when the measured target's reflectivity is 10%.

"450 m @ 80%, 0 klx" means that, when the solar illuminance is 0 klx and the measured target's reflectivity is greater than 80% (the reflectivity of a concrete floor or a road surface is 15%–30%, and the reflectivity of a white plaster wall is 90%–99%), the maximum measurable distance is 450 m.

"190 m @ 10%, 100 klx" means that when the solar illuminance is 100 klx and the measured target's reflectivity is greater than 10% (the reflectivity of a concrete floor or a road surface is 15%–30%, and the reflectivity of a white plaster wall is 90%–99%), the maximum measurable distance is 190 m.

Most LiDAR sensors on the market use diffuse reflection objects (with a reflectivity of 90%) as the testing benchmark. However, this parameter has limited practical significance. The measurable distance at a reflectivity of 10% has greater practical significance.

2.3.2 Point Cloud Data Rate

Point cloud data rate is also called sampling frequency or pulse frequency. It refers to the maximum number of laser beams emitted by the laser within a unit of time. Given the same conditions, a higher frequency means a higher number of measured points and a higher operating efficiency.

The L1's point cloud data rate is affected by which echo mode is used. Three echo modes are available: single-echo, dual-echo, and triple-echo mode. In single-echo or dual-echo mode, the maximum sampling frequency is 240 kHz (that is, 240,000 laser beams emitted per second). In triple-echo mode, the maximum sampling frequency is 160 kHz. Theoretically, the maximum number of points measured per second in the dual-echo or triple-echo mode is 480,000. In practice, the number of points measured in the second and third echoes are very small. The number of measured points is the highest at a sampling frequency of 240 kHz in dual-echo mode. **Therefore, it is recommended to choose the dual-echo mode if you need more measured points, or choose the triple-echo mode if you need higher penetration.**

2.3.3 Scan Mode and FOV

The L1 can produce different scan shapes in different scan modes. Please note that the shape formed by the LiDAR on the ground is determined by the laser scan mode, the flight direction and speed, and the terrain. **The Livox LiDAR on DJI L1 supports non-repetitive scan mode and repetitive scan mode.**

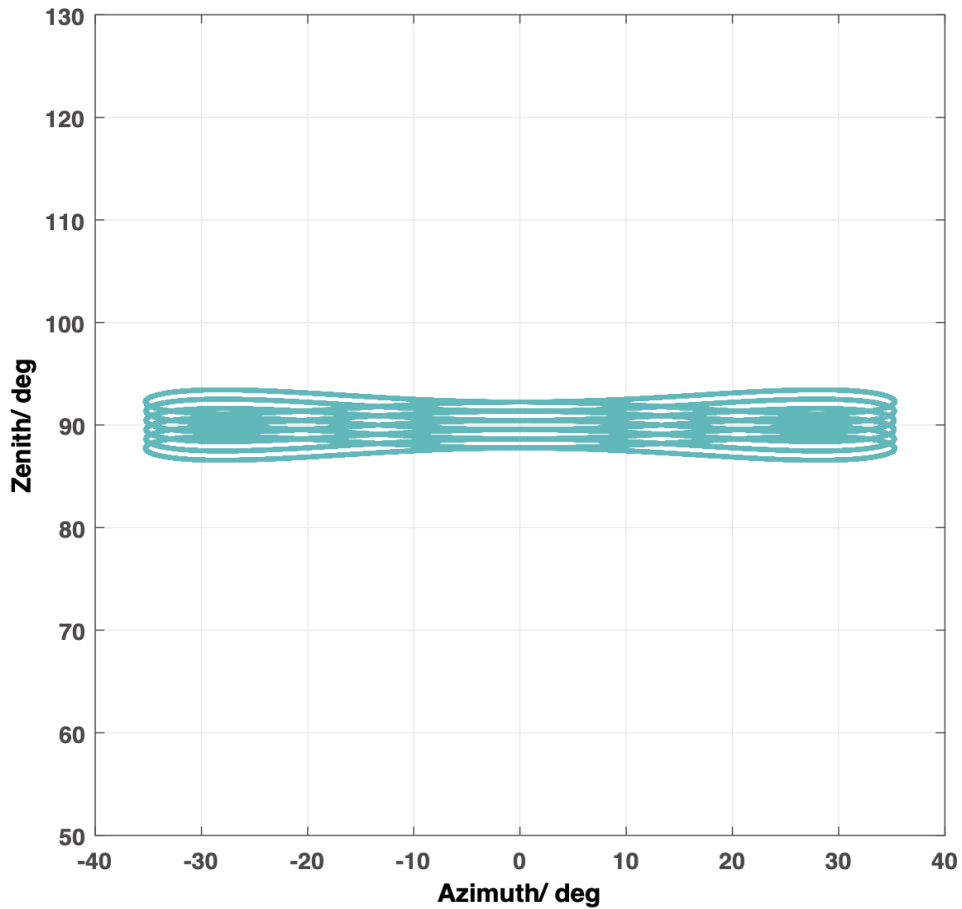


Figure: Scan shapes formed in 0.1s with repetitive scan mode of L1

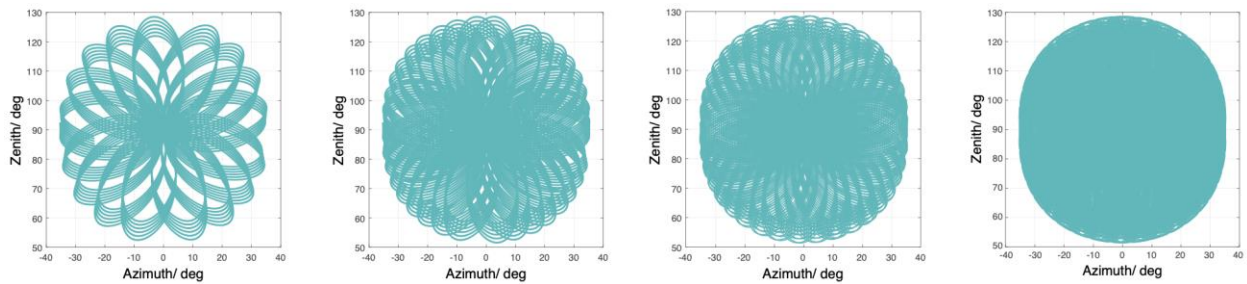


Figure: Scan shapes formed in 0.1s, 0.2s, 0.5s, and 1s with non-repetitive scan mode of L1

Field of view (FOV), also known as the scan angle, represents the angle covered by the LiDAR sensor, or the angle at which laser signals are emitted. The FOV of L1 varies in different scan modes

Repetitive scan: FOV $70.4^{\circ} \times 4.5^{\circ}$. In this scan mode, the vertical field is narrower, but the accuracy is higher. This mode is recommended for high-accuracy surveying and mapping.

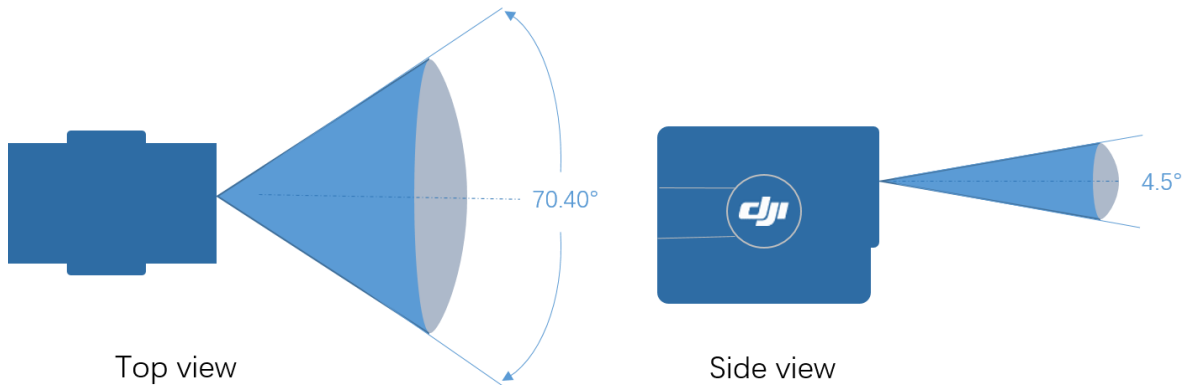


Figure: Scan angle in repetitive scan mode

Non-repetitive scan: FOV $70.4^{\circ} \times 77.2^{\circ}$. In this scan mode, the vertical FOV is wider. This mode is recommended for data capturing of complex structures, such as building facades.

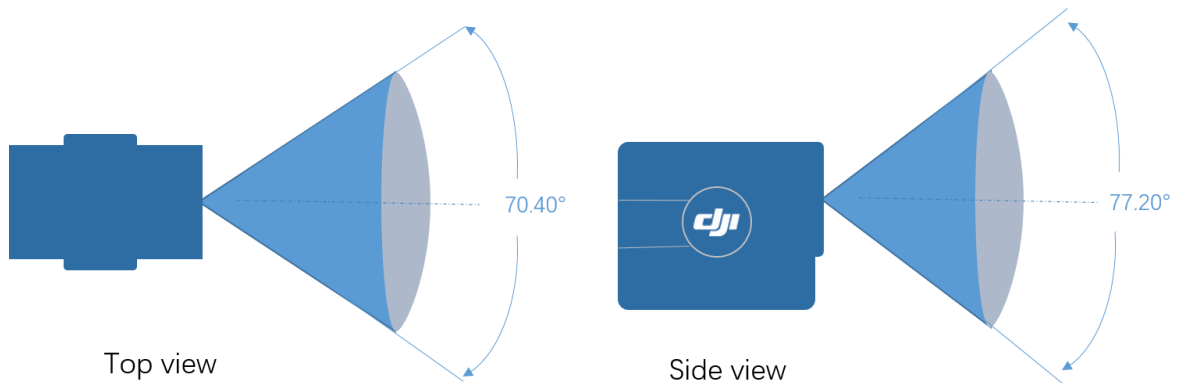


Figure: Scan angle in non-repetitive scan mode

Note:

The effective range of L1 varies based on where the object is within the FOV. The closer to the edge of the L1's FOV, the shorter the effective range.

The closer to the center of the L1's FOV, the farther the effective range. See the figure below for details.

