UAV Training Manual

Guidebook

2024

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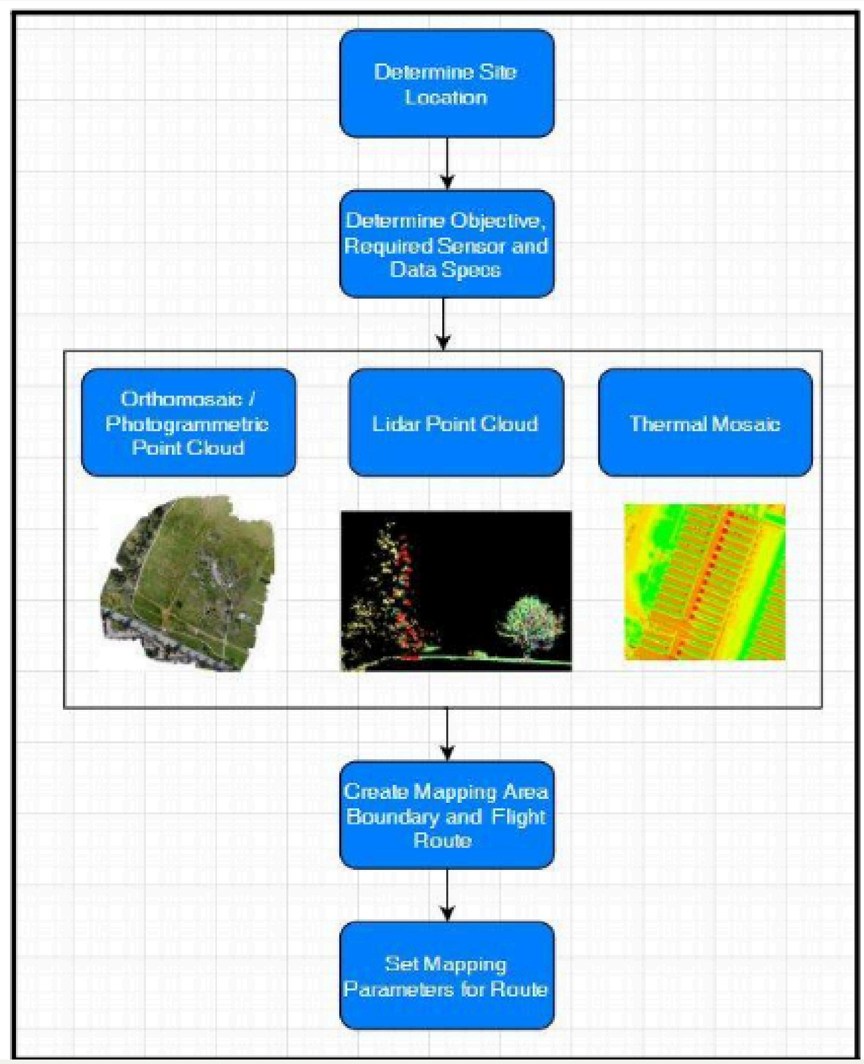
Flight Planning in DJI Pilot 2

Flight Planning Overview:

- Flight plans or routes, enable automated survey of a study site maintaining flight parameters
- Flight planning parameters directly influence the quality of data, appropriate applications, and duration of survey
- Saved routes can be recalled and reflown at a later date ensuring consistent data is collected over multiple dates
- In DJI Pilot 2 there are many types of routes, this presentation focuses on “Mapping” routes for photogrammetry and LiDAR

General Workflow:

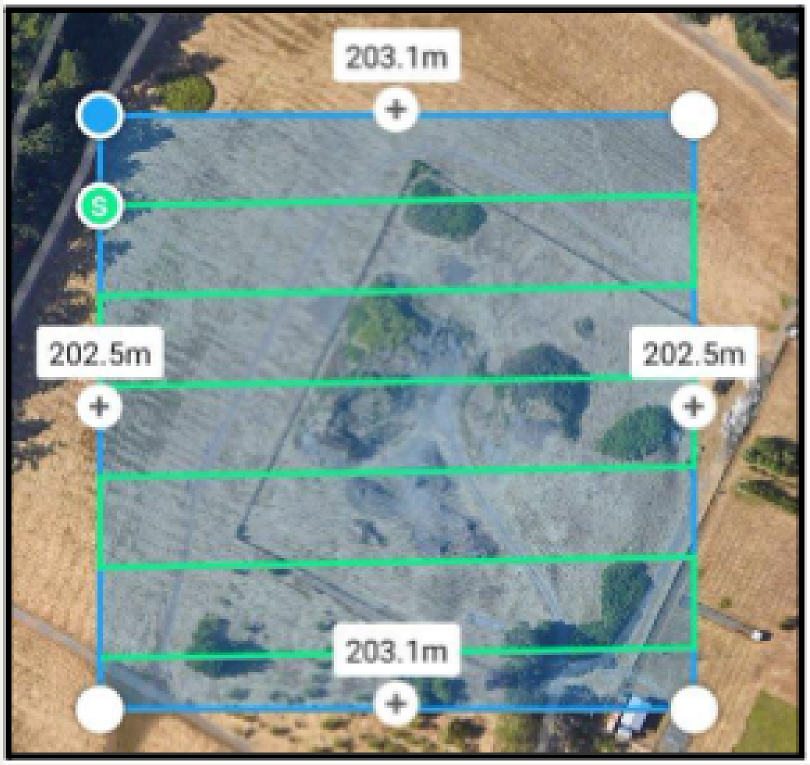


Basic Pre-Flight Knowledge:

Determine Objective, Sensor, and Data Specs:

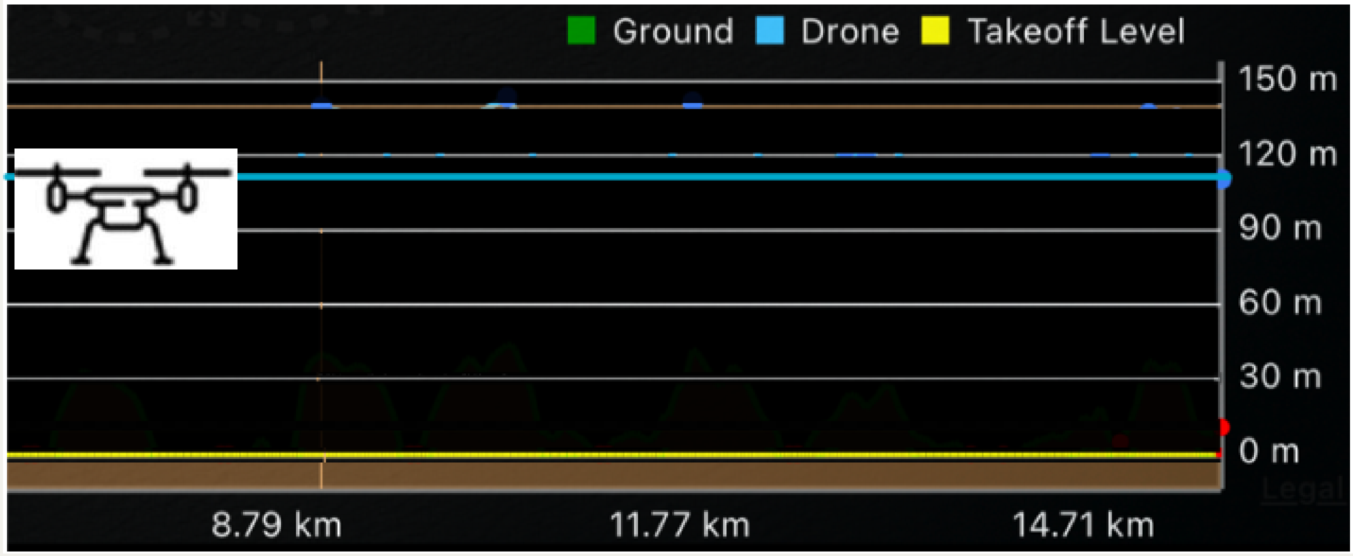
- The objective of the mission will help determine what sensor(s) to use, a ground control strategy, and what specifications are intended for the final data
- Some sites and applications may not require all sensors or have the same ground control requirements

Mapping Area:



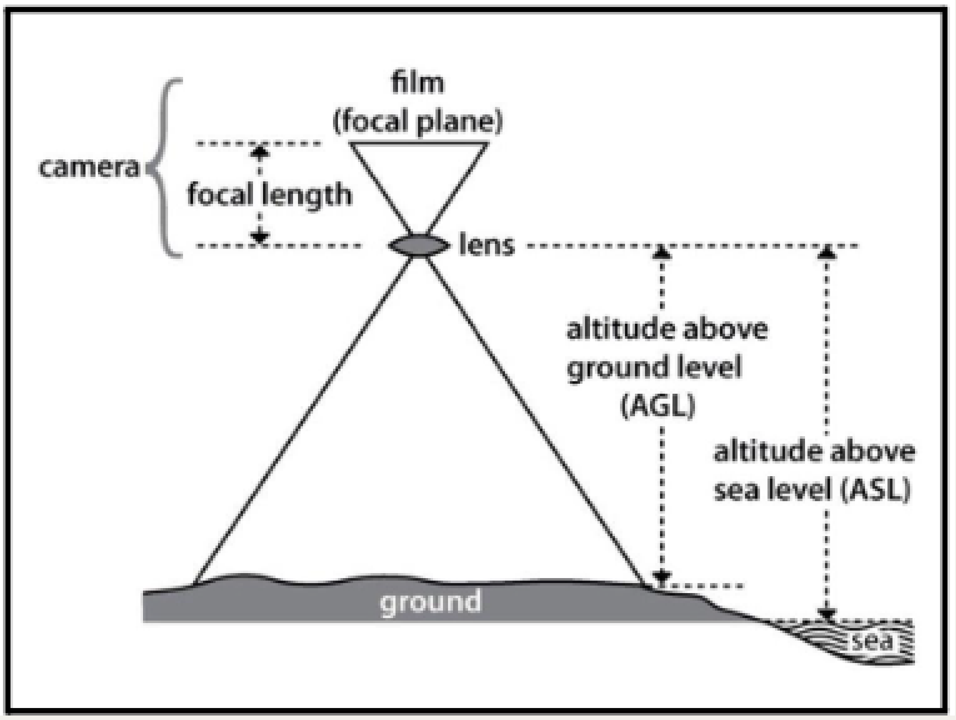
- Mapping Area (blue) defined by polygon with vertices (white circles)
- Starting point (S)
- Flight lines (green) that indicate where the drone will fly during the mission
- The number of flightlines required to map a given area is related to flight altitude and side overlap
- For Photogrammetric missions, overlapping photos are acquired consecutively

Altitude Relative to Takeoff Point:

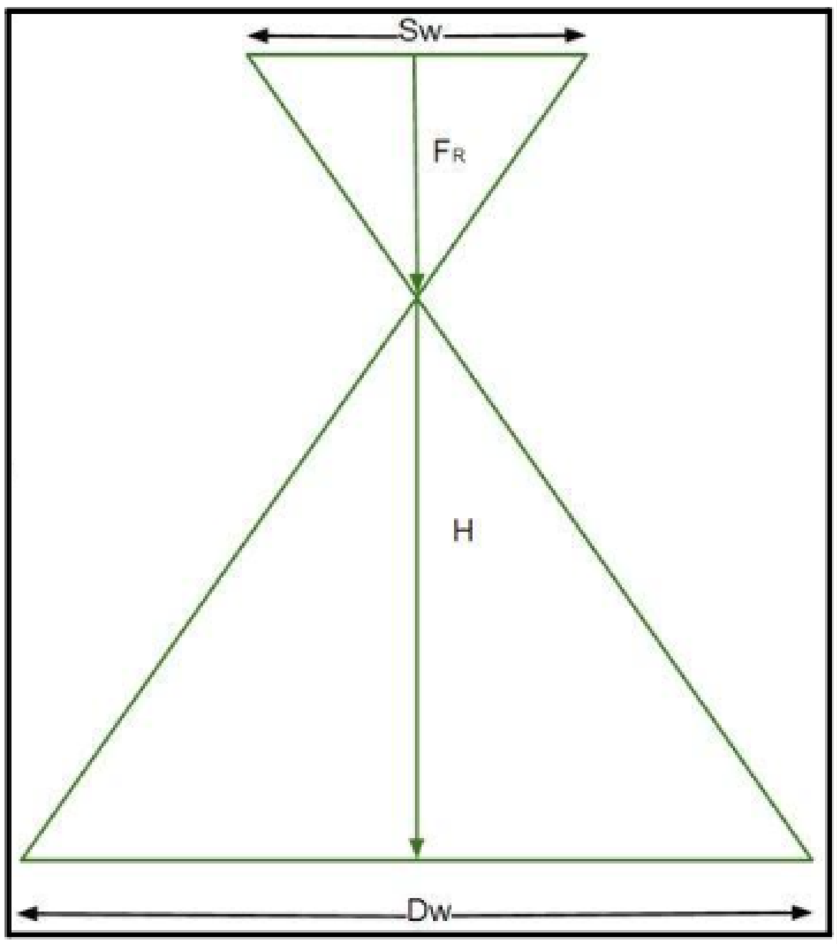


Photogrammetric Flight Planning

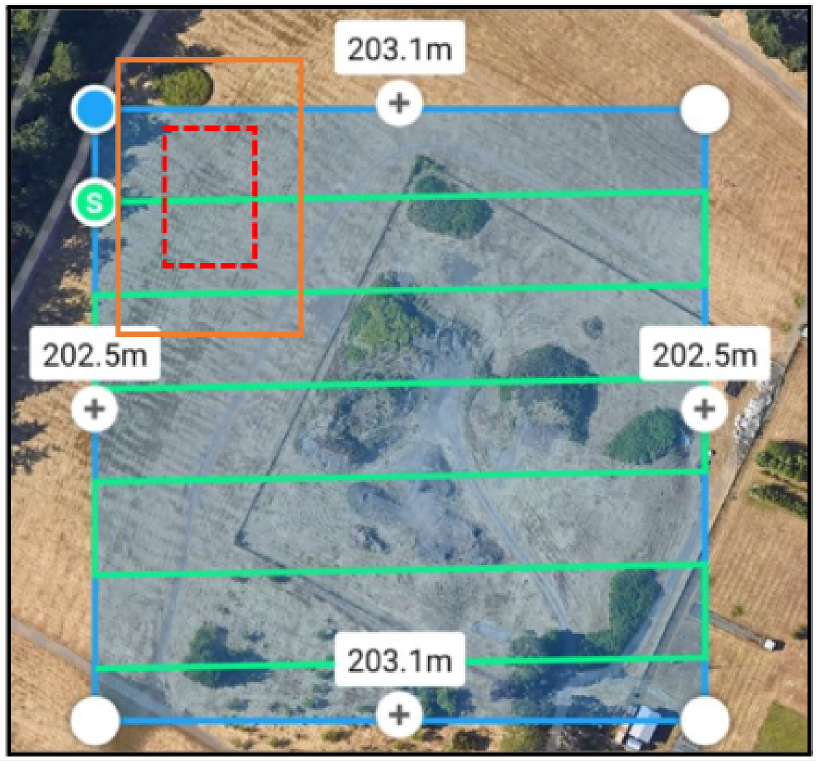
Basic Flight Parameters - Photogrammetric