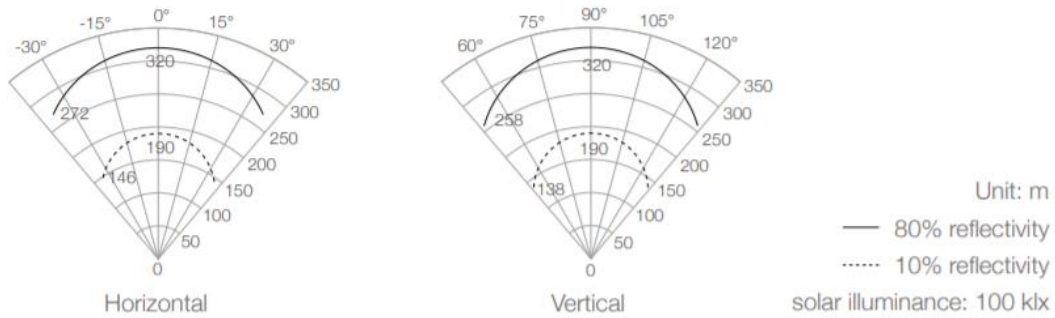


Figure: Effective range of L1 within the FOV

2.3.4 Beam Divergence Angle

A divergence angle, if any, of the beams from the LiDAR can produce light spots which increase in size as the distance increases.

2.3.5 Ranging Accuracy

Ranging accuracy refers to the discrepancy between the LiDAR-measured distance and the actual distance. Ranging accuracy is different from system accuracy in that the former does not represent the accuracy of the final result.

3. DJI L1 Field Operation Guide

3.1 RTK/PPK

For the purpose of point cloud data processing, L1 needs to have centimeter-accurate **positioning data with either RTK or PPK**. The **RTK FIX status needs to be maintained throughout the duration of the L1 flight mission**. If RTK connection stability cannot be guaranteed, PPK could also be used. The detailed workflows of each method are described below.

3.1.1 Ntrip (Custom Network RTK) Solution

In the RTK settings page of the DJI Pilot App, you can choose Custom Network RTK, and enter the NTRIP account information to connect to the Ntrip service. (Note: The remote controller must be

connected to the internet through WiFi or the 4G dongle). If the Ntrip service is connected and the RTK status is FIX throughout the flight, the base station file will be automatically saved in the results file.

3.1.2 D-RTK 2 Base Station Solution

Set up D-RTK 2 at a known point. Switch the D-RTK 2 to Mode 5. In the RTK settings page of the DJI Pilot App, select D-RTK 2 as RTK Service Type. Then link the aircraft to the D-RTK 2. In the RTK settings page, go to the Advanced Settings (Pin: 123456 by default). Modify the D-RTK 2's coordinates to the coordinates of the known point.

When high absolute accuracy is needed, **you must set up the D-RTK 2 at a known point instead of directly using its self-convergent GNSS coordinates.** This is because the static convergent coordinates of the D-RTK 2 have an error in the meter-level. If the D-RTK 2 position is not corrected with known coordinates, the absolute accuracy of the result cannot be guaranteed and the point cloud data from multiple flights might not be consistent.

Note when setting up the D-RTK2 at a known point it is important to add the rod height. When post processing, the default output will be WGS84 unless otherwise selected.

After setting up the D-RTK 2 base station, you can connect the aircraft to the D-RTK 2 for the flight mission.

Alternatively, you can use the PPK method where no real-time connection between the drone and the D-RTK 2 is required. **With the PPK method, the distance between the D-RTK 2 and the aircraft is recommended to be within 10km.** Select "None" in the RTK service type. Turn off the RTK Positioning switch to go to GNSS flight mode. After data collection for the mission is completed, use a Type C cable to connect the D-RTK 2 to a PC. Copy the base station file with a suffix of .DAT for the corresponding time slot and paste the file in the same folder as L1's result file. In this way, DJI Terra will use the D-RTK 2 data for PPK processing to calculate the accurate POS data.

3.1.3 Third-party RTK Solution

A third-party RTK base station device can also be used for PPK. In this case, no connection is required between the drone and the RTK base station. The distance between the third-party RTK base and the aircraft is recommended to be within 10km. After the flight is completed, search for the base station file for the corresponding time slot and rename the file following the suffix rules below. Then, copy the base station file to the same directory as the LiDAR files. **If the third-party RTK base station has no coordinates input for the known point, you can open the .O base station file in text form and modify the "APPPO POSITION XYZ" value to be the corrected coordinate of the RTK base in the ECEF coordinate system.**

The L1 supports the following base station protocols and versions. (Note: The name of the renamed file DJI_YYYYMMDDHHMM_XXX should be consistent with the name of the .RTK file in the point cloud data directory). If there is a .RTB file in the same directory, it needs to be deleted.

Data format	Version	Message	Rename to
Rinex	V2.1.x	/	DJI_YYYYMMDDHHMM_XXX.obs
	V3.0.x	/	
RTCM	V3.0	1003, 1004, 1012, 1014	DJI_YYYYMMDDHHMM_XXX.rtcn
	V3.2	MSM4, MSM5, MSM6, MSM7	
OEM	OEM4	RANGE	DJI_YYYYMMDDHHMM_XXX.oem
	OEM6	RANGE	
UBX	/	RAWX	DJI_YYYYMMDDHHMM_XXX.ubx

Table: RTK protocol types supported by L1

Note: Base station files are necessary for L1 data processing. If neither Ntrip nor PPK files exist, L1 data cannot be processed. If the RTK is disconnected during the flight, the mission will be automatically paused to ensure data validity.

3.2 IMU Calibration

IMU calibration is a prerequisite for LiDAR accuracy. It is a key factor that impacts the final point cloud accuracy. For the L1, please note that IMU calibration is required **before, during (every 100s of the flight mission), and after data collection** to ensure the inertial navigation system accuracy.

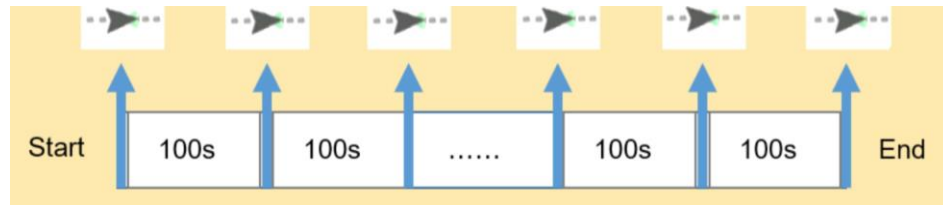


Figure: IMU calibration is needed before, during, and after the flight

Below are two ways of IMU calibrations that can be used during manual/mission (flight route) flight.

3.2.1 Calibration Flight Button in Manual Flight

Fly the drone to a proper altitude, switch to the camera screen, and click on the "Calibration Flight" button. M300 RTK will automatically fly forward and backward 3 times to calibrate the IMU system at current altitude. Make sure there are no obstacles in the 30m range ahead of the drone.



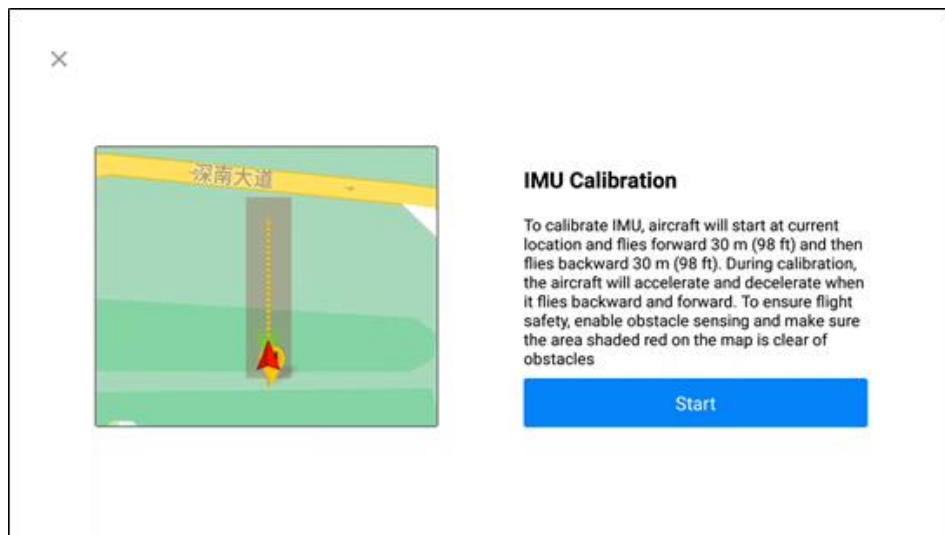
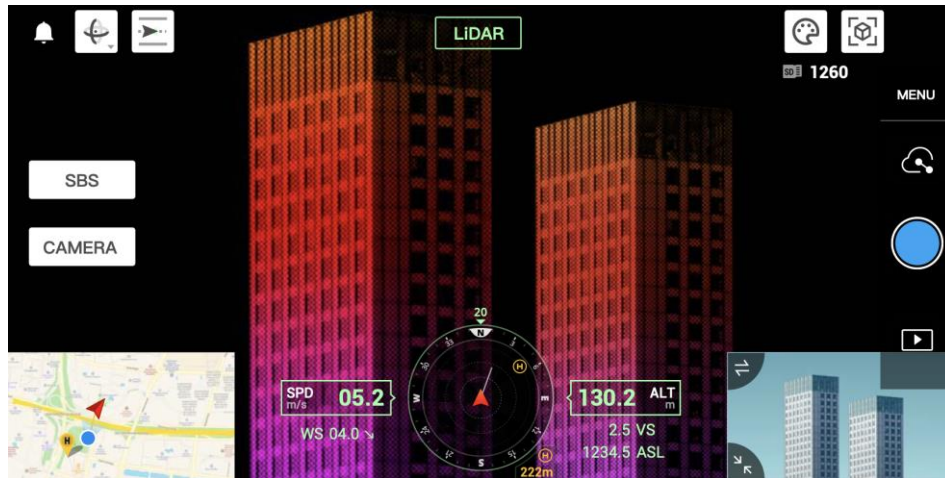


Figure: Manual IMU Calibration Option

3.2.2 IMU Calibration in Mapping/Oblique/Linear Flight Missions

In mapping/oblique flight missions, you can find the toggle “IMU Calibration”. When turned on, acceleration and deceleration calibration flights will be inserted to the flight route at the starting point, the ending point, turning points, and along the route (every 100s). The calibration routes are shown in yellow in the figure below.



Figure: Calibration flight route

For a linear flight mission, the calibration flight route is inserted automatically to the beginning, during the mission (every 100s between two waypoints) and the end of the flight routes.

3.2.3 IMU Calibration in Waypoint Flight Missions

In waypoint flight missions, you can find the IMU Calibration option in the route parameters.

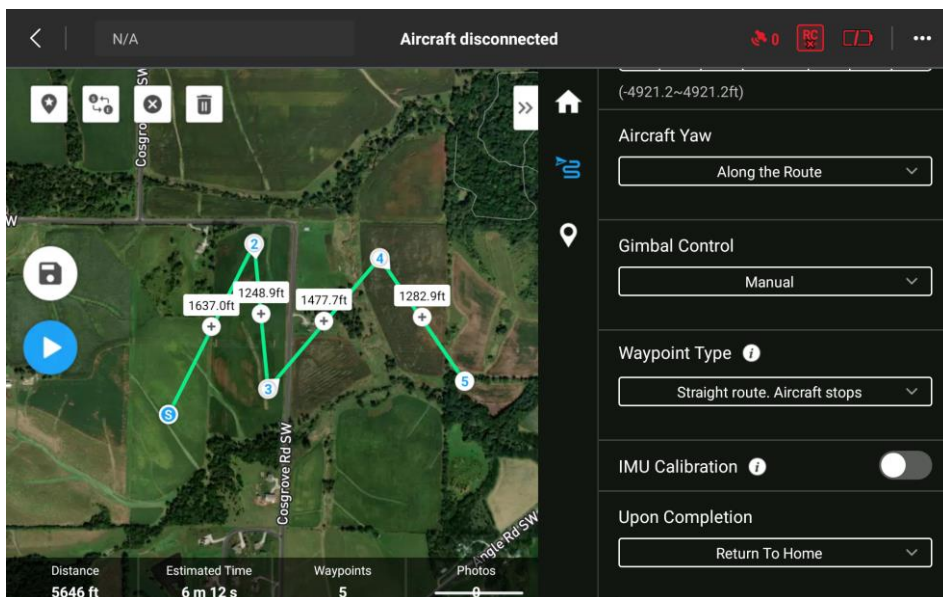


Figure: IMU Calibration option in a waypoint flight mission

In the waypoint settings, you would need to add the action “Start point cloud modeling recording” at the waypoint you want to start at, and add the action “Finish point cloud modeling recording” at the point you would like to end at. In this case, if the IMU Calibration option is turned on, you’ll find the IMU calibration section inserted automatically to the flight route (shown in yellow).

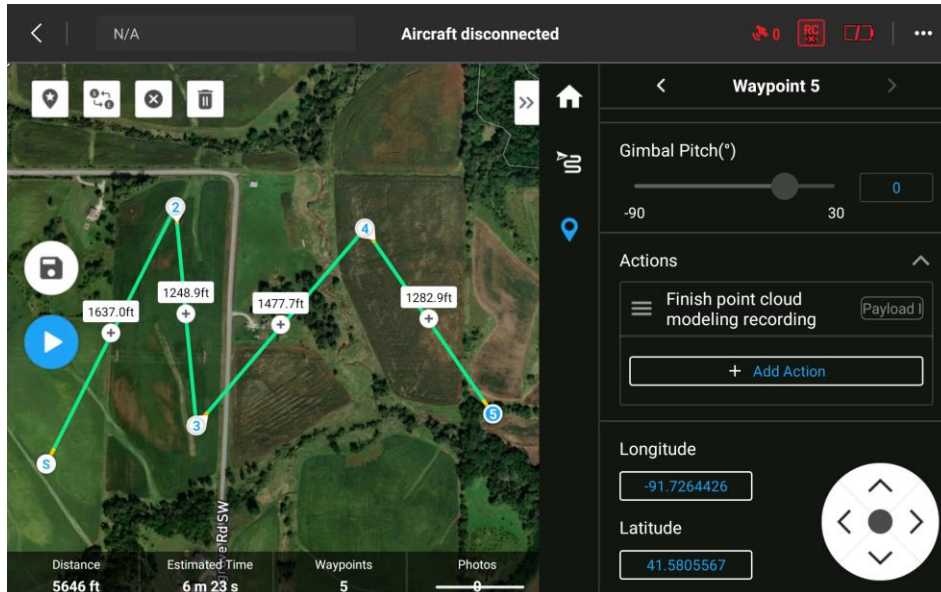


Figure: IMU calibration inserted to waypoint flight mission (Start point cloud modeling at Waypoint 1 and finish at Waypoint 5)

3.3 RGB Camera Recalibration

When the L1 has regular colorization issues, such as multiple lines appearing in the point cloud with ghosting effect, the user will need to recalibrate the internal and external parameters of the RGB camera of L1 following the below steps. Before you start please check your firmware versions referring to [Section 1. Supported Firmware and Software Versions](#).

Note: This is a premium feature included in DJI Terra Pro and more advanced versions.

3.3.1 Calibration data collection

- Create a 2D Mapping mission in DJI Pilot App and draw an area of around 200m*200m; The area should have vertical structures like buildings;
- Camera type: Zenmuse L1 - Lidar Mapping;
- Flight Route Altitude: 100m;
- Speed: 10m/s;

- Enable the “Elevation Optimization” option;
- In Advanced Settings, Side Overlap: 50%;
- In Payload Settings, select “Single Return”, “240 kHz” and “Repetitive Scan”, and enable the “RGB Coloring” option;
- Save the mission;
- In L1 camera settings, disable the camera dewarping;

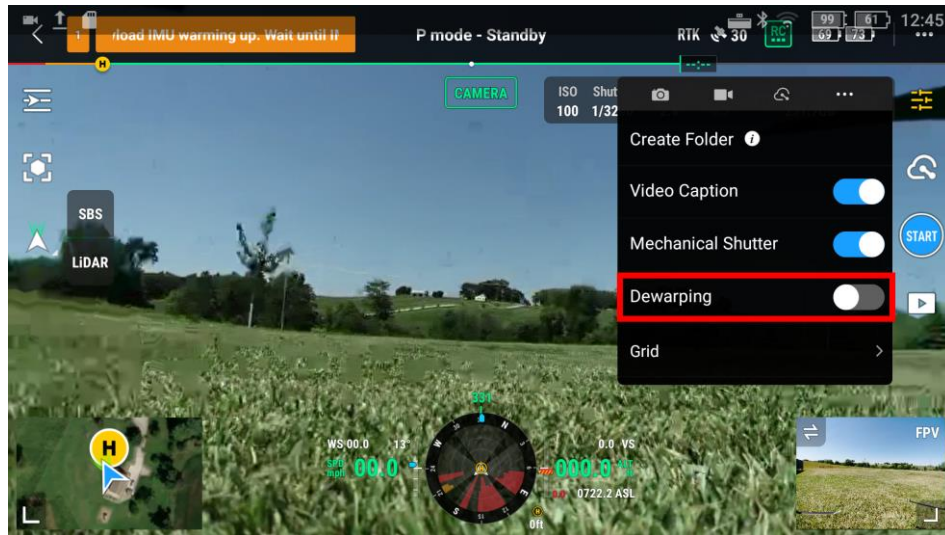


Figure: Dewarping Option in the Camera Settings

- Execute the flight mission and obtain the raw data files collected by L1 and check whether the images are clear and sharp, if not they cannot be used for calibration.

3.3.2 Use DJI Terra software to generate the calibration files

- Use DJI Terra version 3.1.0 or above to create a new “LiDAR Point Cloud Processing” reconstruction mission;
- Import the dataset collected by defining the dataset directory and changing the “Scenarios” option to “Zenmuse L1 Calibration”;
- Start processing in Terra;
- When the reconstruction is completed, please check if the point cloud model colorization is ok or not. If there are still multiple layers or ghosting effects, please repeat step 1) and 2). If the result is ok, you can proceed to use the calibration files from this mission;
- The calibration file with suffix “.tar” can be found under the PROJECT/lidars/terra_L1_cali” directory as shown below:



Figure: Calibration File Directory

3.3.3 Run the calibration files in L1

- Store the calibration file under the root directory of a microSD card and insert into the L1, connect L1 to a M300 RTK and power on the M300 RTK. Wait for about 5 minutes to complete the calibration. There is no App notification during the calibration currently.
- To confirm the calibration process is completed: remove the microSD card from the L1, open the log file with suffix “.txt”, the calibration process is successful if the log file shows “all succeed”.

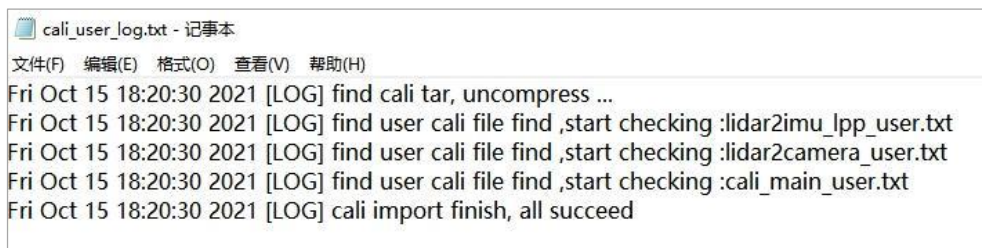
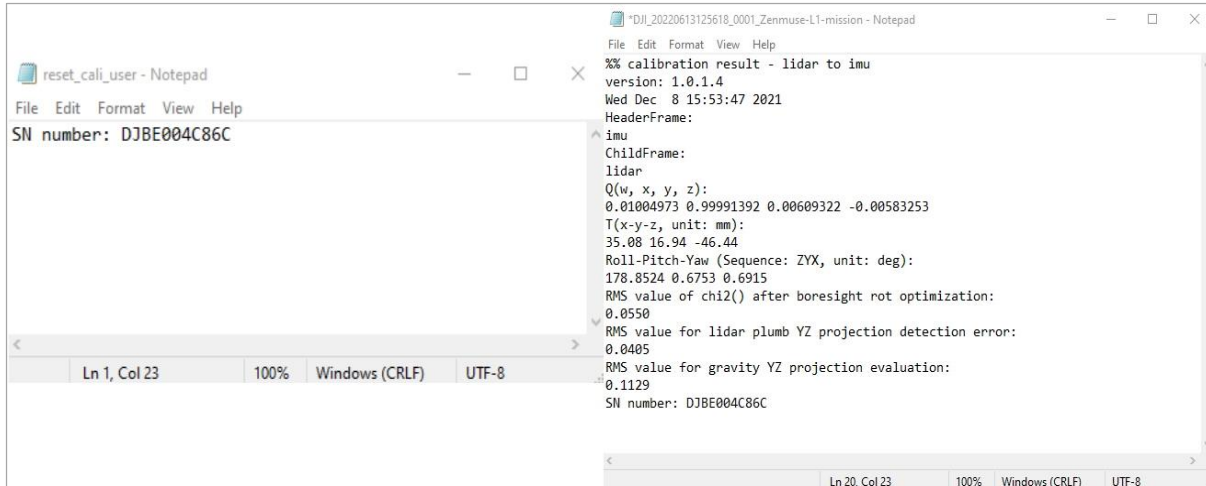


Figure: The txt file will show “all succeed” if the calibration is successful

3.3.4 How to restore factory parameters?

In case you need to restore the factory parameters of the L1 sensor, please follow below steps:

- Create a new .txt text file, and name it as reset_cali_user. Open the file and write the SN serial number of the L1 that needs to be reset, with the format of “SN number: XXXXXXXXXXXXXXXX” (find the SN serial number in the .CLI file that’s saved on the microsd card, or view in the device version information in Pilot app by going to the three dots in the right in manual flight, the three dots sub menu, then About).