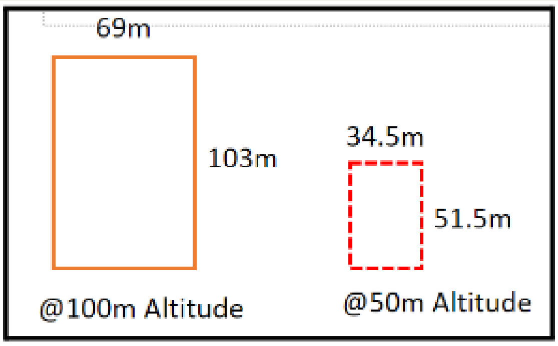


- Altitude or Height (H), is referenced to the take off point, or to a Digital Elevation Model (DEM)
- Image Width at ground (Dw)
- Increase in H will increase image footprint and width (Dw) at ground



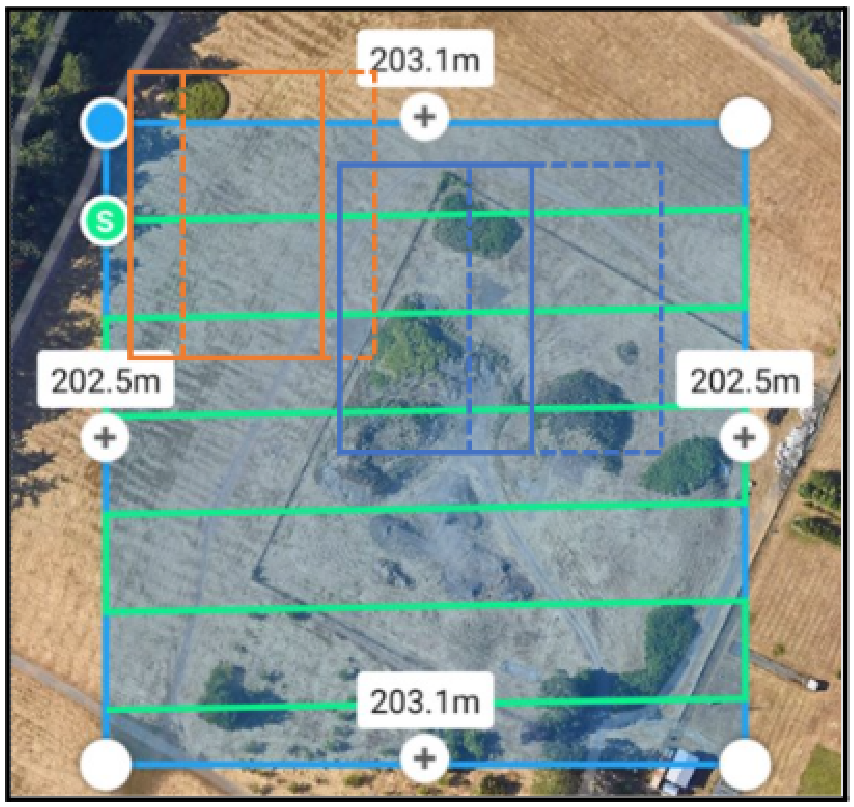
Photogrammetric Mapping - Image footprint and GSD



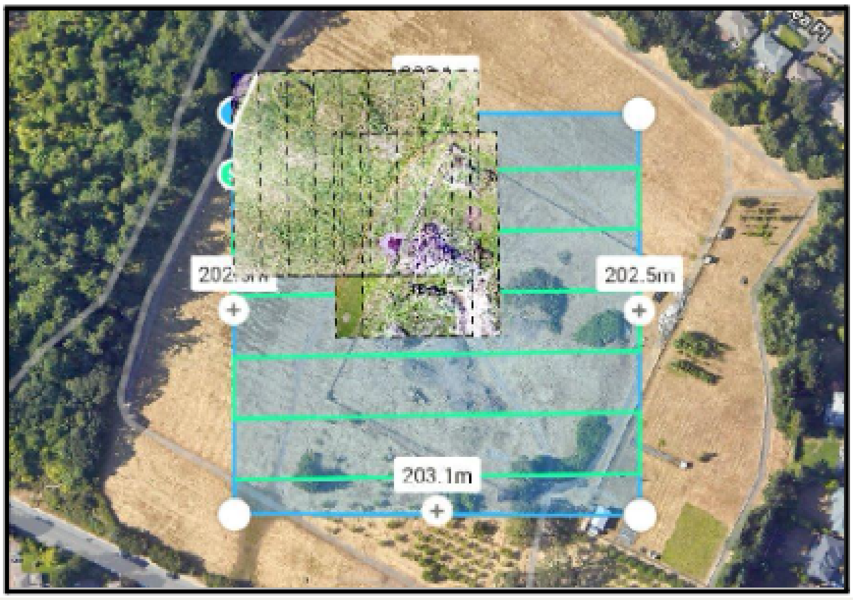


- Image footprint is proportional to flying height
- An individual pixel in an image from the Zenmuse P1 35mm lens camera taken at 100m represents 1.26cm on the ground – this is termed Ground Sample Distance or GSD
- For this camera it is approximated by GSD (cm) =Altitude/80

Photogrammetric Mapping - Forward and Side Overlap



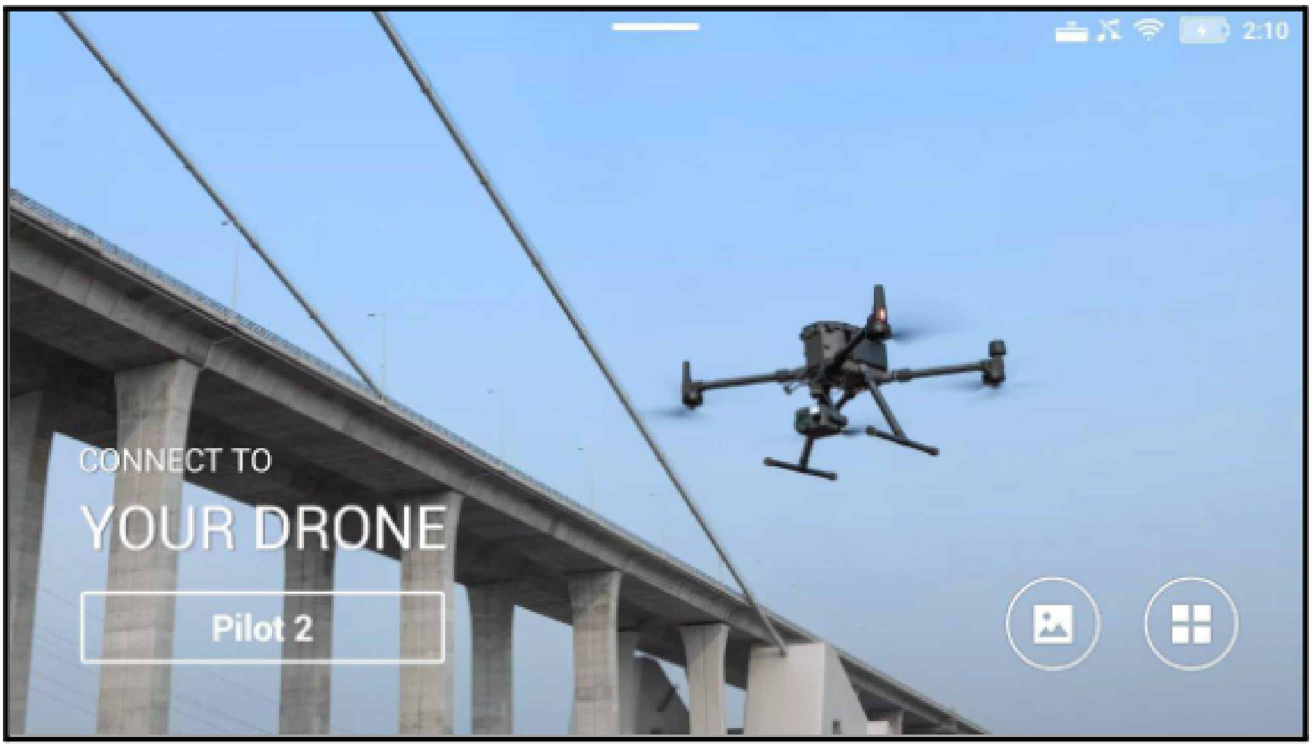
- For camera missions, overlapping photos are taken consecutively along the flightlines
- The amount each photo overlaps a previous one is termed forward overlap ratio
- The amount a photo overlaps between adjacent flightlines is termed side overlap ratio
- For general mapping the default forward overlap ratio of 80% and side overlap of 70% works
- For undulating terrain and forestry this should be set at 80% forward / 80% side or higher
- For a fixed altitude mission time will increase with higher ratio values but quality of reconstruction will increase

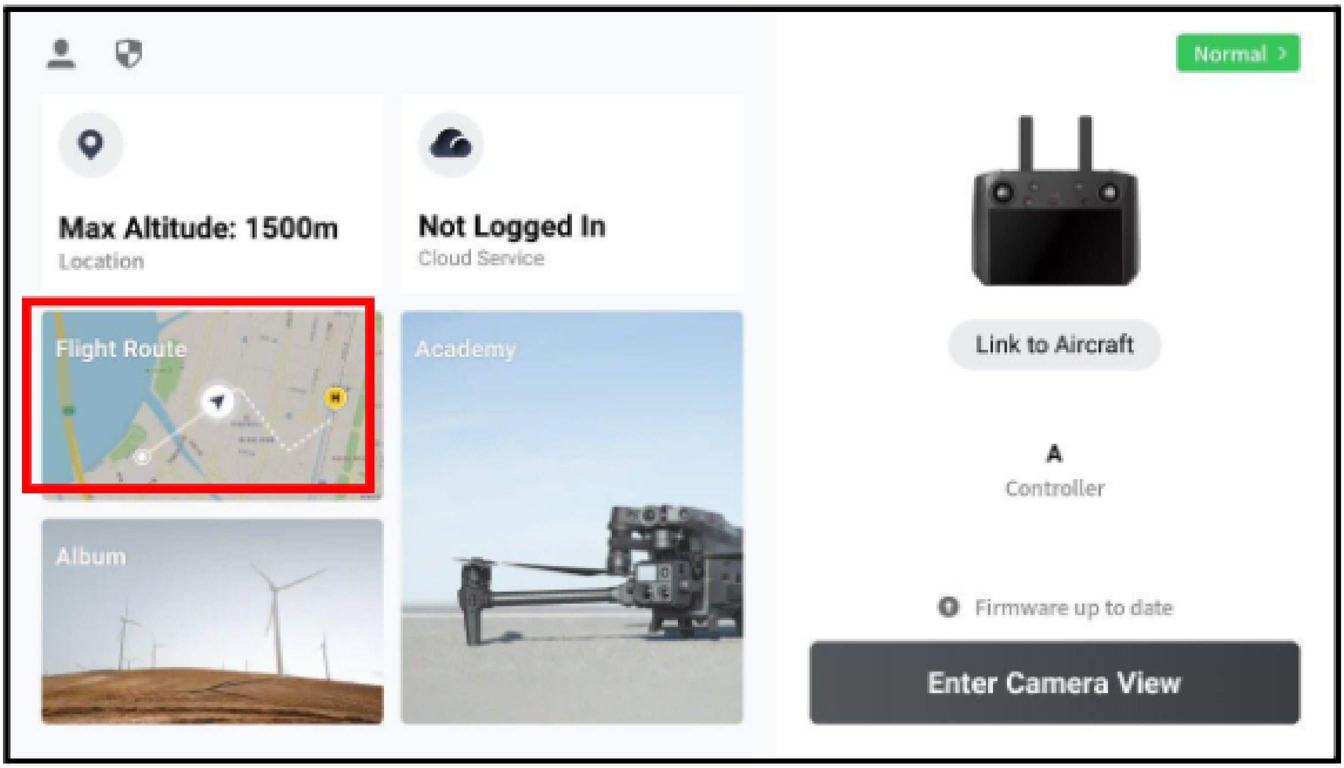


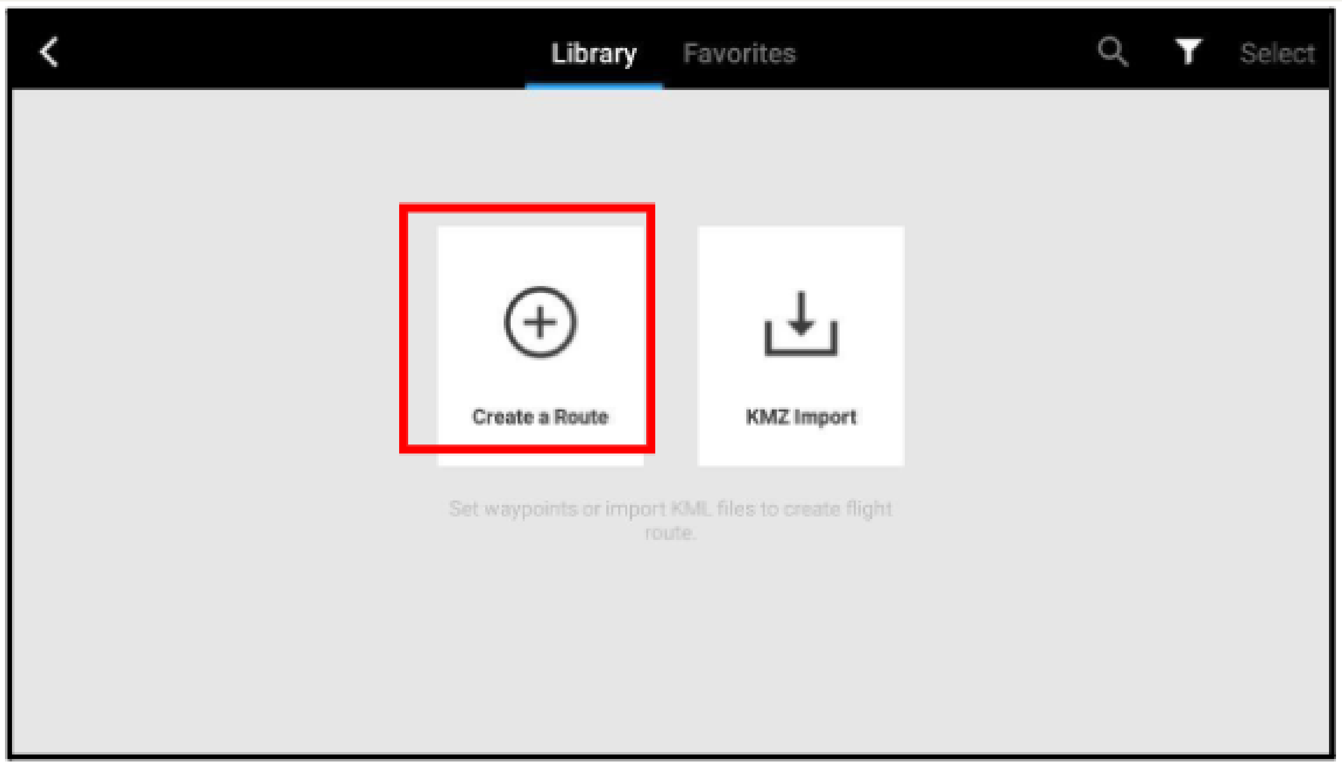
Basic Photogrammetric Mapping Scenario - DJI Pilot 2