- Copy the .txt text file to the root directory of the microSD card, insert the microSD card into the L1 that needs to be calibrated, install the L1 onto the M300 RTK and power on the aircraft, wait about 5 minutes to complete the calibration.
- Record a set of point cloud data, remove the microSD card from the L1. Connect it to a computer and check the .txt format log file. If it displays all succeeded, the reset is successful. Users can also check whether the time parameter of the .CLI file is restored to the factory time.

3.4 Flight Mission Planning

A flight mission of the survey area can be pre-planned with the DJI Pilot App to enable automatic data capture of a polygon area or a strip area. Detailed parameter recommendations for typical scenarios are as below:

3.4.1 Topographic Surveying

This is a typical scenario of LiDAR to generate topographic maps, contour lines, etc. It may also be applicable to forest inventory monitoring by measuring the tree heights and density of the canopy.

Create a "Mapping Mission". You can import the KML file of the target area or manually draw the area on the map. The recommended parameter settings for topographic surveying are as follows:

Category	Parameter Name	Explanation and recommended value
----------	----------------	-----------------------------------

General	Camera type	Zenmuse L1 LiDAR Mapping
	Point Cloud Density	This indicates the number of points per square meter. It is related to parameters such as flight altitude, overlap ratio, flight speed, scan mode. As a core indicator of the data output, point cloud density should be determined first based on the project requirements. Then the flight speed and other parameters should be set based on it.
	IMU Calibration	Enabled
	Altitude Mode	Relative to takeoff point (ALT) is usually selected by default. ASL (EGM96) could be selected if you need to plan the mission with EGM96 altitude.
	Flight Route Altitude	The recommended flight altitude is 50~100 meters. When the ground object's reflectivity is 10%, the L1's measurable distance is 190 meters. The flight altitude should not exceed 150 meters to avoid data loss.
	Target Surface to Takeoff Point	0 by default. This value can be adjusted in case there is an elevation difference between the target surface and takeoff point.
	Takeoff Speed	Can be set to max.

	Speed	Flight speed can be adjusted according to the desired point cloud density. 5-10 m/s is recommended.
Advanced settings	Side Overlap	Recommended to be at least 50%.
	Course Angle	Can be adjusted to your needs
	Margin	0 by default. Can be adjusted to your needs
	Photo Mode	Timed Interval Shots
Payload Settings	Echo Mode and Lidar Sample Rate	Triple Echo & 160kHz can be used for better penetration; Dual Echo & 240kHz can be used for maximum points;
	Scan Mode	Repeat
	RGB Coloring	On

How to enable Terrain Follow Mission?

Terrain-follow Flight

DJI L1 supports terrain-follow flight for waypoint, mapping, and corridor flight plans. With the DJI Pilot app to perform a precise terrain follow flight, enable terrain follow in the mapping mission and import the DSM file including the altitude information.

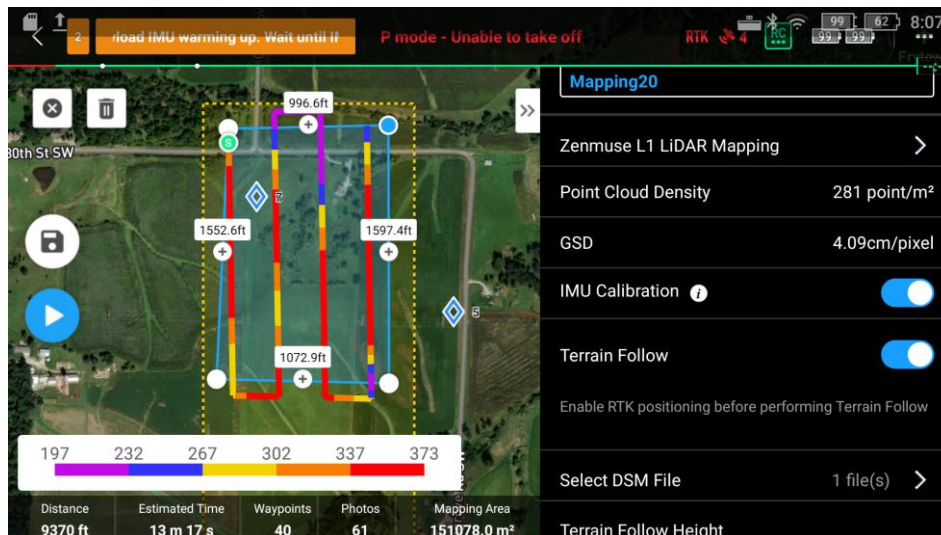
To prepare files for terrain follow missions:

The DSM files of the measurement area can be obtained through the following two methods:

1. Collect the 2D image data of the mapping area and perform a 2D reconstruction through DJI Terra. When processing, make sure to select Fruit Tree mode and use WGS84 as the coordinate system. After processing with DJI Terra, a .tif file will be generated and it can be imported using a microSD to the remote controller
2. Download the terrain mapping data from a geobrowser and import it to the microSD card of the remote controller.

Make sure the DSM file is a geographic coordinate system file, and not a projected coordinate system file. Otherwise, the imported file may not be recognized. It is recommended that the resolution of the imported file should be no more than 10 meters.

Importing Files:



1. Enable Terrain Follow and IMU Calibration in Mapping mission
2. Tap “Select DSM File”, tap +, select and import the file from the microSD card

(I) Prepare the DSM file of the survey area

For a Terrain Follow mission, a DSM file including the elevation information of the terrain needs to be imported. Please note that the DSM file used for Terrain Follow Mission must use the WGS84 coordinate system, rather than projected coordinates. The file should not exceed 20 MB in size, with a preferred resolution of less than 10 meters.

The DSM file of the test area can be obtained in either of the two methods below:

- A. Collect the 2D data of the target area and perform 2D reconstruction in DJI Terra with Fruit Tree mode. A “gsddsm.tif” file will be generated in the “map” folder of the mission files. It can be imported to DJI Pilot App for terrain follow.

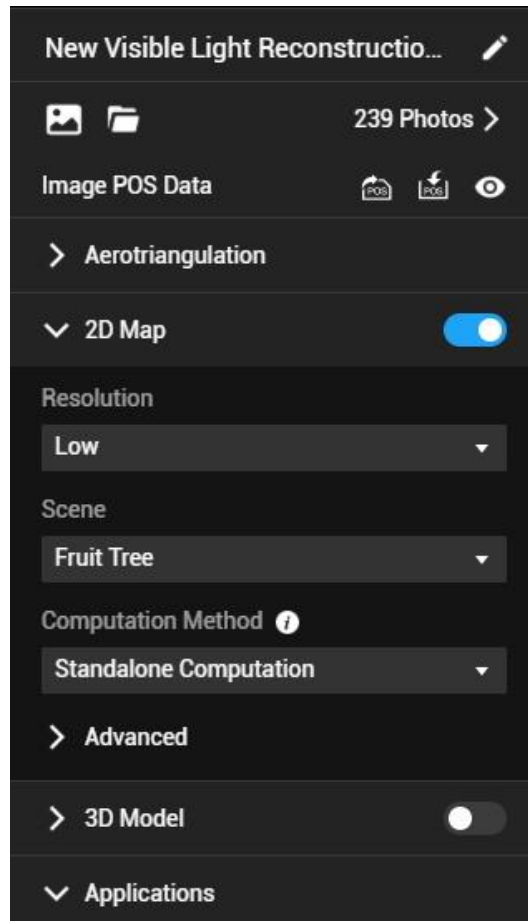


Figure: Fruit Tree mode & Low Resolution need to be selected in Terra

Name	Date modified	Type	Size
AT	6/24/2022 6:24 PM	File folder	
images	6/24/2022 6:22 PM	File folder	
map	6/24/2022 6:25 PM	File folder	

17	6/24/2022 6:25 PM	File folder	
18	6/24/2022 6:25 PM	File folder	
report	6/24/2022 6:25 PM	File folder	
dsm.prj	6/24/2022 6:25 PM	PRJ File	1 KB
dsm.tfw	6/24/2022 6:25 PM	TFW File	1 KB
dsm	6/24/2022 6:25 PM	TIF File	2,989 KB
gsddsm.prj	6/24/2022 6:25 PM	PRJ File	1 KB
gsddsm.tfw	6/24/2022 6:25 PM	TFW File	1 KB
<input checked="" type="checkbox"/> gsddsm	6/24/2022 6:25 PM	TIF File	44 KB
result.prj	6/24/2022 6:25 PM	PRJ File	1 KB
result.tfw	6/24/2022 6:25 PM	TFW File	1 KB
result	6/24/2022 6:25 PM	TIF File	8,466 KB
SDK_Log	6/24/2022 6:25 PM	Text Document	86 KB

Figure: Click on the folder icon, then go to the map folder to find the “gsddsm.tif” file

B. You can also download the terrain elevation data from an open database such as SRTM.

(2) Import the DSM file to DJI Pilot App

Terrain Follow and IMU calibration flight options can be enabled at the same time.

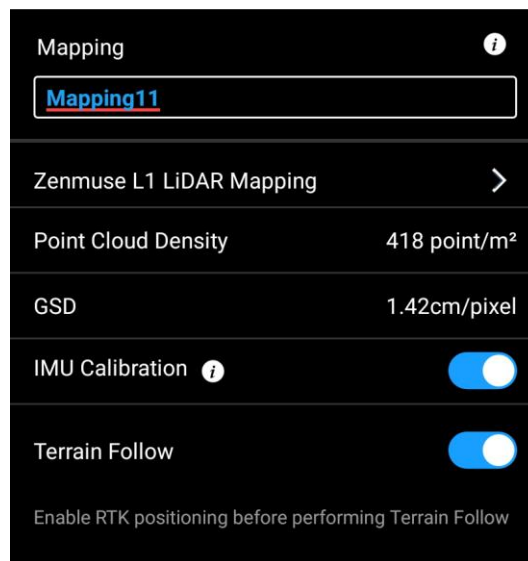


Figure: Terrain Follow Option in DJI Pilot App

You can put the DSM file in a SD card and insert it to the RC. Then click on “Select DSM File” and select the DSM file in the SD card.