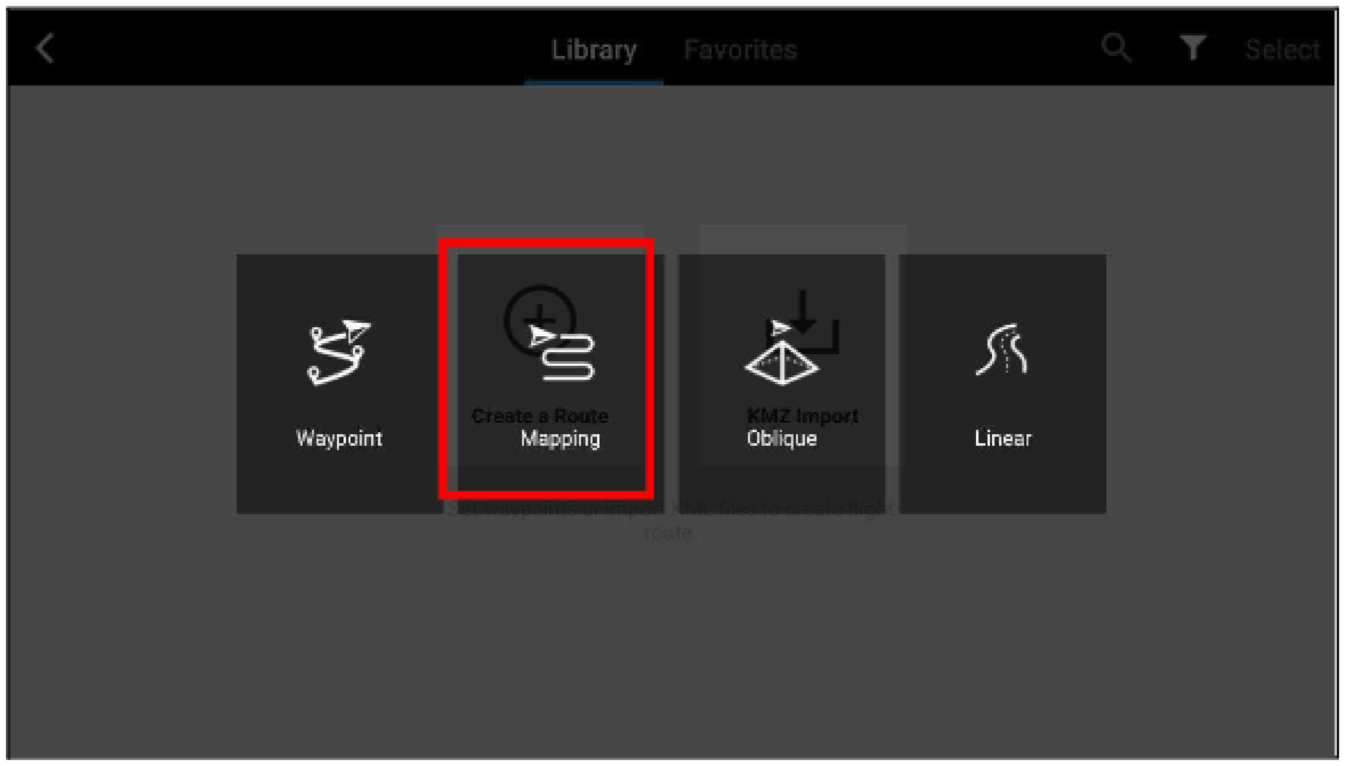
- Live Demo with follow along handout and settings
- Site is mostly flat, no terrain model available, an orthomosaic is required to provide a snapshot of site conditions, it is not anticipated that other datasets or sensor will be integrated

Visual Steps:

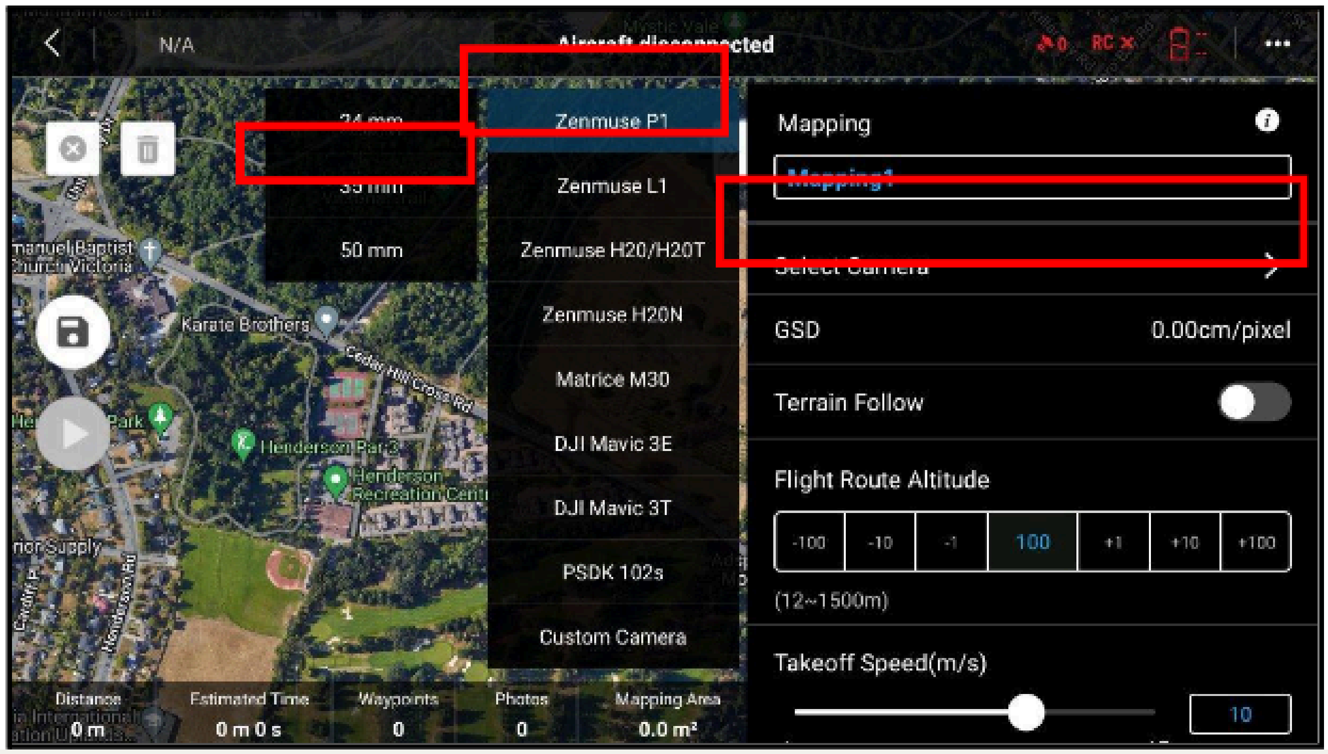


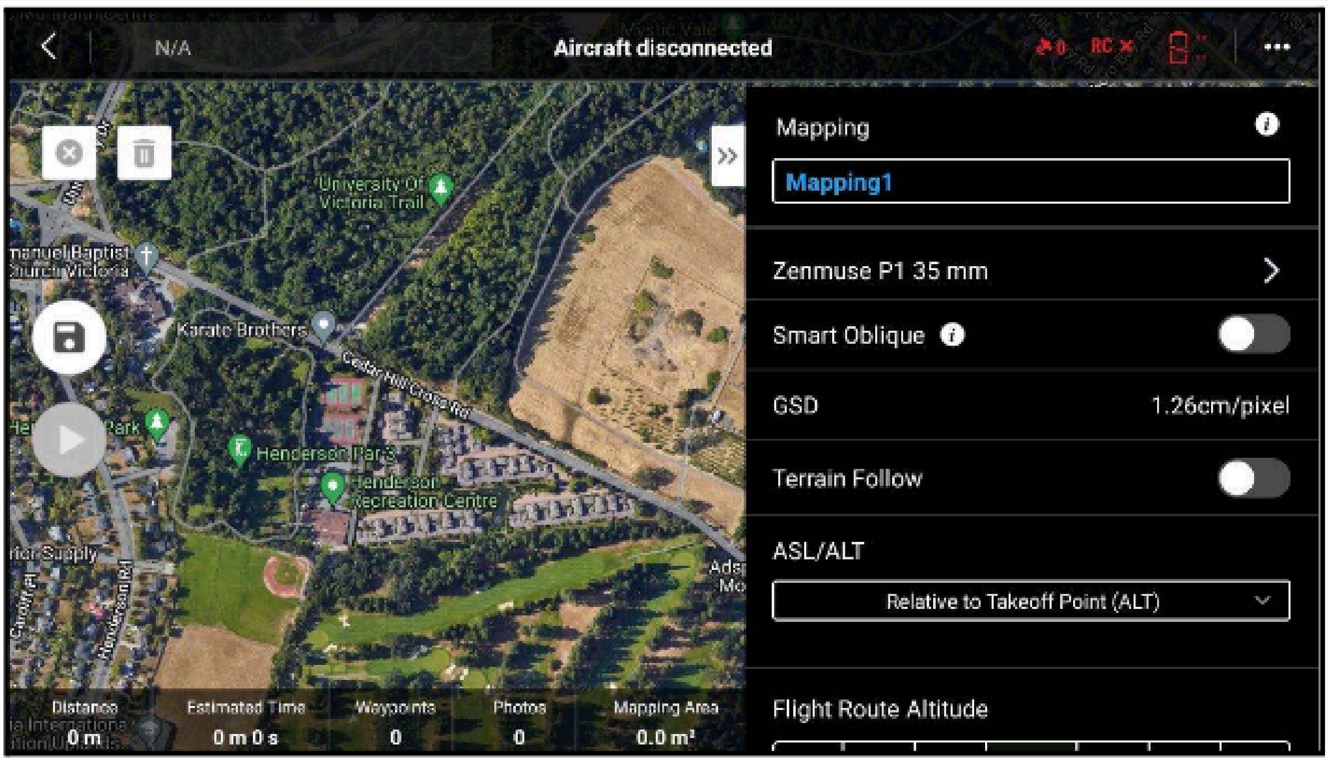

Normal
Max Altitude: 1500m
Location
Not Logged In
Cloud Service
Flight Route
Academy
Album
Link to Aircraft
A
Controller
Firmware up to date
Enter Camera View


Library
Favorites
Select
Create a Route
KMZ Import
Set waypoints or import KML files to create flight route.


Library
Favorites
Select
Waypoint
Create a Route
Mapping
KMZ Import
Oblique
Linear


N/A
Aircraft disconnected
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²

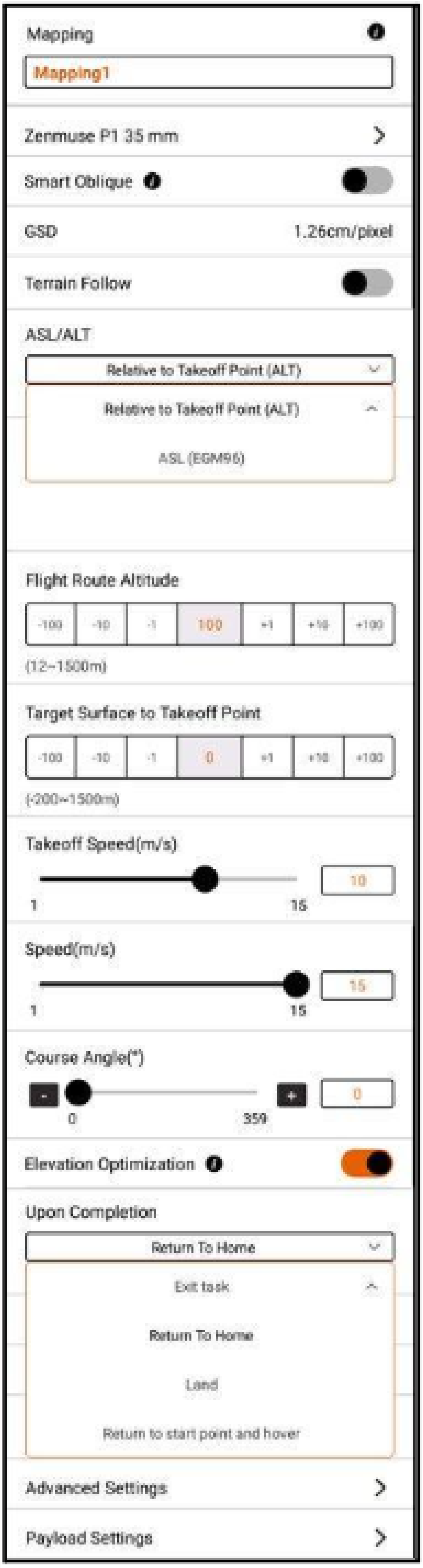

N/A
Zenmuse P1
Zenmuse L1
Zenmuse H20/H20T
Zenmuse H20N
Matrice M30
DJI Mavic 3E
DJI Mavic 3T
PSDK 102s
Custom Camera
50 mm
Mapping
GSD
0.00cm/pixel
Terrain Follow
Flight Route Altitude
-100
-10
-1
100
+1
+10
+100
(12~1500m)
Takeoff Speed(m/s)
10
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²


N/A
Aircraft disconnected
Mapping
Mapping1
Zenmuse P1 35 mm
Smart Oblique
GSD
1.26cm/pixel
Terrain Follow
ASL/ALT
Relative to Takeoff Point (ALT)
Flight Route Altitude
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²


N/A
Aircraft disconnected
203.1m
202.5m
202.5m
203.1m
Distance
1369 m
Estimated Time
2 m 36 s
Waypoints
12
Photos
150
Mapping Area
41009.0 m²

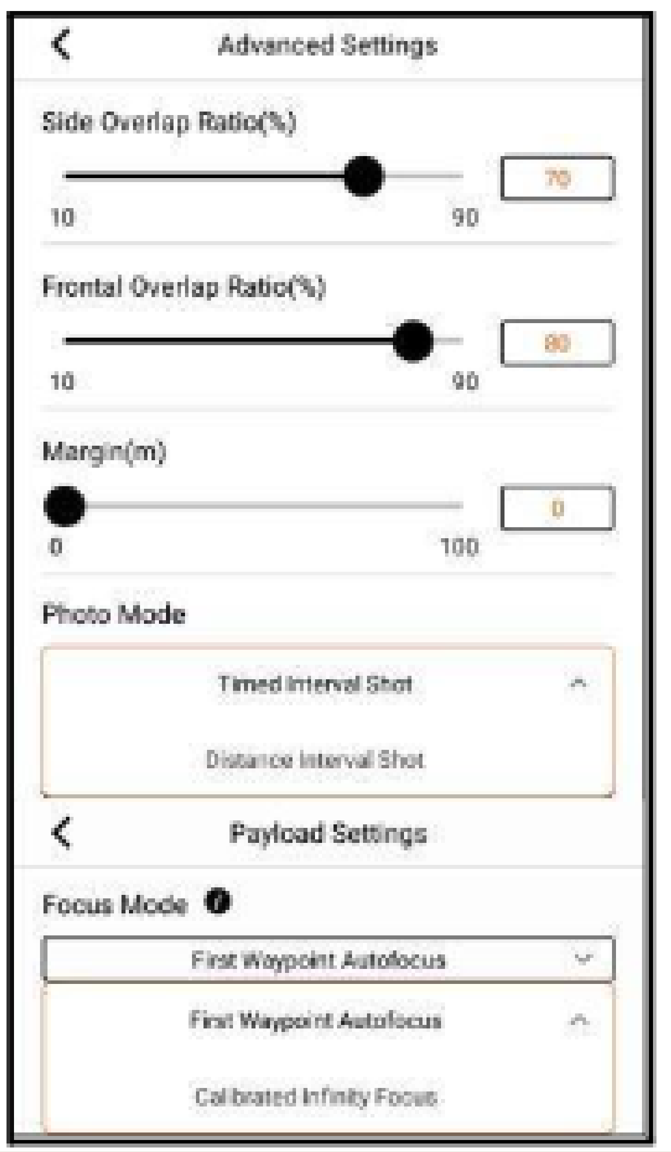

N/A
Aircraft disconnected
87.0m
240.7m
107.9m
76.1m
154.7m
75.3m
287.6m
158.5m
Sun Stream
Gutter Guru
Distance
3173 m
Estimated Time
5 m 23 s
Waypoints
21
Photos
315
Mapping Area
92123.0 m²

Selecting DJI Pilot 2 Parameters for P1 - ALT Relative to Take Off Point



Standard Settings

- **Mission Name** – The name of the mission
- **Camera and options** – The camera selected (Zenmuse P1) and focal length of lens
- **Smart Oblique** – When this is turned on, oblique images and nadir images are captured in a single flight. Unless facades are the primary goal this is typically turned off. Smart Oblique is not available when terrain following is selected.
- **GSD** – The ground sample distance is the size of 1 image pixel on the ground. It is proportional to the flight altitude and can be approximated for the Zenmuse P1 35mm lens by GSD(cm)=Flight Altitude (m) / 80
- **Terrain Follow** – Terrain following will maintain the UAV altitude relative to the height of a provided Digital Elevation Model. When this is turned off, Flight Route Altitude is used.
- **ASL/ATL** – Relative to takeoff point or relative to EGM96 Geoid, leave as default (Only Available when Terrain following is turned OFF)
- **Flight Route Altitude** – The altitude or height relative to the take off point that the route will be flown at (Available only when terrain following is Turned OFF)
- **Target Surface to Takeoff Point** – An offset that is added or Subtracted if the drone is launched from a platform or surface above the ground, or below the ground surface to be mapped. (Available only when terrain following is Turned OFF)
- **Take off Speed** – Once the drone has been launched and reached the Flight Route Altitude, the speed that the drone will fly to the Starting waypoint.
- **Speed (m/s)** – This is the maximum speed the drone will fly during the mission. The maximum speed is a function of forward overlap ratio. When the forward overlap ratio is kept fixed, an increase in altitude will enable increased speeds.
- **Course angle** – The course modifies the orientation of the flight lines. In general the default orientation is often the most efficient.
- **Elevation optimization** – This helps create a higher accuracy elevation model by taking oblique images at the end of the flight; however, this will also increase the time required for a mission.
- **Upon Completion** – At the end of the flight, what action is taken. For most missions it is best to leave this as the default - Return to Home



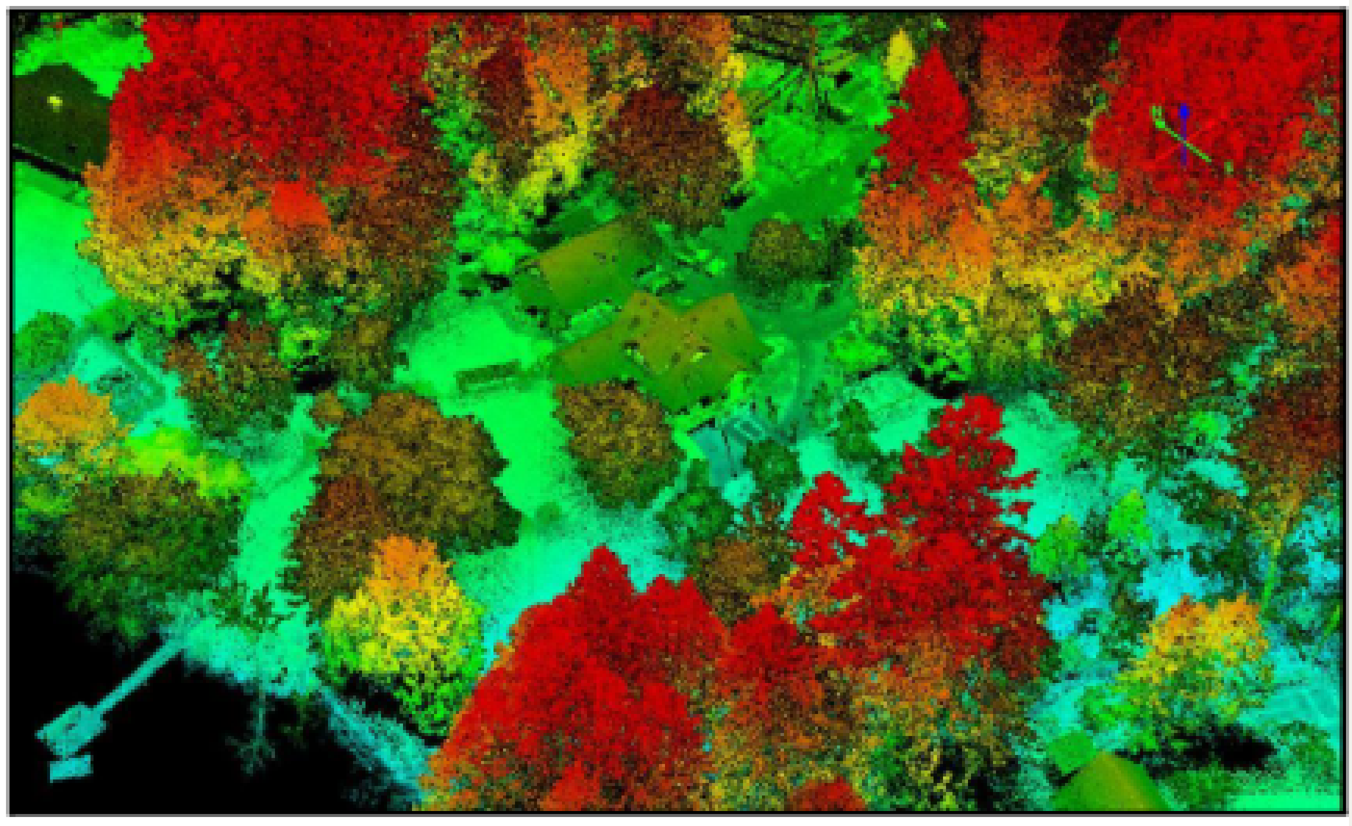
Advanced Settings

- **Side overlap Ratio** – The side overlap ratio determines the image footprint overlap between adjacent flightlines. Increasing sidelap, reduces the spacing between adjacent flightlines and typically requires more flightlines and therefore a longer mission duration. The default value of 70% works for many sites but should be increased to 80 or 90% for complex terrains or sites where forest and trees are the dominant feature.
- **Forward overlap Ratio** – The forward overlap ratio determines the image footprint overlap between consecutive images, the default is 80%. Increasing overlap will decrease the maximum speed possible for the flight. For sites with complex undulating topography or features dominated by tall features such as trees, it is recommended to increase this value 90%.
- **Margin** – The margin is used to buffer the extents of a study area. For example, by setting the margin at 10m, the mapping area will be increased outward by a radius of 10m.

- **Photo Mode** – Photos are either taken using a timed interval, or based on a distance interval. DJI previously had recommended using timed interval, however distance interval is now recommended in Pilot 2 training modules and will produce a dataset with fewer photos during the turns and should also process faster.

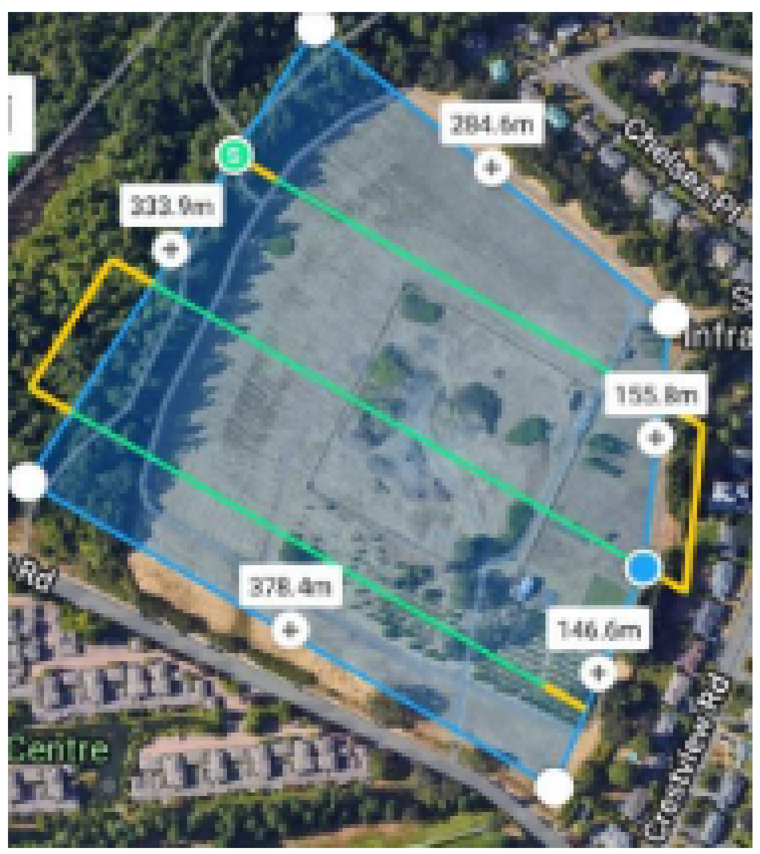
Payload Settings

- **Focus Mode** – The Focus mode is either at First Waypoint Autofocus or Calibrated Infinity. For First Waypoint Autofocus the platform will fly to the first waypoint and then focus on the ground at that location. Calibrated Infinity requires precalibrating the lens before the flight and should only be set when this technique has been learned and understood.
- **Dewarping** – Dewarping should be left off for mapping missions



LiDAR Flight Planning

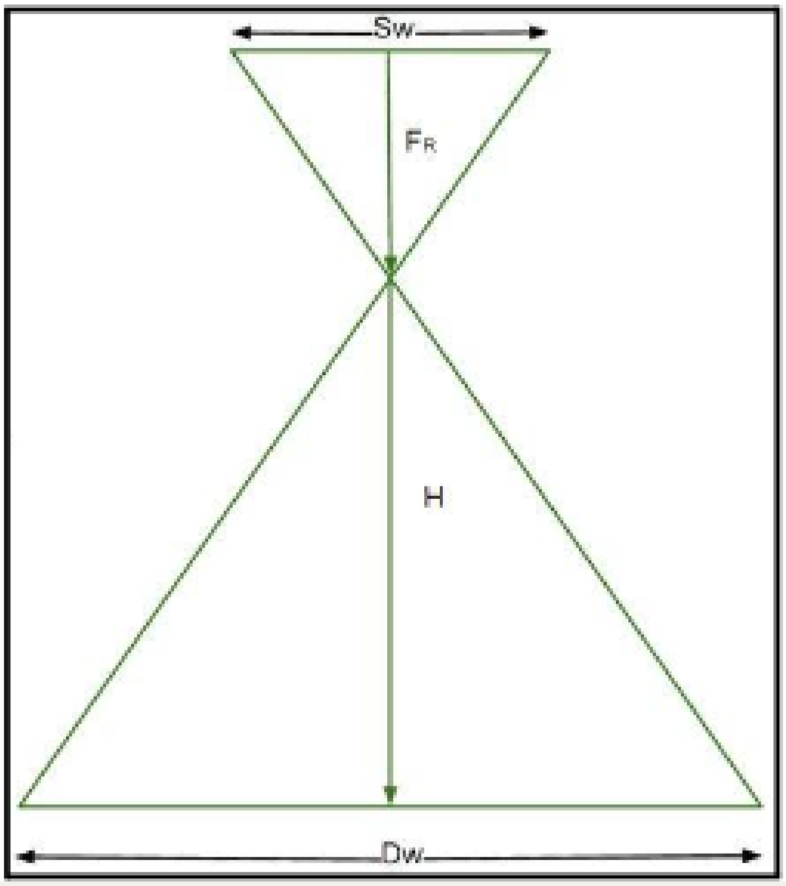
Mapping Area - LiDAR



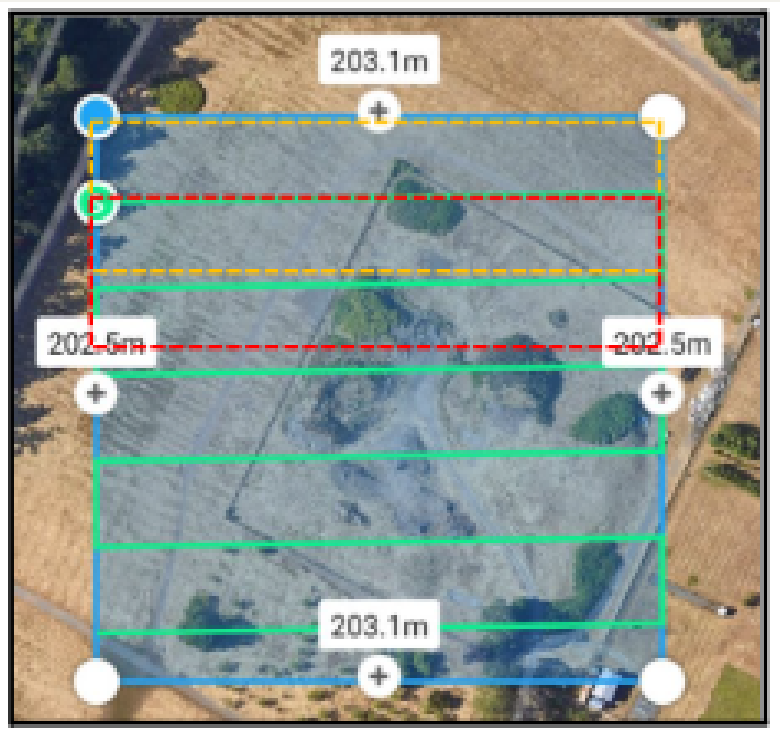
- Mapping Area (blue) defined by polygon with vertices (white circles)
- Starting point (S)
- Flight lines (green) that indicate where the drone will fly during the mission
- Yellow line portions indicate where the IMU calibrates and are included within the mapping area, and outside
- The number of flightlines required to map a given area is related to flight altitude and side overlap

Parameters - LiDAR

- Altitude or Height (H), is referenced to the take off point, or to a Digital Elevation Model (DEM)
- Field of view determines the angle covered by a flightline on the ground (L1 is 70.4°)
- Flightline width at ground (Dw)
- Increase in H will increase flightline width (Dw) at ground