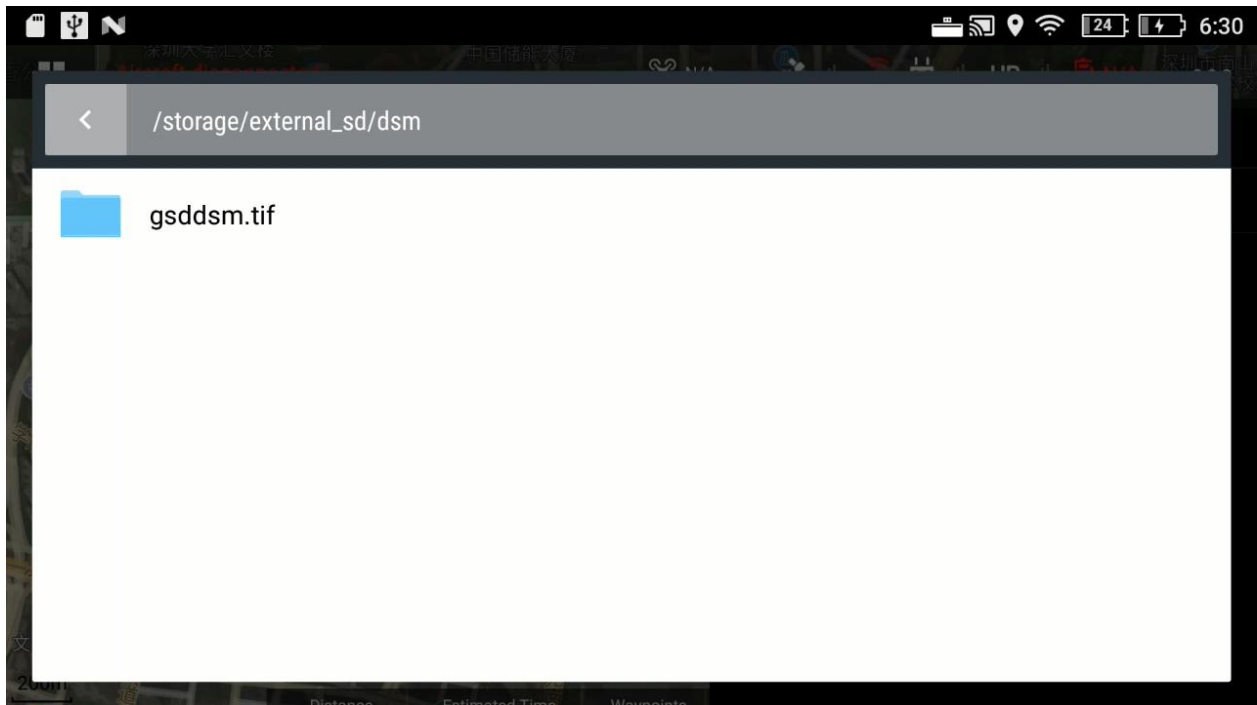


Figure: Select the DSM file in the SD card

You can see the area covered by the DSM file on the map now. Then you can plan the survey area within this area.

Terrain Follow is recommended when the elevation difference of the survey area is greater than 100 meters.

3.4.2 Riverbank / Road Surveying

When the survey area is a narrow strip of land such as roads, railways, riverbanks, etc., Linear Flight Mode can be used for L1 mission planning.

Category	Parameter Name	Explanation and recommended value
General	Camera type	Zenmuse L1 LiDAR Mapping

	Single Route	Off by default If enabled, the aircraft will only fly a single flight path along the route.
	Point Cloud Density	This indicates the number of points per square meter. It is related to parameters such as flight altitude, overlap ratio, flight speed, scan mode. As a core indicator of the data output, point cloud density should be determined first based on the project requirements. Then the flight speed and other parameters should be set based on it.
Flight Band	Left/Right extension length	Can be adjusted based on the width of the survey area. To ensure accuracy, it is recommended to adjust this value to have at least 3 flight routes covering one band.
	Flight band cutting distance	As default
Flight Band-Payload Settings	Echo mode and Lidar Sample Rate	Triple Echo & 160kHz can be used for better penetration; Dual Echo & 240kHz can be used for maximum points;
	Scan mode	Repeat
	RGB Coloring	On

Flight Route	Include Center Line	Recommended to be enabled.
	Altitude Mode	Relative to takeoff point (ALT) by default
	Flight Route Altitude	50-100 meters is recommended; maximum 150 meters
	Target Surface to Takeoff point	0 by default
	Speed	Flight speed can be adjusted according to the desired point cloud density. 8-12 m/s is recommended.
	IMU Calibration	Enabled
	Photo Mode	Timed Interval Shot
Flight Route-Advanced Settings	Side Overlap	Recommended to be at least 50%.

3.4.3 Powerline

L1 can be used to collect the point cloud data of transmission lines and the power pylons. As there are undulations in the power line corridor, the recommended workflow is to use the “Live Mission Record” function to create a **waypoint flight mission** so that we can fly with variable heights.

- (1) In the DJI Pilot App, go to Flight Route - Create a Route - Waypoint - Live Mission Rec. Note that you need to record in RTK mode;
- (2) Fly the M300 RTK 10-20m above the power pylon and record the current point by pressing the C1 button.



Figure: View from the top of a power pylon to record a waypoint (you can adjust the gimbal to be -90° and adjust the aircraft position)

- (3) Repeat this action for all structures within the mission area.
- (4) Save the mission;
- (5) Edit the mission parameters according to the table below:

Category	Parameter Name	Explanation and recommended value
General settings	Gimbal	Zenmuse L1
Route settings	Speed	6-10m/s
	Aircraft Yaw	Along the Route

	Gimbal Control	Manual
	Waypoint Type	Straight route. Aircraft stops
	IMU Calibration	On
	Power Saving Mode	Off
	Upon Completion	Return to Home by default
Waypoint settings	First waypoint	Add an action "Gimbal Pitch Rotation" and set the degree to be -90° Add an action "Timed Interval Shot" and "Start point cloud modeling recording"
	Last waypoint	Add an action "Finish point cloud modeling recording"
L1 payload settings (in the MENU button)	Sampling Rate	240 kHz
	Scanning Mode	Non-repetitive
	Return Mode	Dual
	RGB Coloring	On

3.5 Checkpoint Setup

In topographic surveying missions, checkpoints can be used to verify the point cloud accuracy. The output result from the L1 is 3D point cloud data in LAS format. Unlike the 3D models obtained with visual cameras, the point cloud contains no structural information, so its checkpoints differ from those in visible light surveying. If you use normal photogrammetry markers and mark the checkpoints in RGB mode, there will be an extra error due to the colorization. Please note the GCP management feature is not supported for L1 data in Terra.

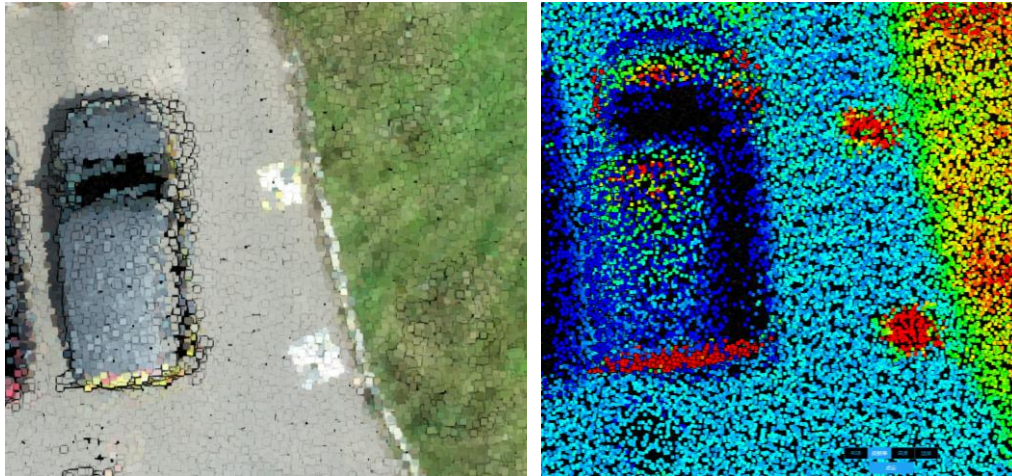


Figure: Example of normal photogrammetry checkpoints – not recommended for LiDAR as you cannot tell the center of it in reflectivity mode

Two types of checkpoints are recommended for LiDAR, as shown below:

3.5.1 3D Checkpoints

L1 point clouds can be displayed in reflectivity mode. Therefore, if the checkpoints are marked with significant differences in reflectivity, they can be clearly recognized in the point cloud model. Highly reflective points are recommended to be used for checkpoint markings. The checkpoint size should be greater than 1m x 1m. When measuring the checkpoint in DJI Terra, you can use the RGB display mode to roughly locate the checkpoint and then switch to reflectivity display mode to accurately measure the coordinate of the center of the checkpoint.



Figure: Example of a 3D checkpoint in the field (the white paint is highly reflective while the black paint is non-reflective)

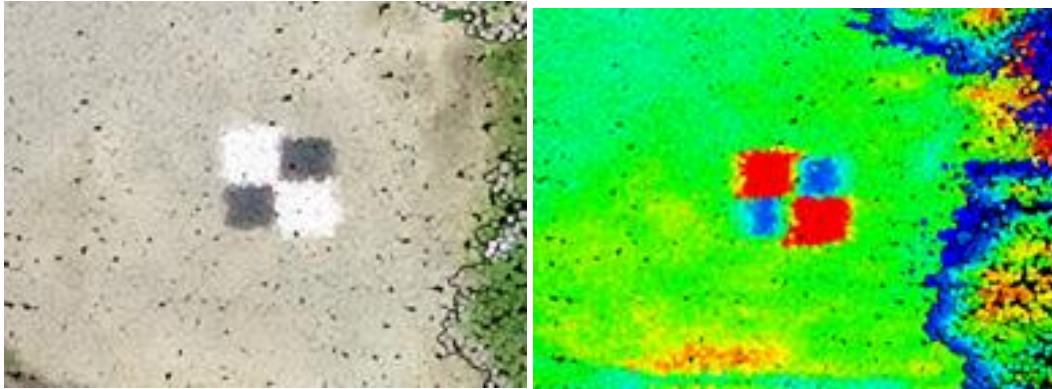


Figure: Checkpoints shown in the point cloud (left: RGB; right: reflectivity)

In addition, if there are objects with sharp reflectivity differences in the survey area, such as a zebra crossing, they can be also used as checkpoints.