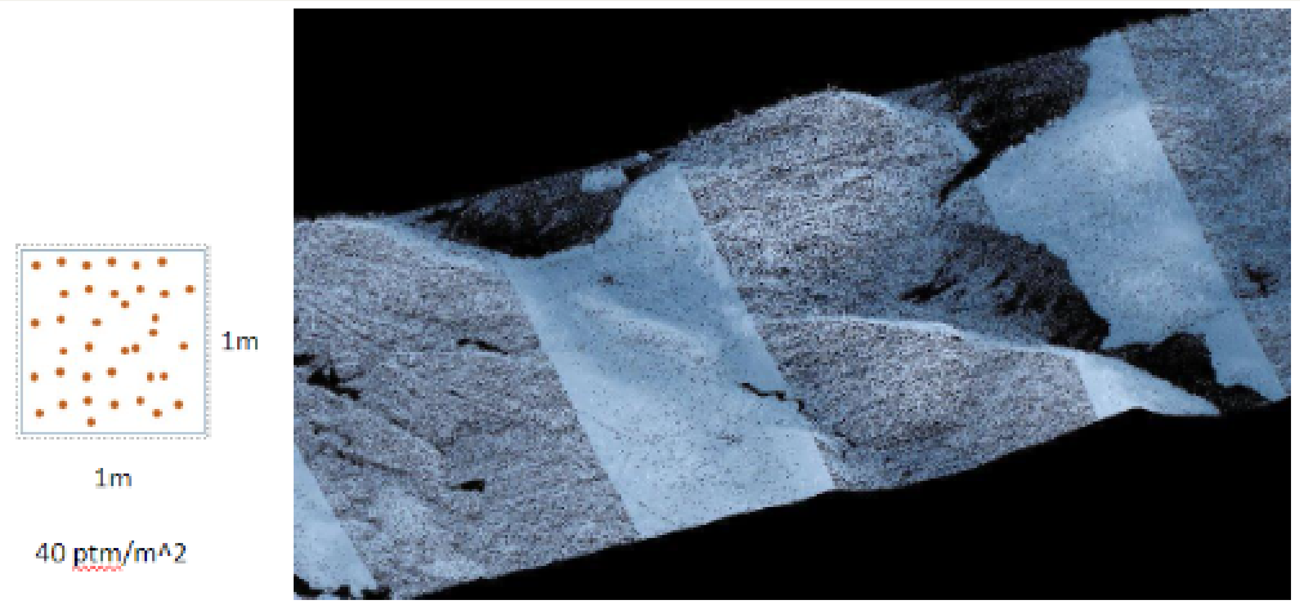


LiDAR Mapping - Flightline Side Overlap



- Lidar sensors emit and record laser pulses continuously during flightlines
- Flightlines have side overlap but depending on the site and application this can be much lower, 20-50% than photogrammetric missions ~60-95%
- RGB images can be taken concurrently with built in camera and have their own forward and side overlap values but usually there is not enough overlap for creating an orthomosaic

LiDAR Mapping Parameters



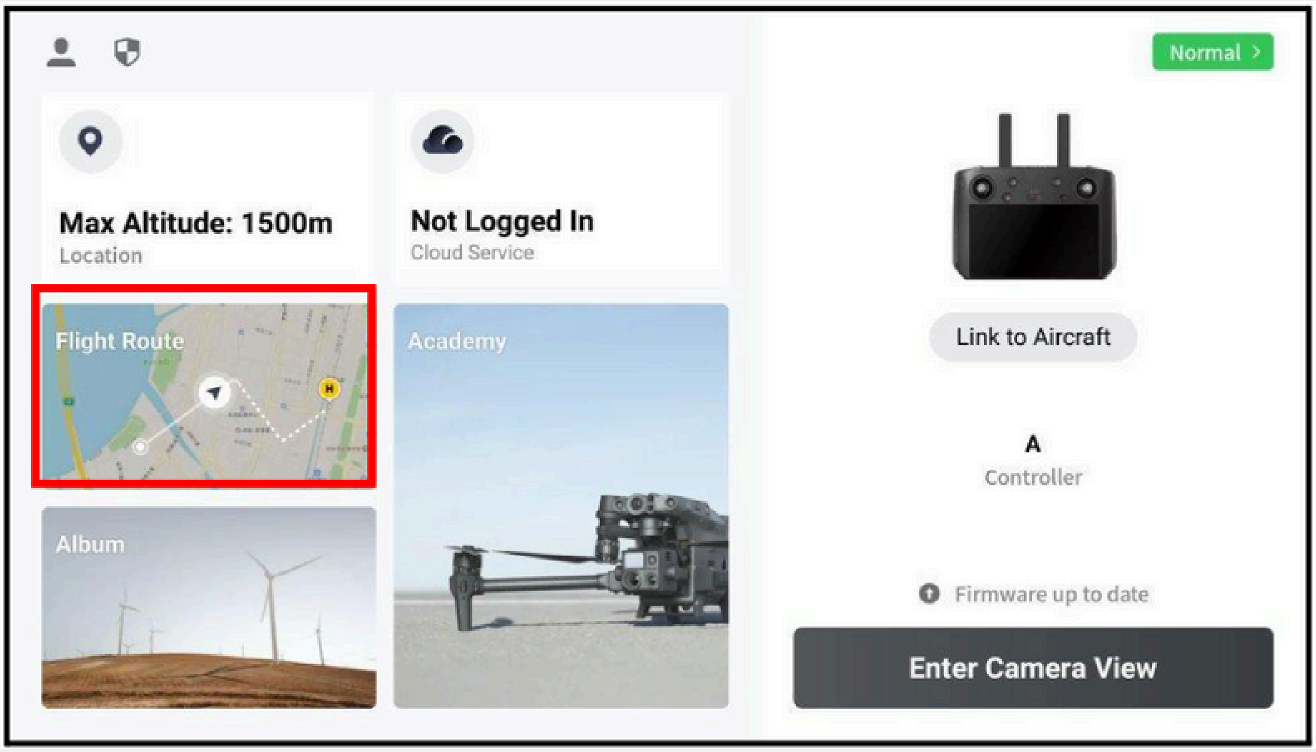
Source: https://gis.stackexchange.com/questions/270961/open-source-approach-to-classifying-and-removing-lidar-points-from-overlapping-s

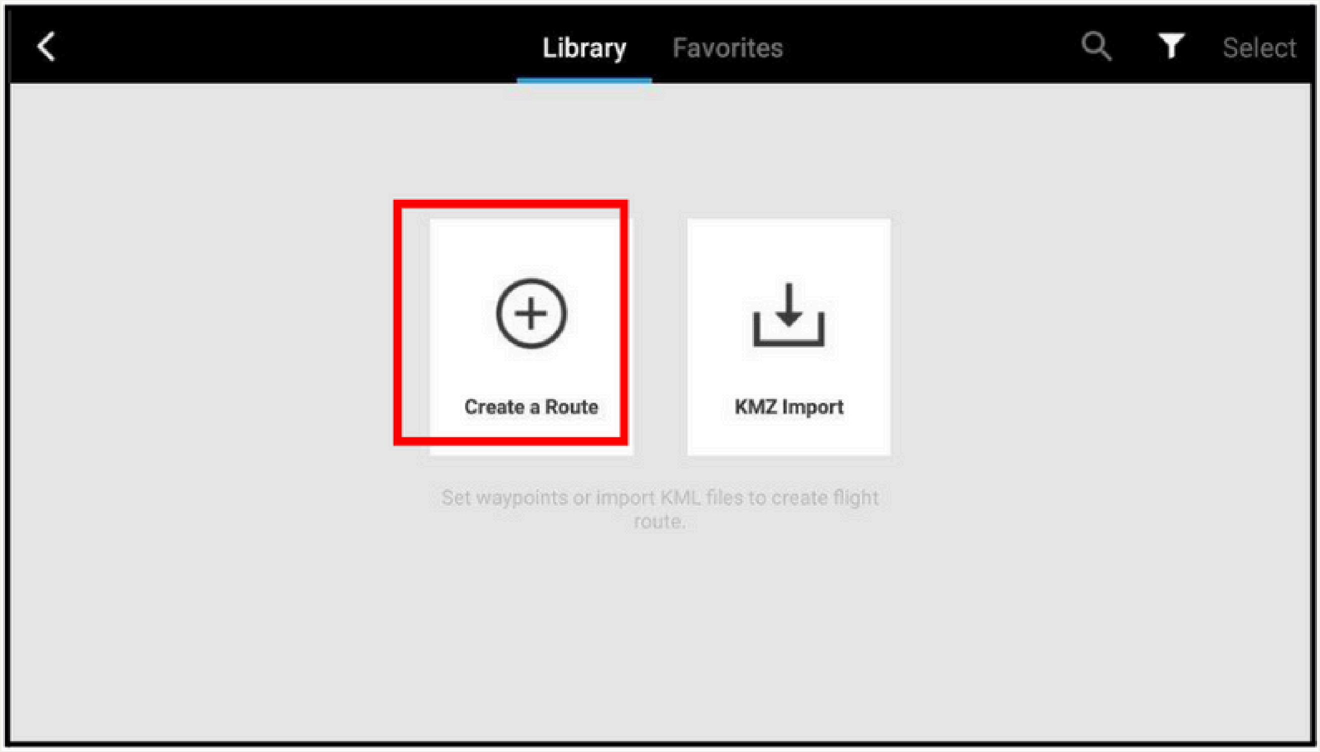
- Point Density – the number of measurements per m^2
- Point Density is a function of the speed of platform, the sampling rate, and the scanning mode
- Where flightlines overlap the final point density will be approximately doubled

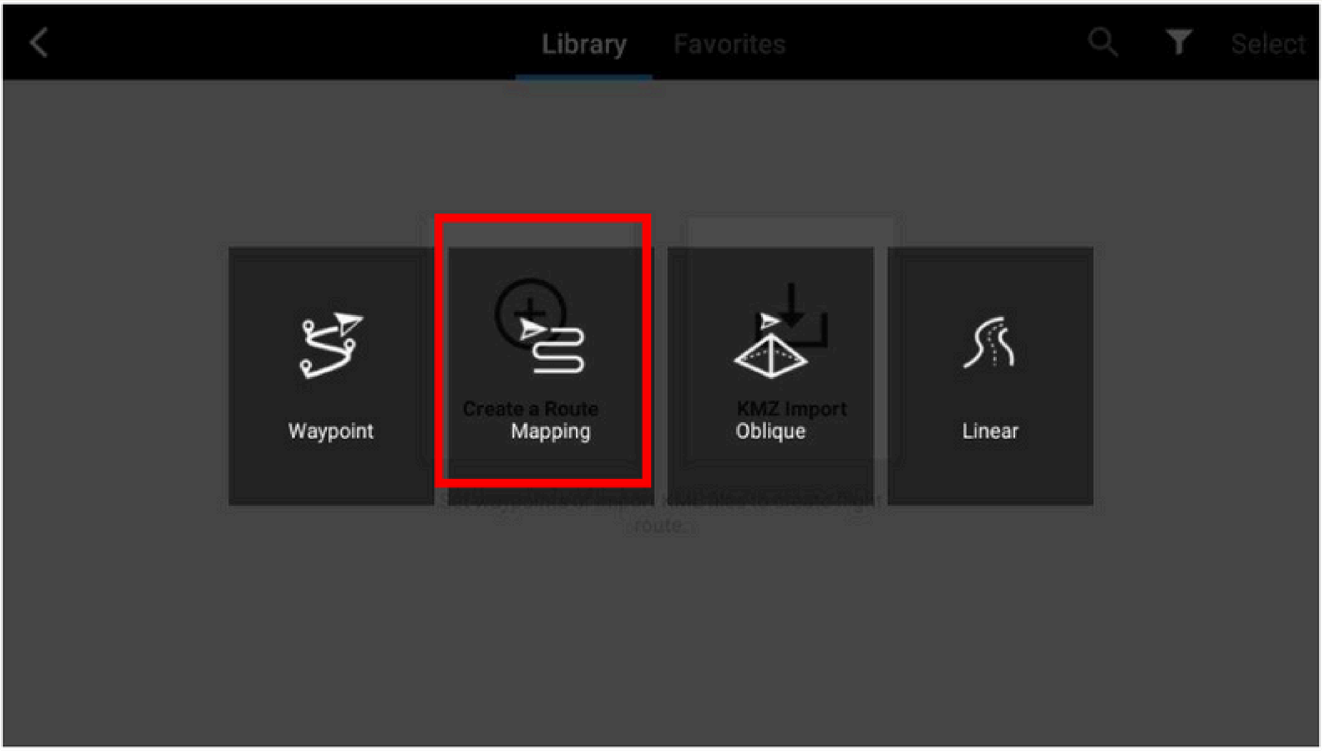
Basic LiDAR Mapping Scenario - DJI Pilot 2

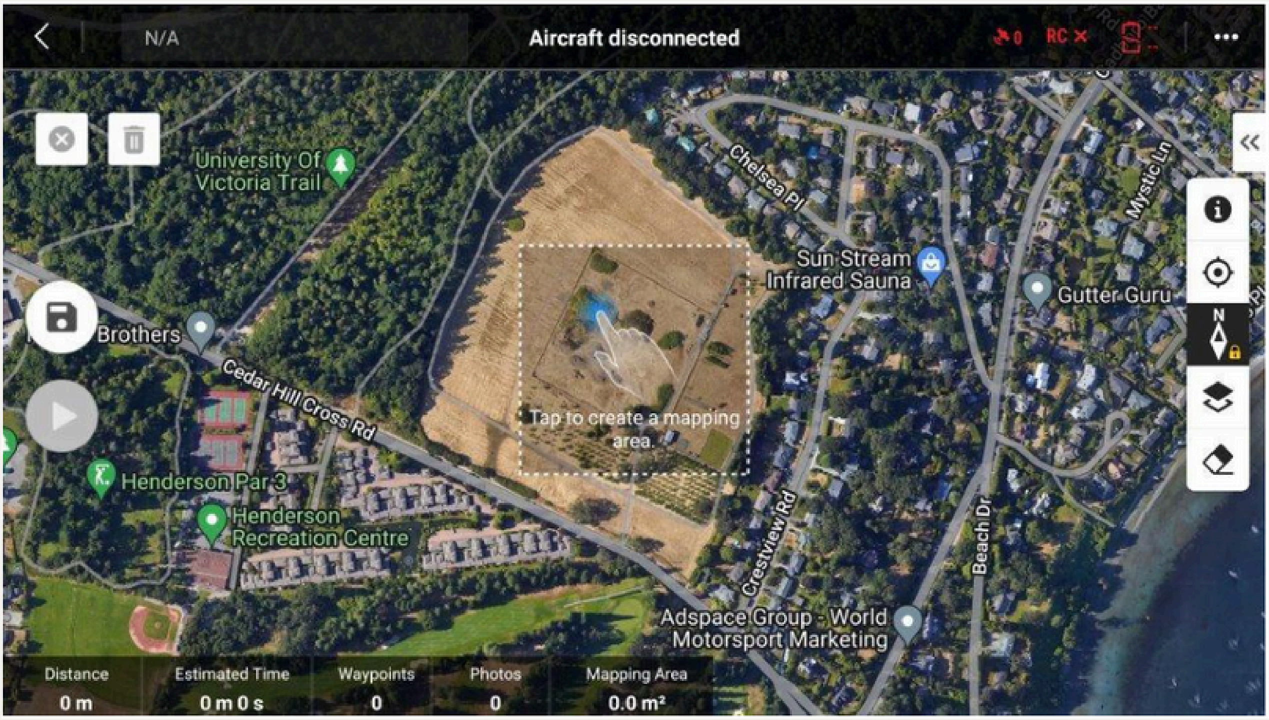
- Live Demo with follow along handout and settings
- Site is mostly flat, no terrain model available, a lidar point cloud is required with the intent to create digital terrain model that extends below Tree canopies.