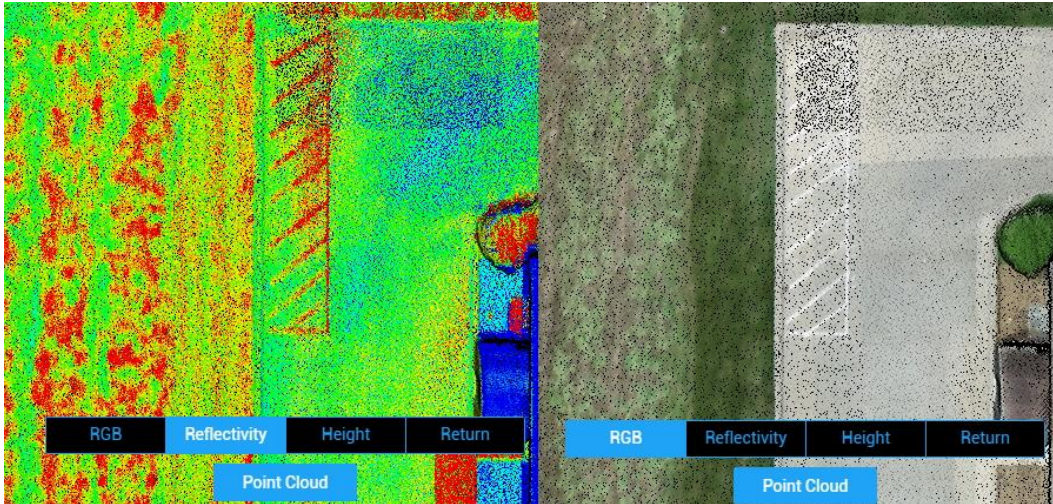


Figure: Parking Lot lines in the point cloud result (left: reflectivity; right: RGB)

3.5.2 Elevation Checkpoints

When you use third-party point cloud analysis software such as TerraSolid, LiDAR360 or Point Cloud Automata, they may provide the feature to output an elevation accuracy report. Usually, the elevation accuracy check feature is based on the assumptions that the horizontal accuracy of the LiDAR system can be neglected, and the points near the checkpoint are all on the same elevation plan.

Therefore, it is recommended to set up the elevation checkpoint on a flat surface of at least 1m*1m in size. The checkpoints should be evenly distributed in the survey area and have differences in elevation, rather than all being located on the same plane. To test the penetrability of LiDAR, it is recommended to set a certain number of checkpoints under trees.

Use	Number	Easting	Northing	Known Z	Laser Z	Dz
<input checked="" type="checkbox"/>	2000	496011.90	7451657.23	257.547	257.606	+0.059
<input checked="" type="checkbox"/>	2001	496016.24	7451659.99	257.481	257.528	+0.047
<input checked="" type="checkbox"/>	2002	496017.43	7451662.23	257.430	257.512	+0.082
<input checked="" type="checkbox"/>	2003	496019.28	7451663.93	257.465	257.541	+0.076
<input checked="" type="checkbox"/>	2004	496021.41	7451665.71	257.466	257.519	+0.053
<input checked="" type="checkbox"/>	2005	496045.07	7451648.91	257.573	257.587	+0.014
<input checked="" type="checkbox"/>	2006	496044.68	7451648.50	257.562	257.610	+0.048
<input checked="" type="checkbox"/>	2007	496043.53	7451647.54	257.593	257.649	+0.056
<input checked="" type="checkbox"/>	2008	496042.92	7451646.99	257.617	257.648	+0.031
<input checked="" type="checkbox"/>	2009	496041.54	7451645.93	257.642	257.686	+0.044
<input checked="" type="checkbox"/>	2010	496040.87	7451645.38	257.641	257.694	+0.053
<input checked="" type="checkbox"/>	2011	496039.66	7451644.42	257.661	257.721	+0.060
<input checked="" type="checkbox"/>	2012	496039.01	7451643.82	257.683	257.727	+0.044
Average magnitude		0.0623		Average dz		+0.0623
Std deviation		0.0230		Minimum dz		+0.0140
Root mean square		0.0662		Maximum dz		+0.1170

Figure: An elevation accuracy report produced by TerraSolid

3.6 Field Data Collection

3.6.1 Power on L1 for Warmup

Before recording data, you need to attach the L1 to the single-downward gimbal of M300 RTK and power it on to warm up the L1. The warmup takes about 3–5 minutes. Wait until a “Payload IMU warmed up” prompt appears.

3.6.2 Flight Mission Execution

If the IMU Calibration feature is enabled in the mission settings, the drone will automatically perform IMU calibration by performing a shuttle flight. No data will be collected during the calibration.

During the flight, you can switch between Camera, LiDAR, and SBS (side by side) view by pressing on the left side option. If the flight mission is paused and then resumed, the drone will automatically perform IMU calibration at the breakpoint.

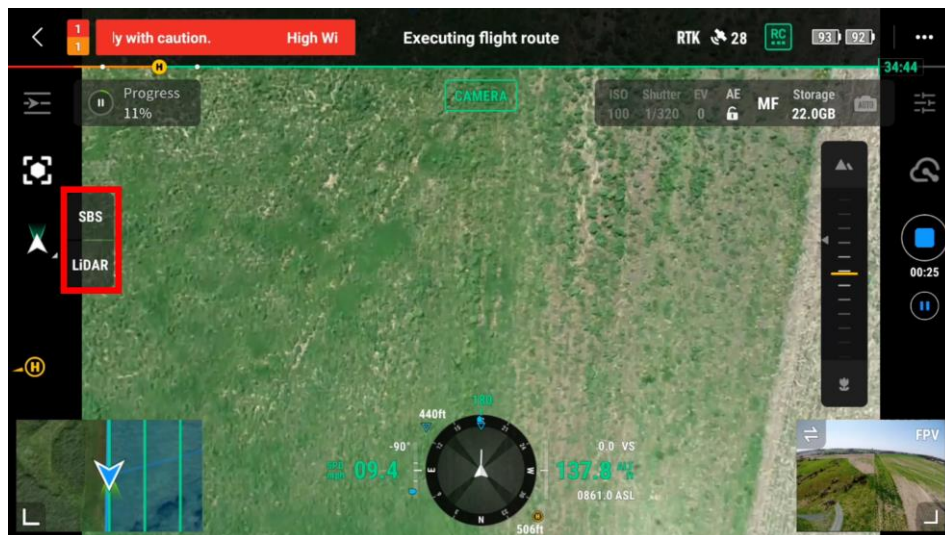


Figure: automated flight screen (camera view)

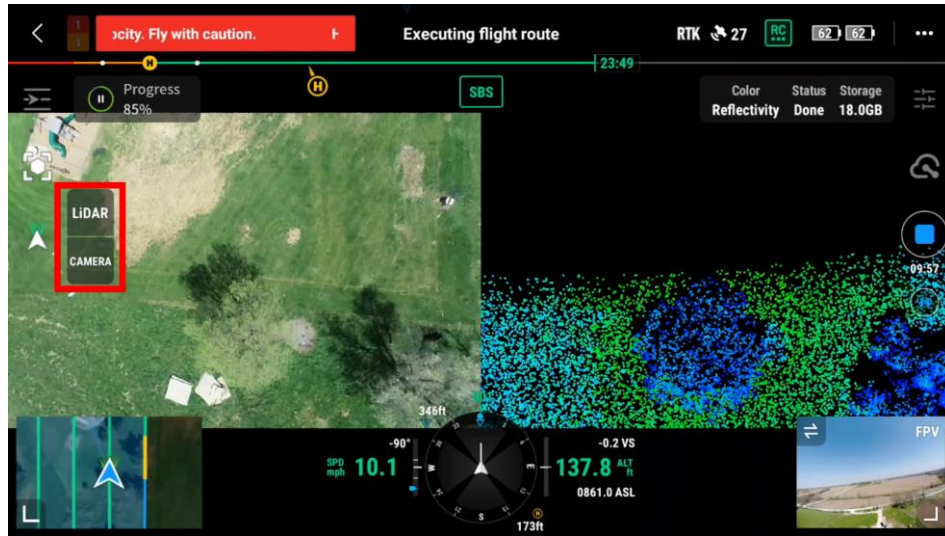


Figure: automated flight screen (LiDAR view)

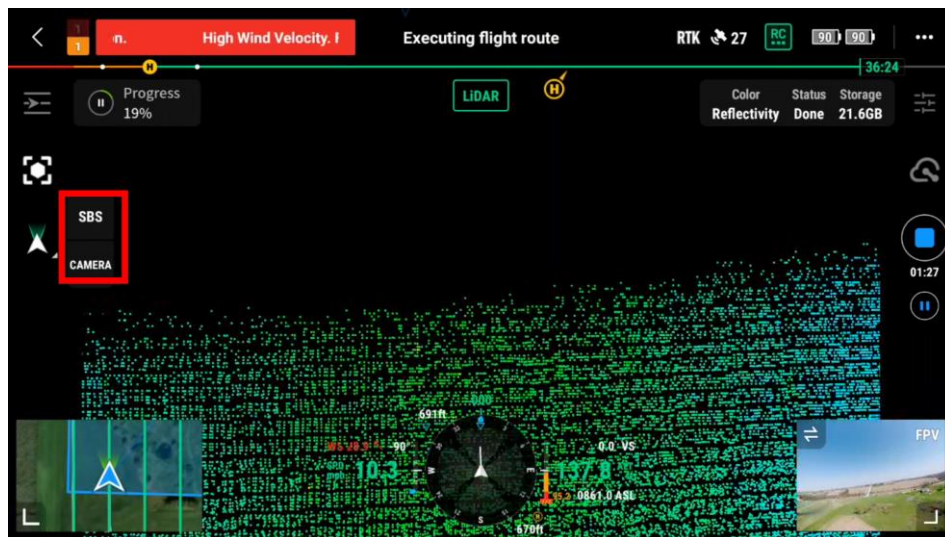


Figure: automated flight screen (SBS view)

3.6.3 Manual Data Collection

When you need to collect L1 data of building facades, powerlines, or other complex structures, manual flight is also an option.

L1 Camera Parameters

You can set L1 parameters in "MENU". Recommended parameter values for manual flight are: "Non-repetitive scan", "Dual-echo", "240 kHz Sample rate", "RGB coloring" on, and 3s as the shooting interval. Make sure that the Ntrip is properly connected or an RTK base station has been set up before the flight.

RGB coloring means that the L1's visible-light camera takes photos concurrently to collect LiDAR point cloud data. We recommend always enabling this option except during nighttime operations.

Point Cloud Record

Fly the drone near the target area and adjust the gimbal to a proper angle for data collection. Then click on the "LiDAR" option on the left side of the viewer to go to the point cloud screen and click the point cloud recording button to start recording. During manual flight, we recommend a speed of 5 - 12 m/s and a distance from the subject of 50-100 meters. During the manual flight, once the aircraft flies at a constant speed for 100s, you need to pause the point cloud recording, perform the IMU calibration and then resume the point cloud recording.



Figure: Manual flight screen

Note: Do not collect data when the drone is static on the ground or hovering in the air, otherwise DJI Terra may encounter reconstruction errors in data post-processing.