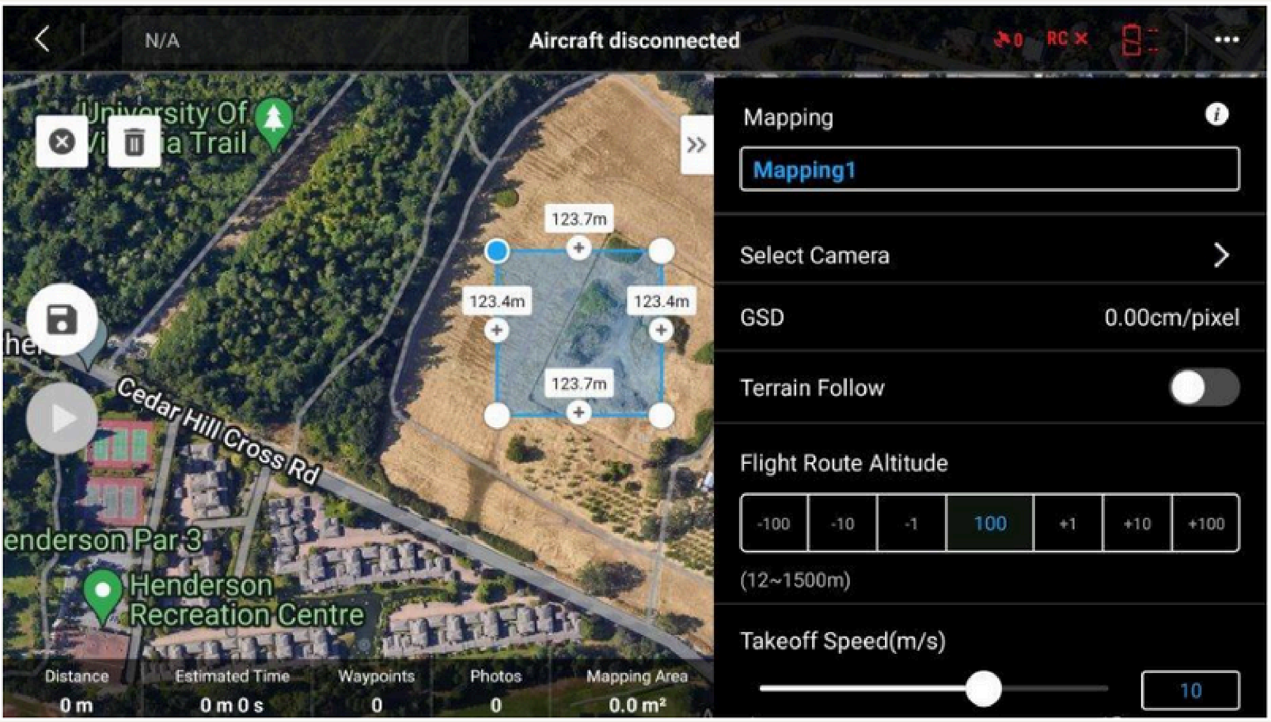
Visual Steps:

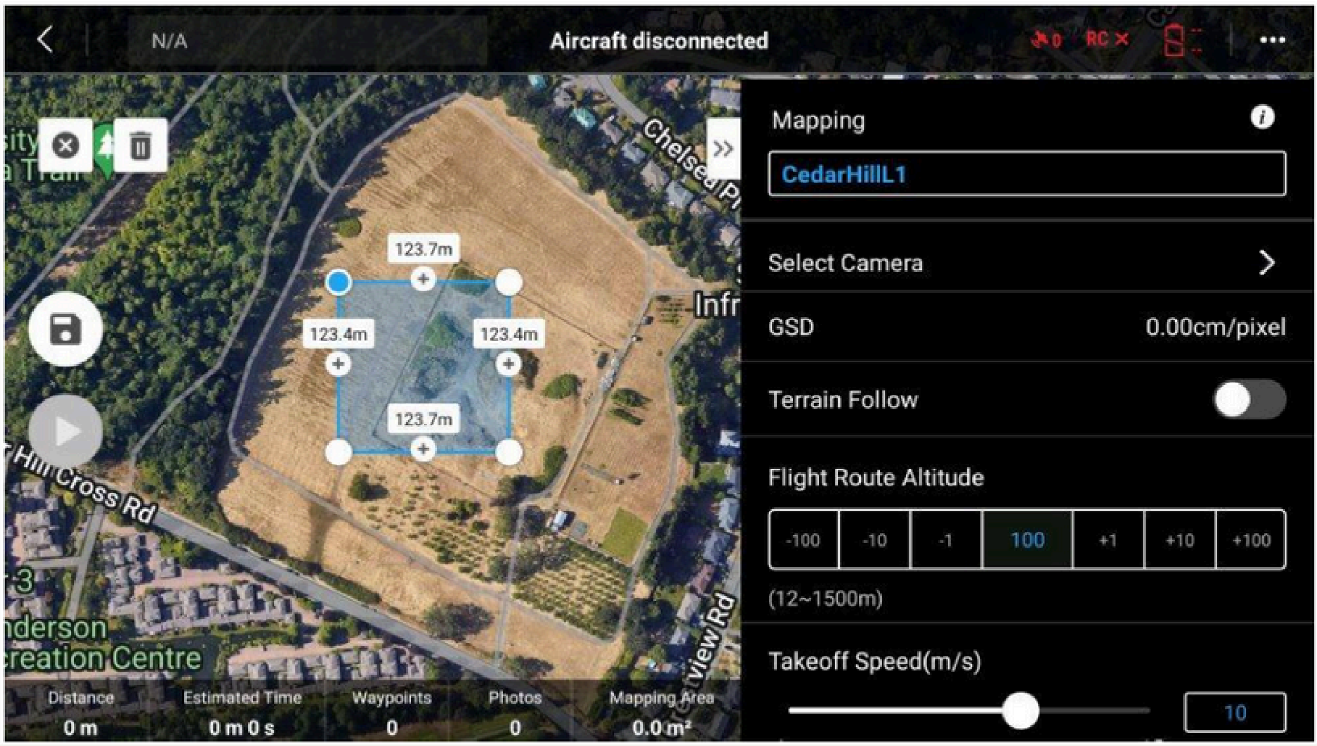


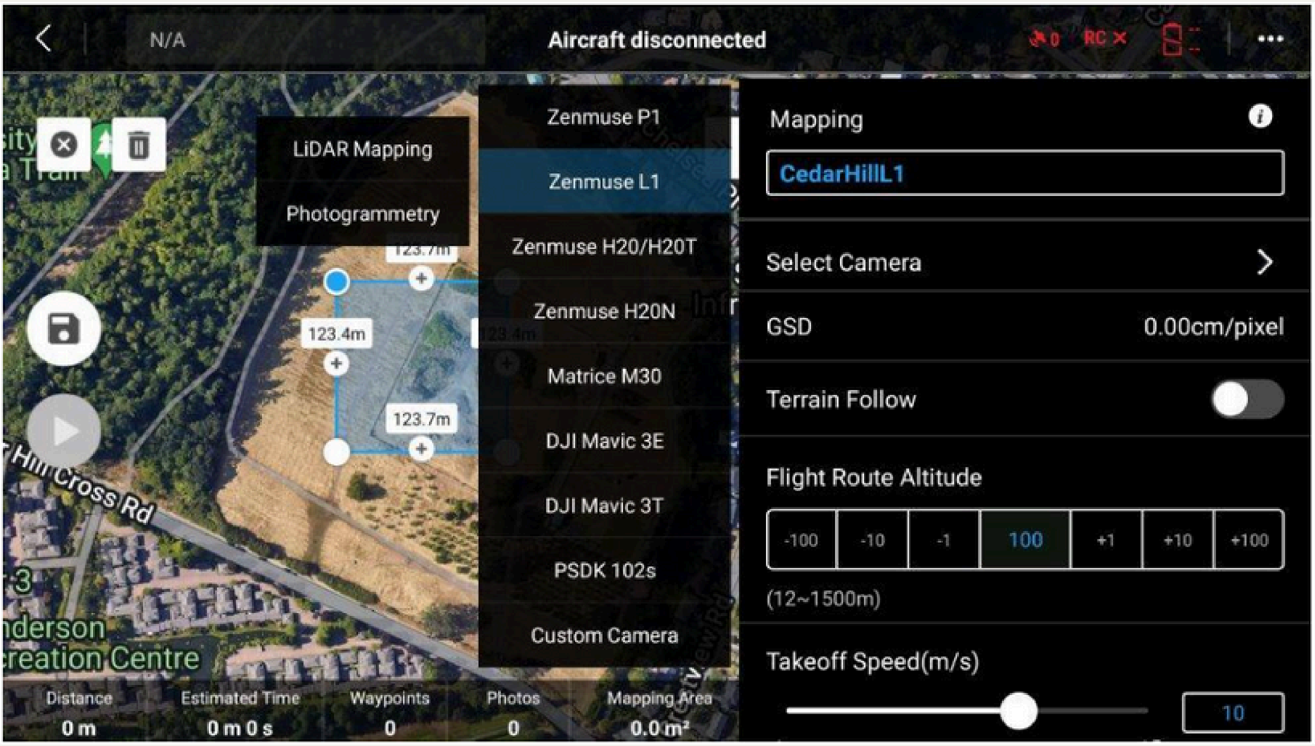

Library
Favorites
Select
Create a Route
KMZ Import
Set waypoints or import KML files to create flight route.

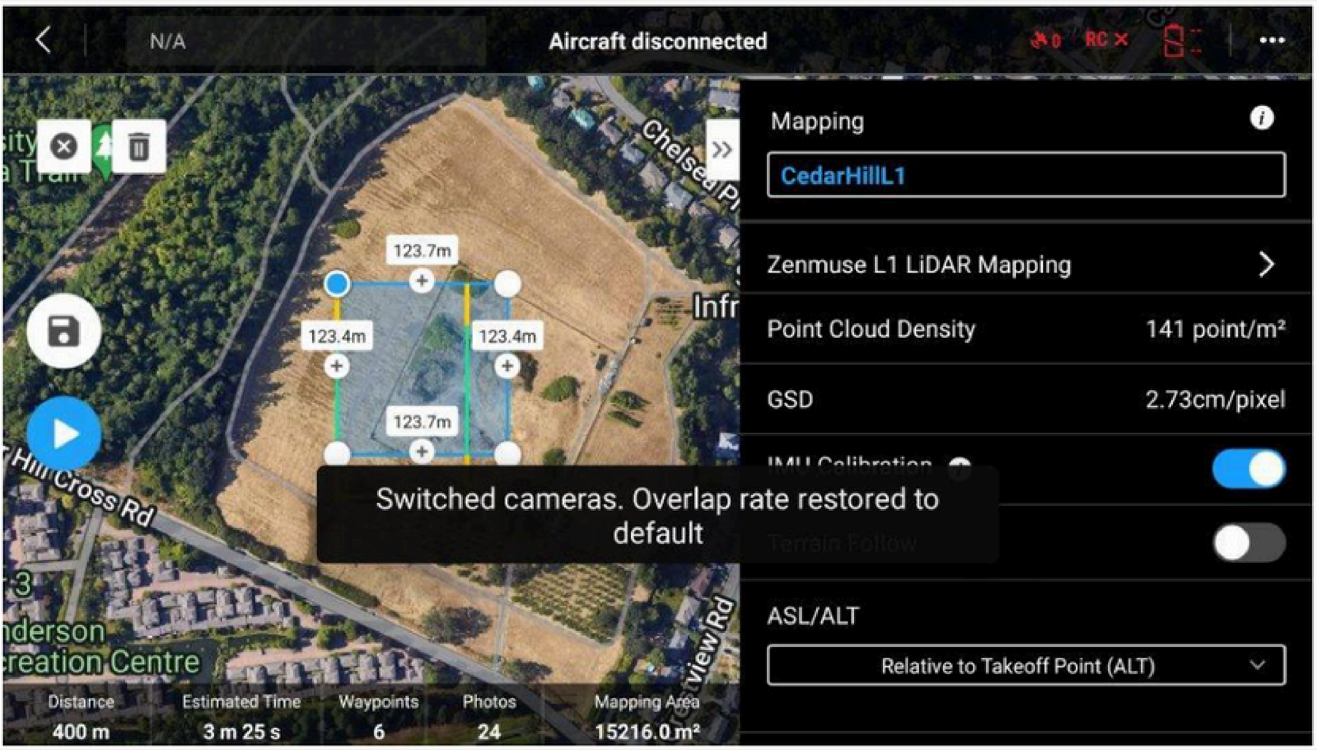

Library
Favorites
Select
Waypoint
Mapping
Oblique
Linear

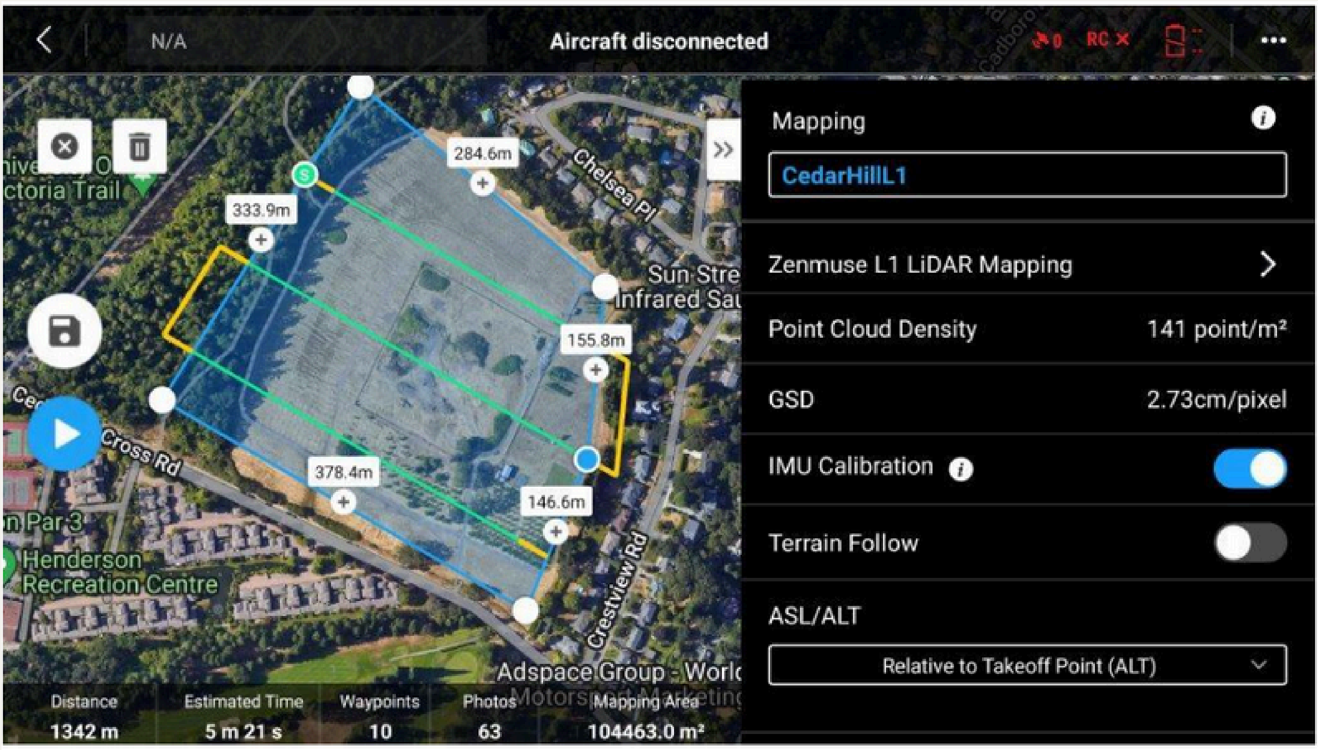

N/A
Aircraft disconnected
RC ×
University Of Victoria Trail
Chelsea Pl
Sun Stream Infrared Sauna
Gutter Guru
Mystic Ln
Brothers
Cedar Hill Cross Rd
Tap to create a mapping area.
Henderson Par 3
Henderson Recreation Centre
Crestview Rd
Beach Dr
Adspace Group - World Motorsport Marketing
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²