3.7 Data Storage

In manual flight mode, the collected point cloud data and RGB images (if RGB coloring enabled) are saved in the micro SD card of L1 at DCIM/DJI_YYYYMMDDHHMM_serial number_XXX. You can search for the data by time.

When a flight mission is completed, the collected data are saved in the DCIM folder of the micro SD card and named after the mission name.

The LiDAR files should include files with suffixes of CLC (LIDAR camera calibration data), CLI (LIDAR IMU calibration data), CMI (visual calibration data), IMU (inertial navigation data), LDR (LiDAR point cloud raw data), MNF (visual data, which is currently omitted with no impact), RTB (RTK base station data), RTK (RTK main antenna data), RTS (RTK sub-antenna data), and RTL (rod arm data). If model coloring is enabled, there will also be JPG files (photo data).

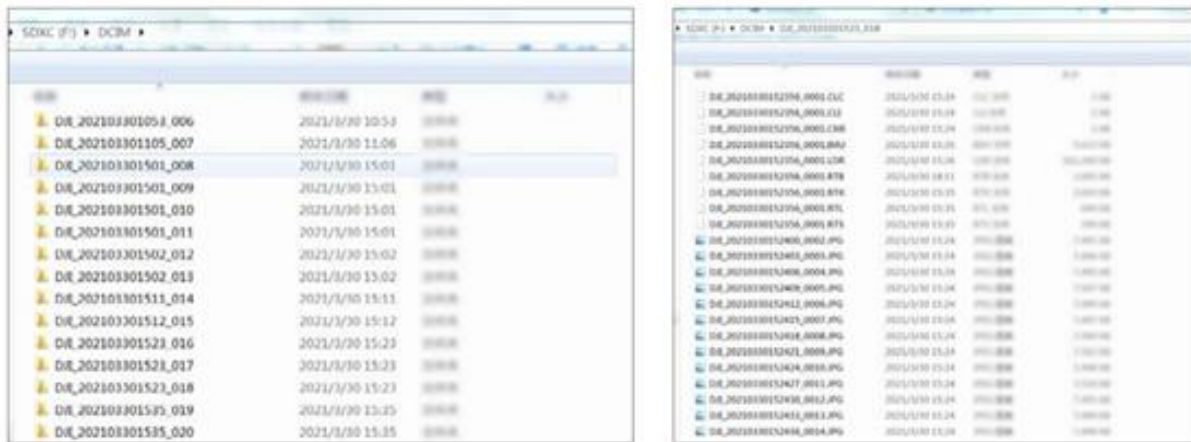


Figure: Example of a test data folder and its contents

If the .RTB file is missing, it is because the RTK was not connected or was disconnected during the flight. Please refer to [Section 3.1](#) for the detailed requirements of RTK/PPK setup.

4. Processing L1 Data with DJI Terra

4.1 Prepare Your Computer

For L1 data processing, the computer must be equipped with an NVIDIA graphics card and at least 4 GB of VRAM. The CPU must be i5 or above, and 4 GB of memory is required for storing every 1 GB of raw point cloud files. You can refer to the table below to determine the size of raw point cloud data to be processed by Terra.

Graphic Card	RAM	Max Size of Raw Point Cloud
GeForce GTX 1050Ti with 4GB of VRAM	16GB	4GB
	32GB	8GB
	64GB	16GB
	128GB	32GB

Figure: Correspondence between computer memory and maximum raw point cloud file size

All L1 LiDAR data processing functions are free of charge except point cloud accuracy optimization. You can download and install the software from the DJI website:

<https://www.dji.com/downloads/products/dji-terra>

Optimize Point Cloud Accuracy: When enabled, DJI Terra will optimize point cloud data collected at different times during processing for higher overall consistency. This is a premium feature included in DJI Terra Pro and more advanced versions. Each L1 comes with a 6-month license for the Electricity version. You can find the license information in the package. Note: With the complimentary DJI Terra license, you can only bind 1 device and cannot unbind it.

4.2 Reconstruction Steps

(1) Create a mission and select "LiDAR Point Cloud Processing" as the mission type.

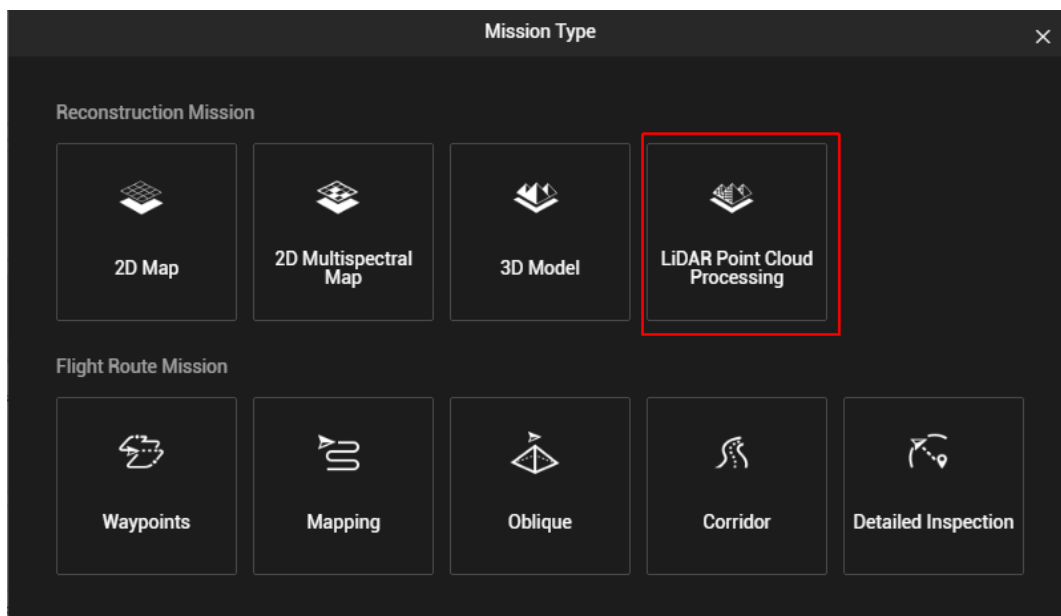


Figure: LiDAR point cloud processing types

(2) Click to add LiDAR point cloud data as a folder.

The selected folder should include files with the suffixes CLC, CLI, CMI, IMU, LDR, RTB, RTK, RTL, and RTS. JPG photos are not required.

How to merge the data from multiple flights into one LAS file?

You can put the data folders of multiple flights into one directory, and select this parent folder that contains the data files. In this way you will get only one LAS file.

Alternatively, you can select multiple L1 data file folders for processing. Then you will get a LAS file for each folder.

(3) Select Point Cloud Density

Three density levels are available: high, medium, and low, corresponding to 100%, 25%, and 6.25% of the point cloud data for processing. Point cloud density only affects the number of result points. It does not have a significant impact on the accuracy of the result.

(4) Output Coordinate System Settings

Set the coordinate system according to the project requirement.

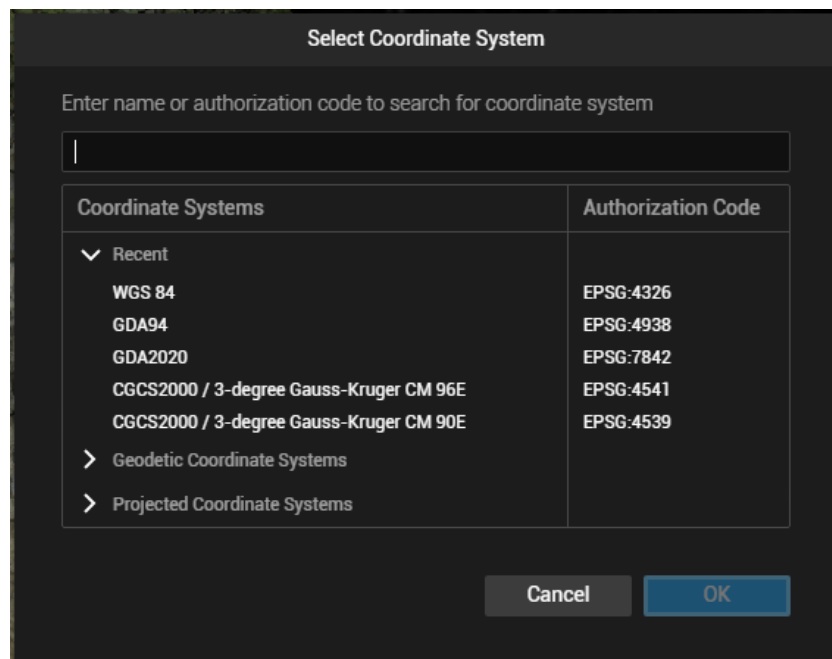


Figure: Select Coordinate System

Most point cloud analysis software does not allow users to view LAS point clouds in a geodetic coordinate system. If you've selected the geodetic coordinate system as the output coordinate system (such as WGS84: EPSG 4326), the result may not be shown properly when you open it with third-party software (such as CloudCompare or LiDAR360). To avoid this issue, you need to select a projection system as the output coordinate system.

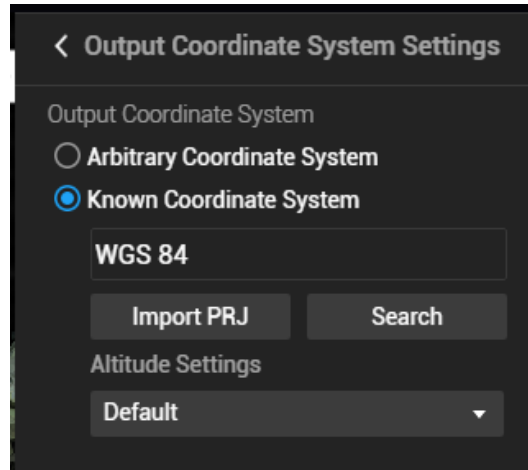


Figure: If WGS84 shown above is selected, the point cloud may be shown as a single line in other softwares. Please change to projection system such as WGS84 UTM projection.

Altitude settings: The Default setting is ellipsoidal height. You may change it to EGM96 height or other options.

(5) Parameter Settings

Point cloud effective distance: The cloud points with a distance greater than the set value from the LiDAR emission center will be filtered out during post-processing. The default value of this parameter is 250 meters. Do not set it too low or most of the points will be filtered out.

Optimize Point Cloud Accuracy: This function optimizes the adjustment of the point cloud data scanned at different times to improve the overall accuracy. It is recommended to keep this function enabled for surveying and mapping purposes. **However, for power line reconstruction, this option is recommended to be turned off.**

Also if efficiency matters more than accuracy to you, this feature can be disabled, as the processing time can be significantly longer when it's enabled.

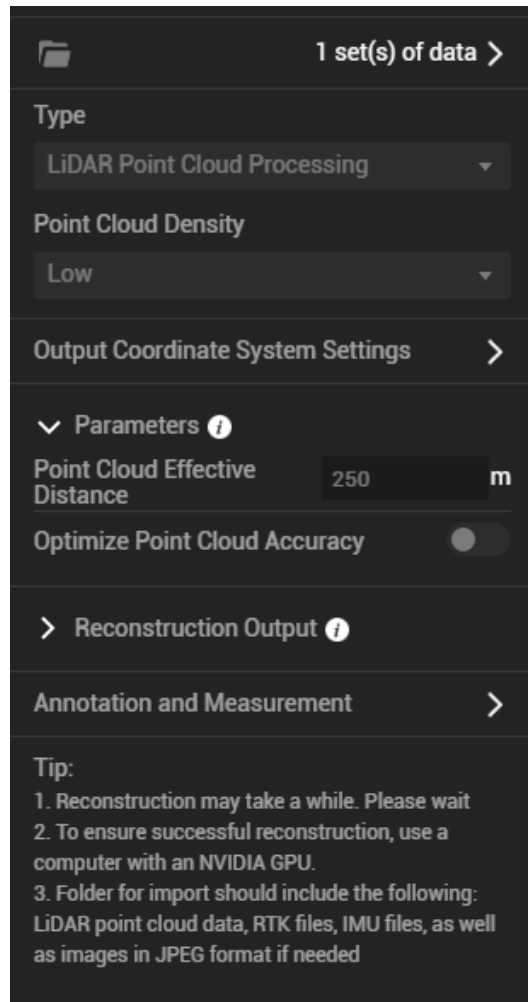


Figure: Reconstruction parameter settings

(6) Select the Reconstruction Output Format

3D point clouds in PNTS (the format used for display in DJI Terra) and LAS format (the standard format of airborne LiDAR output) will be selected by default. You can also choose to output the point cloud in PLY (for MeshLab), PCD (for CloudCompare), or S3MB (for SuperMap) format.

(7) Start Processing

Click "Start Processing" to start reconstruction. During processing, you can click "Stop" to pause the process, and the software will save the current progress. If you resume the process, the software will continue data processing from the breakpoint.

You can start multiple point cloud processing tasks at the same time. Before the first task is completed, the other tasks will be pending in the queue. Tasks are processed in the order they were started and will be started one by one after all prior tasks are completed.

(8) View Results

After the reconstruction is completed, you can move, zoom, rotate, or perform other actions on the result. You can also switch between different views:

RGB: Display the result in their true colors.

Intensity: Display the result based on the reflectivity received by the LIDAR. The reflectivity is graded on a scale of 0-255, where 0-150 corresponds to diffuse reflection objects with a reflectivity of 0-100%, and 151-255 corresponds to total reflectivity objects. Since light reflected by the same object may be received by the LiDAR at different angles, the reflectivity values of the same ground object may vary as shown on the reflectivity map. This is a normal phenomenon.

Height: Display different colors for different altitudes of the point cloud.

Return: Display different colors for result data of different echos.

(9) Quality Report

The quality report for LiDAR point cloud processing is interpreted as follows:

DJI Terra Lidar Quality Report

Input Information Overview

Item	Value
Pose Data Collection Time	56.913 min
Point Cloud Collection Time	38.108 min
Lidar Block Count	1

Pose Data Collection Time: time consuming of collecting POS data
 Point Cloud Collection Time: time consuming of collecting Point Cloud
 Lidar Block Count: the number of imported LiDAR data folders

Process Parameters

Process Parameters	Value
Resolution	Low

Resolution: point cloud density used in LiDAR point cloud processing
 High: 100% point clouds used
 Medium: 25% point clouds used
 Low: 6.25% point clouds used

Production

the reconstruction result file in different format

Production List
PNTS File
LAS File
PCD File
PLY Point File
S3MB Point File

Performance Overview

Item	Value
Pose Process Time	2.368 min
Georeference Time	1.370 min
LPP Time	126.735 min
Lidar Colorize Time	0.711 min
Save Result Time	0.951 min
Total Process Time	134.974 min

1. Pose Process Time: time consuming of solving poses
2. Georeference Time: time consuming of solving point clouds and converting coordinates
3. LPP Time: time consuming of point cloud accuracy optimization
4. Lidar Colorize Time: time consuming of point cloud RGB coloring
5. Save Result Time: time consuming of saving point cloud results (.pnts, .las, .ply, .pcd, .s3mb)
6. Total Process Time: Total time consuming of point cloud processing

Figure: Interpretation of LiDAR point cloud report parameters

4.3 Result Files

The result files output by DJI Terra include a LAS point cloud result and an OUT trajectory file.

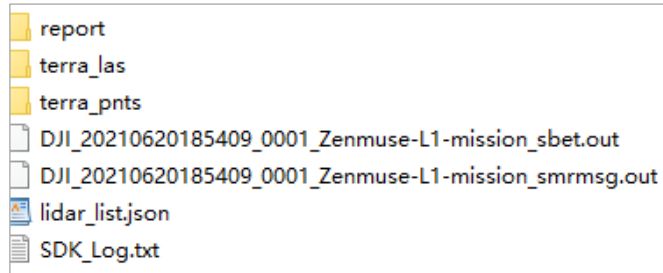


Figure: Result files output by DJI Terra

***.las:** The LAS point cloud output by DJI Terra is the standard result of airborne LiDAR. The LAS version is V1.2 and the file can be directly imported to most analysis software. The LAS result records information such as the 3D point coordinates, RGB color information, reflectivity, time, number of echoes, the echo that each 3D point belongs to, the total number of points in each echo, and the scan angle.

***_sbet.out:** The post-processing trajectory file of the mission, which records the trajectory information after adjustment and solution. The file can be imported into third-party software for trajectory display. During DJI Terra's data processing, the point cloud accuracy optimization function is an adjustment process. For this reason, you don't need to perform a second adjustment using third-party software. The file is stored in binary format, and its data items, units, and types are as follows:

Item	Unit	Type	Size
GPS Time (seconds of week)	seconds	double	8 bytes
Latitude	radians	double	8 bytes
Longitude	radians	double	8 bytes
Altitude	meters	double	8 bytes
x body velocity	meters/second	double	8 bytes

y body velocity	meters/second	double	8 bytes
z body velocity	meters/second	double	8 bytes
Roll	radians	double	8 bytes
Pitch	radians	double	8 bytes
Platform heading	radians	double	8 bytes
Wander angle	radians	double	8 bytes
x body acceleration	meters/second	double	8 bytes
y body acceleration	meters/second	double	8 bytes
z body acceleration	meters/second	double	8 bytes
x body angular rate	radians/second	double	8 bytes
y body angular rate	radians/second	double	8 bytes
z body angular rate	radians/second	double	8 bytes

Table: Interpretation of SBET file parameters

***_smrmsg.out:** Post-processing precision file. It contains the root-mean-square error of the smoothed position, direction, and speed. Its data items, units, and types are as follows.

Item	Unit	Type	Size
GPS Time (seconds of week)	seconds	double	8 bytes

North position RMS error	meters	double	8 bytes
East position RMS error	meters	double	8 bytes
Down position RMS error	meters	double	8 bytes
North velocity RMS error	meters/second	double	8 bytes
East velocity RMS error	meters/second	double	8 bytes
Down velocity RMS error	meters/second	double	8 bytes
Roll position RMS error	arc-minutes	double	8 bytes
Pitch position RMS error	arc-minutes	double	8 bytes
Heading position RMS error	arc-minutes	double	8 bytes

Table: Interpretation of SMRMSG file parameters

4.4 FAQ

4.4.1 Error Message: The LiDAR point cloud POS data is abnormal.

Possible cause: The RTK was disconnected during the flight, or there was no RTK base station data available; or L1 was static/hovering in the air during data collection. Currently, DJI Terra doesn't support post-processing of data collected by a drone sitting still on the ground.

4.4.2 Error Message: The raw data is missing or the file path is wrong.

Possible cause: Some required raw files are missing. For example, the RTK base station data is missing as the RTK was turned off during the flight; or the file suffix is incorrect. Please refer to [3.1 RTK/PPK](#) to understand the detailed requirements for the RTK files.

4.4.3 Error Message: The raw data of the LiDAR point cloud is abnormal.

Possible cause: The collection time of the laser point cloud file (LDR) in the input path does not correspond to or does not overlap with the collection time of other files, which may be caused by mistakes in file copying.

4.4.4 Error Message: LiDAR point cloud accuracy optimization failed.

Possible cause: The flight altitude was too high, the speed was too fast, or the overlap was set too low, resulting in insufficient overlapping points for point cloud accuracy optimization. In this case, we recommend you increase the overlap and recollect the data, or disable "Point cloud accuracy optimization" when you don't require high accuracy.

4.4.5 Error Message: LiDAR point cloud POS calculation failed.

Possible cause: The content of some files in the input path is incorrect or data is missing; the time values in the IMU and RTK files (RTB, RTK, RTS, or RTL) do not overlap or match. In this case, you should check the data. You will probably need to recollect the data.

4.4.6 Issue: Quality of point cloud model is poor, or the result has severe data loss.

- (1) Poor inertial navigation accuracy: Data collection started before the inertial navigation system completed warmed-up, or IMU calibration not performed correctly
- (2) Poor POS accuracy: The RTK was not fixed, the RTK base station was moved, or the coordinate systems of the self-built base station and multiple RTK base stations were inconsistent (for example, no known coordinates were configured for D-RTK 2).
- (3) Low overlap: The collection time of the LiDAR point cloud file only partially overlaps with that of other input files, or the side overlap was set too low. In particular, in areas with fluctuating terrain, setting an excessively low lateral overlap can result in hollowing in the result.
- (4) No objects scanned: For example, in a flight with gimbal pitch -90° , the facades of a building may be hollowed due to the lack of scanned objects. In a power line scan, if the drone flies over the object only once, some power lines may be blocked by those above them at certain angles. In an area with significant elevation differences, some objects may fall out of the measurable range of L1.
- (5) Low cutting distance of point cloud: The point cloud cutting distance set is less than the actual effective point cloud distance.

4.4.7 How to achieve a good vertical accuracy?

The following are important to achieve a good vertical accuracy:

- Make sure the RTK is always fixed;
- Set the base station on a known point if you are using D-RTK 2, make sure that you have considered the length of D-RTK 2 from bottom to top of antenna (it 's 1.8 m if the rod is fully extended to the ground); When setting the known coordinate and elevation in Pilot app, **make sure to use WGS84 and ellipsoid height in unit m**. Restart the M300 and D-RTK2 when there is a base station position change error in Pilot app.
- You may need to check the geoid height in the survey area.