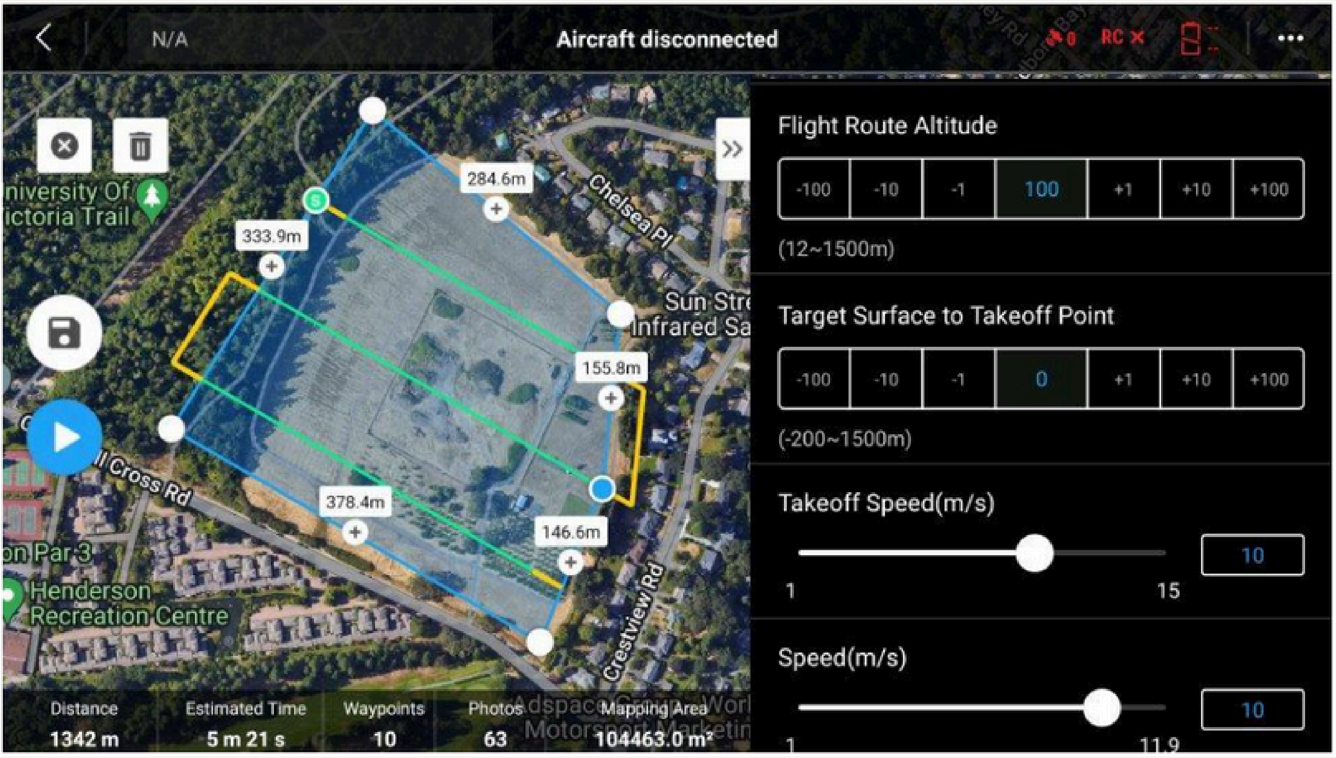

N/A
Aircraft disconnected
RC ×
Cedar Hill Cross Rd
Henderson Recreation Centre
123.7m
123.4m
123.4m
123.7m
Mapping
Mapping1
Select Camera
GSD
0.00cm/pixel
Terrain Follow
Flight Route Altitude
-100
-10
-1
100
+1
+10
+100
(12~1500m)
Takeoff Speed(m/s)
10
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²

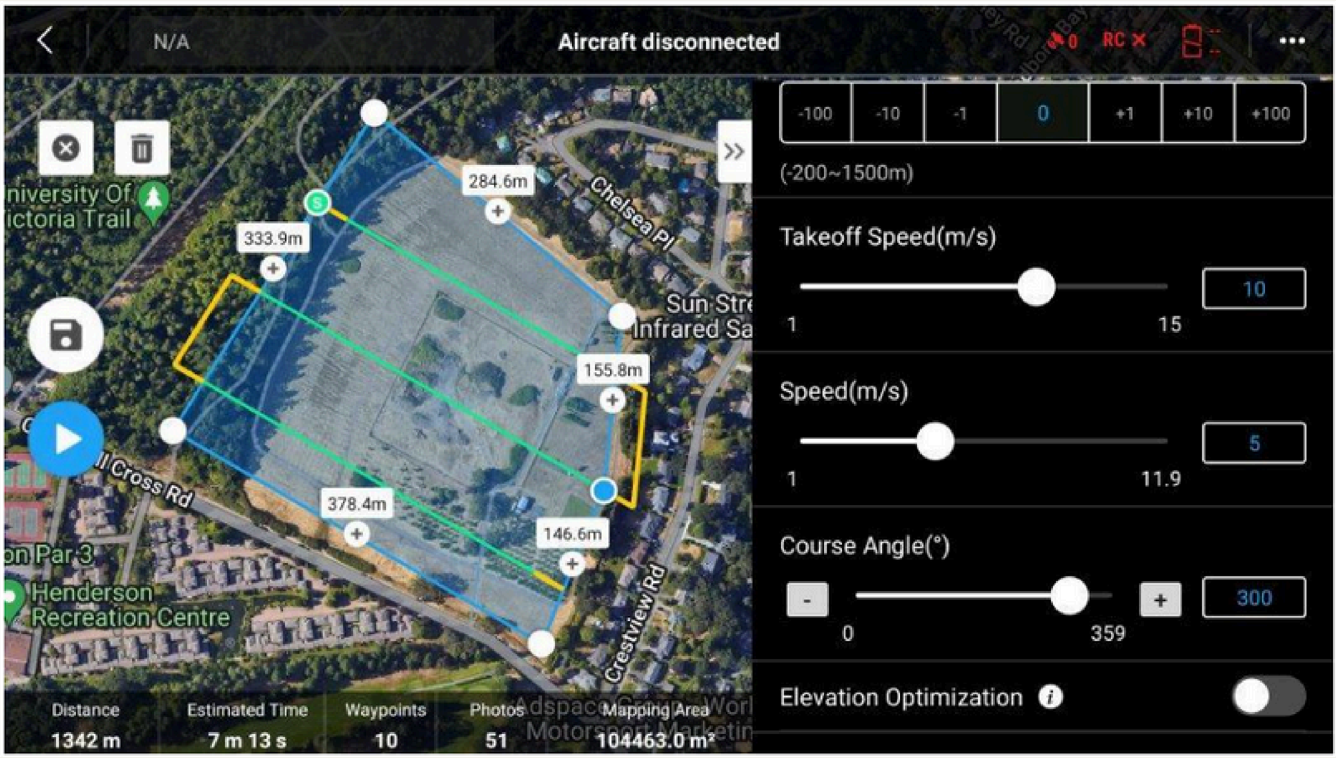

N/A
Aircraft disconnected
RC
123.7m
123.4m
123.4m
123.7m
Hill Cross Rd
nderson
reation Centre
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²
Mapping
CedarHillL1
Select Camera
GSD
0.00cm/pixel
Terrain Follow
Flight Route Altitude
-100
-10
-1
100
+1
+10
+100
(12~1500m)
Takeoff Speed(m/s)
10

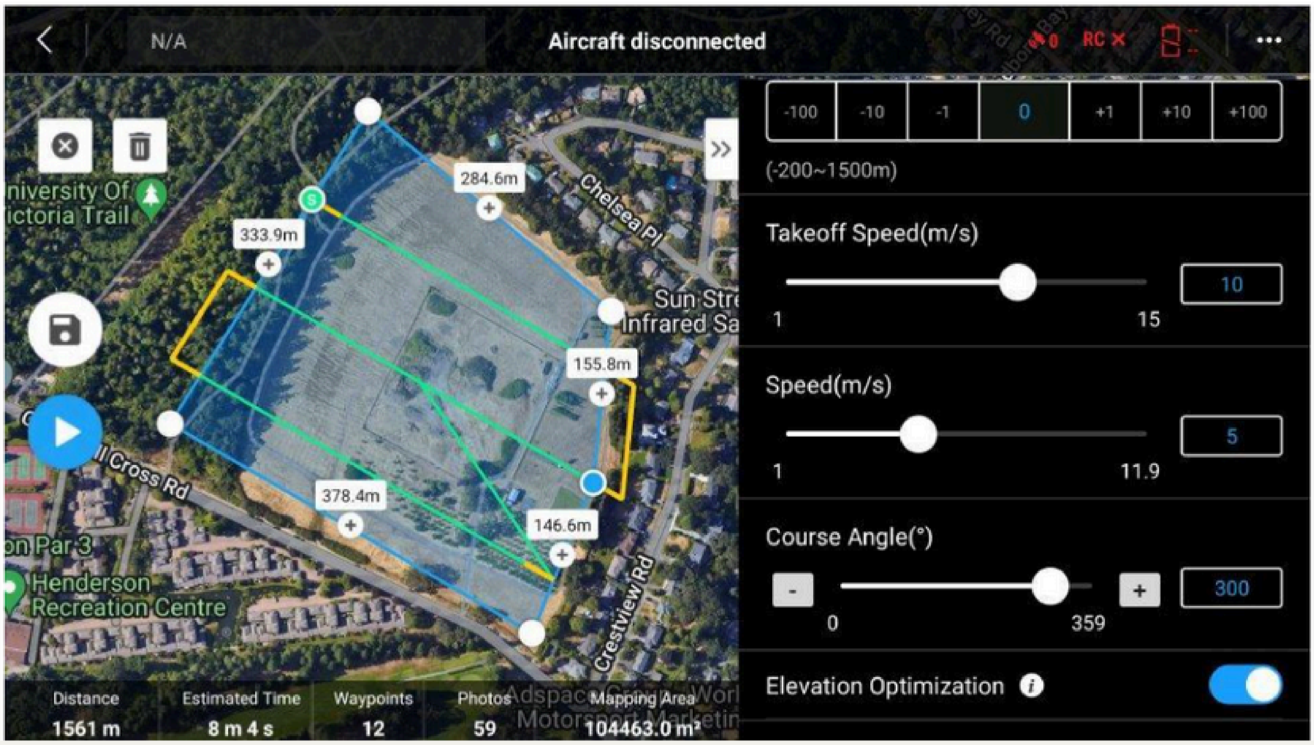

N/A
Aircraft disconnected
RC
LiDAR Mapping
Photogrammetry
Zenmuse P1
Zenmuse L1
Zenmuse H20/H20T
Zenmuse H20N
Matrice M30
DJI Mavic 3E
DJI Mavic 3T
PSDK 102s
Custom Camera
123.4m
123.7m
Hill Cross Rd
nderson
reation Centre
Distance
0 m
Estimated Time
0 m 0 s
Waypoints
0
Photos
0
Mapping Area
0.0 m²
Mapping
CedarHillL1
Select Camera
GSD
0.00cm/pixel
Terrain Follow
Flight Route Altitude
-100
-10
-1
100
+1
+10
+100
(12~1500m)
Takeoff Speed(m/s)
10

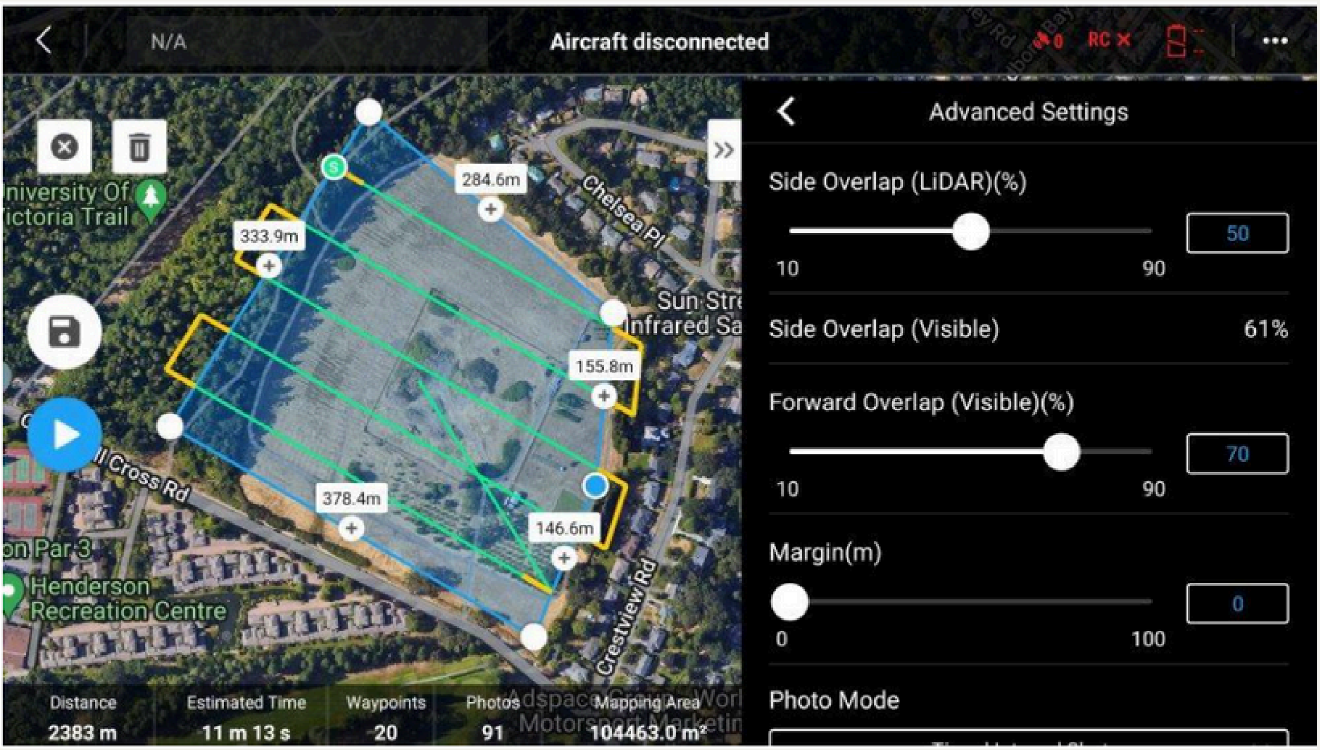

N/A
Aircraft disconnected
RC ×
Mapping
CedarHillL1
Zenmuse L1 LiDAR Mapping
Point Cloud Density 141 point/m²
GSD 2.73cm/pixel
IMU Calibration
Terrain Follow
ASL/ALT
Relative to Takeoff Point (ALT)
Switched cameras. Overlap rate restored to default
123.7m
123.4m
123.4m
123.7m
Chelsea Pl
Hill Cross Rd
Crestview Rd
Distance 400 m
Estimated Time 3 m 25 s
Waypoints 6
Photos 24
Mapping Area 15216.0 m²


N/A
Aircraft disconnected
RC ×
Mapping
CedarHillL1
Zenmuse L1 LiDAR Mapping
Point Cloud Density 141 point/m²
GSD 2.73cm/pixel
IMU Calibration
Terrain Follow
ASL/ALT
Relative to Takeoff Point (ALT)
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Cross Rd
Crestview Rd
Henderson Recreation Centre
Adspace Group - World
Distance 1342 m
Estimated Time 5 m 21 s
Waypoints 10
Photos 63
Mapping Area 104463.0 m²


N/A
Aircraft disconnected
RC
Flight Route Altitude
-100
-10
-1
100
+1
+10
+100
(12~1500m)
Target Surface to Takeoff Point
-100
-10
-1
0
+1
+10
+100
(-200~1500m)
Takeoff Speed(m/s)
1
15
10
Speed(m/s)
1
11.9
10
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Crestview Rd
Henderson Recreation Centre
Distance
1342 m
Estimated Time
5 m 21 s
Waypoints
10
Photos
63
Mapping Area
104463.0 m²

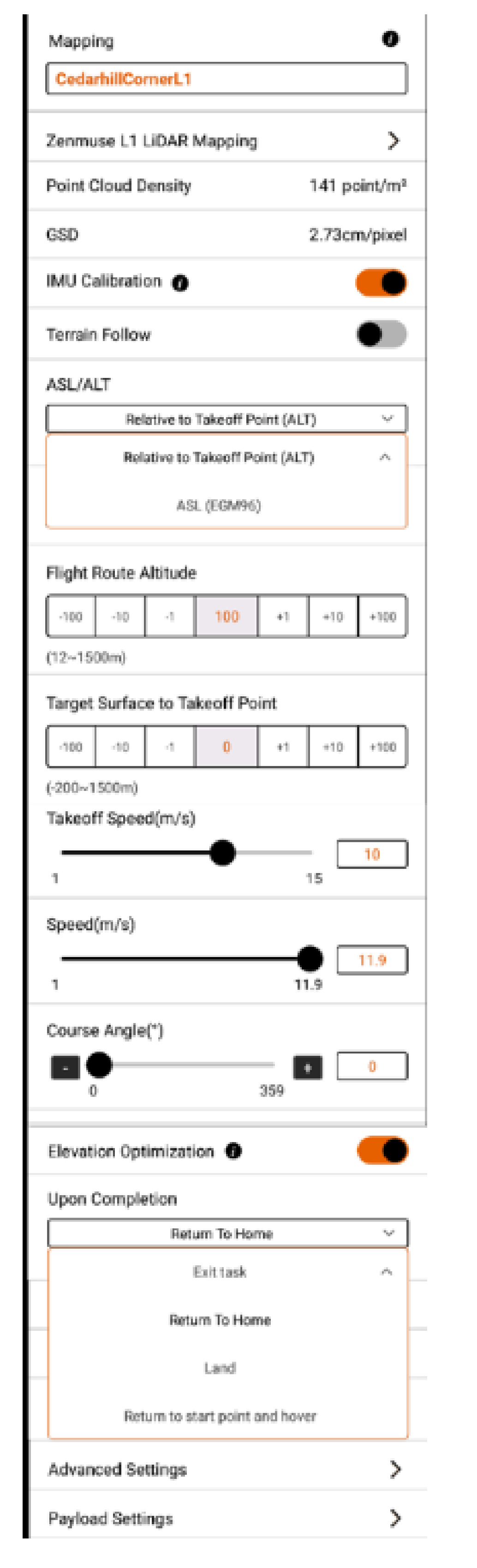

N/A
Aircraft disconnected
RC
-100
-10
-1
0
+1
+10
+100
(-200~1500m)
Takeoff Speed(m/s)
1
15
10
Speed(m/s)
1
11.9
5
Course Angle(°)
-
+
0
359
300
Elevation Optimization
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Crestview Rd
Henderson Recreation Centre
Distance
1342 m
Estimated Time
7 m 13 s
Waypoints
10
Photos
51
Mapping Area
104463.0 m²


N/A
Aircraft disconnected
-100
-10
-1
0
+1
+10
+100
(-200~1500m)
Takeoff Speed(m/s)
1
15
10
Speed(m/s)
1
11.9
5
Course Angle(°)
0
359
300
Elevation Optimization
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Crestview Rd
Henderson Recreation Centre
Distance
1561 m
Estimated Time
8 m 4 s
Waypoints
12
Photos
59
Mapping Area
104463.0 m²


N/A
Aircraft disconnected
Advanced Settings
Side Overlap (LiDAR)(%)
10
90
50
Side Overlap (Visible)
61%
Forward Overlap (Visible)(%)
10
90
70
Margin(m)
0
100
0
Photo Mode
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Crestview Rd
Henderson Recreation Centre
Distance
2383 m
Estimated Time
11 m 13 s
Waypoints
20
Photos
91
Mapping Area
104463.0 m²

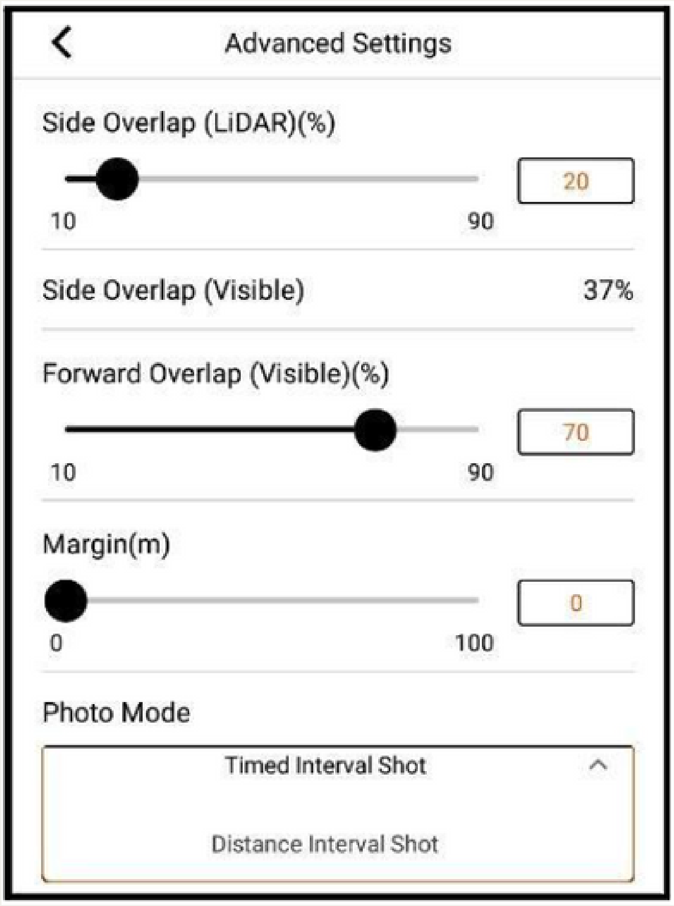
N/A
Aircraft disconnected
RC
284.6m
333.9m
155.8m
378.4m
146.6m
Chelsea Pl
Crestview Rd
Henderson Recreation Centre
Side Overlap (LiDAR)(%)
10
90
50
Side Overlap (Visible)
61%
Forward Overlap (Visible)(%)
10
90
70
Margin(m)
0
100
0
Photo Mode
Distance Interval Shot
Distance
2383 m
Estimated Time
11 m 13 s
Waypoints
20
Photos
81
Mapping Area
104463.0 m²

Selecting DJI Pilot 2 Parameters for L1 - ALT Relative to Take Off Point



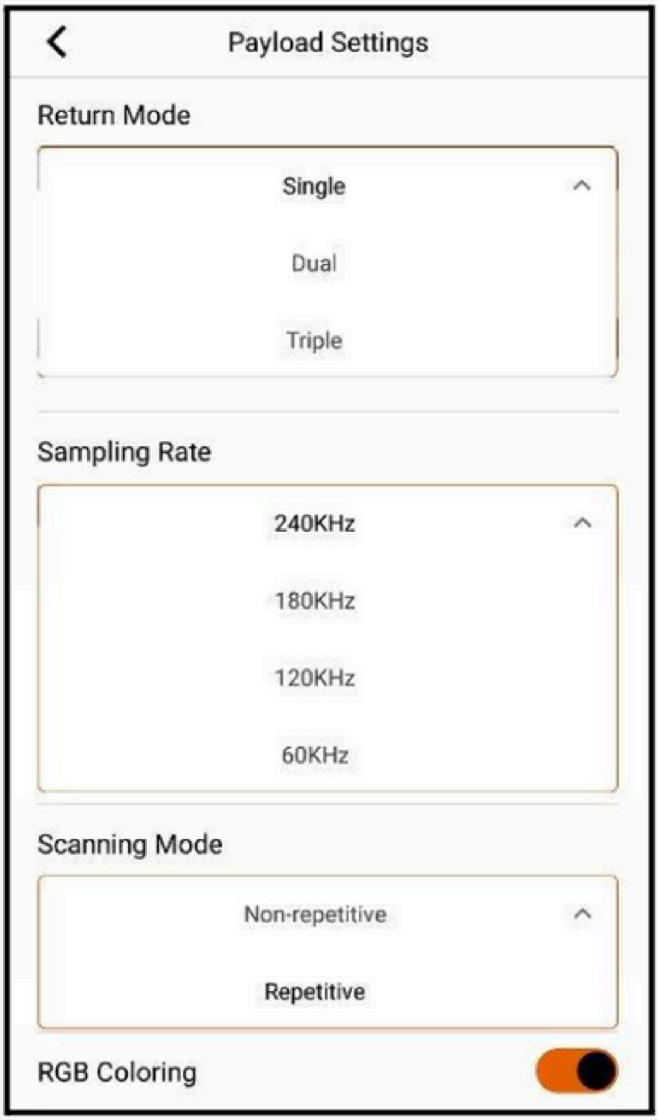
Standard Settings

- **Mission Name** - The name of the mission
- **Camera and Options** – In this case it is either Zenmuse L1 in Lidar Mapping Mode, or Zenmuse L1 in Photogrammetric Mode
- **Point Density** – The Point density is and estimation of the density of lidar points / m^2. This is a function of speed, side overlap, sampling rate, and Scanning mode.
- **GSD** – The ground sample distance is the size of 1 image pixel on the ground at a given altitude. It is proportional to the flight altitude and can be approximated for the Zenmuse L1 lens by GSD(cm)=Flight Altitude (m) / 36.5
- **IMU Calibration** – IMU calibration should be turned on for most mapping missions. The IMU Calibration shows up as yellow coloured route segments where the drone will fly back and forth in a calibration maneuver. Calibration segments will extend outside of the mapping area so it is important to ensure no obstructions are in the way.
- **Terrain Follow** – Terrain following will maintain the UAV altitude relative to the height of a provided Digital Elevation Model. When this is turned off, Flight Route Altitude is used.
- **ASL/ATL** – Relative to takeoff point or relative to EGM96 Geoid, leave as default (Only Available when Terrain following is turned OFF)
- **Flight Route Altitude** – The altitude or height relative to the take off point that the route will be flown at (Available only when terrain following is Turned OFF)
- **Target Surface to Takeoff Point** – An offset that is added or Subtracted if the drone is launched from a platform or surface above the ground, or below the ground surface to be mapped. (Available only when terrain following is Turned OFF)
- **Take off Speed** – Once the drone has been launched and reached the Flight Route Altitude, the speed that the drone will fly to the Starting waypoint.
- **Speed** – This is the maximum speed the drone will fly during the mission. For open sites or for applications that do not require high point densities this could be run towards the maximum. For forestry and sites requiring canopy penetration of high point densities it is recommended to decrease this to ~5 m/s.
- **Course angle** – The course modifies the orientation of the flight lines. In general the default orientation is often the most efficient.
- **Elevation Optimization** – This helps create a higher accuracy elevation model by taking oblique images at the end of the flight; however, this will also increase the time required for a mission.
- **Upon Completion** – At the end of the flight, what action is taken. For most missions it is best to leave this as the default - Return to Home



Advanced Settings

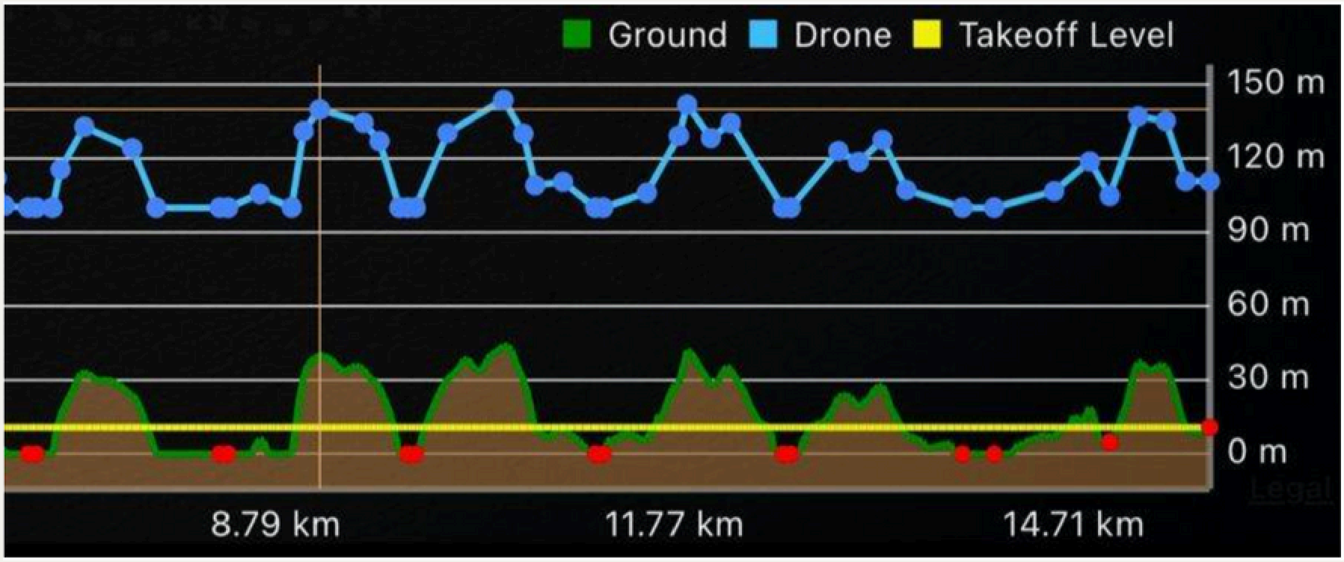
- **Side overlap (Lidar) (%)** – The side overlap LiDAR ratio determines the percentage that adjacent flight lines overlap. The areas where side overlap occur will tend to have increased point densities. Applications such as forestry where canopy penetration is important may increase this up to 50% to maximize returns from the ground. Increasing side overlap will increase the number of flightlines necessary and increase overall flight duration.
- **Side overlap (Visible)** – The side overlap ratio determines the image footprint overlap between adjacent flightlines. Increasing sidelap, reduces the spacing between adjacent flightlines and typically requires more flightlines and therefore a longer mission duration. If a photogrammetric reconstruction is a goal for the mission using the L1 20MP camera it is important that this value is considered to be successful.
- **Forward overlap (Visible)** – The forward overlap ratio determines the image footprint overlap between consecutive images, the default is 70%. Increasing overlap will decrease the maximum speed possible for the flight. If photogrammetric reconstruction is important this value should be considered.
- **Margin** – The margin is used to buffer the extents of a study area. For example, by setting the margin at 10m, the mapping area will be increased outward by a radius of 10m.
- **Photo Mode** – Photos are either taken using a timed interval, or based on a distance interval. DJI previously had recommended using timed interval, however distance interval is now recommended in Pilot 2 training modules and will produce a dataset with fewer photos during the turns and should also process faster.



Playload Settings

- **Return Mode** – The return mode is the number of return possible for an outgoing pulse. For flat surfaces this can be left at single, for forestry it should be set at triple. In single and dual mode the max sampling rate is 240Khz, in triple mode it is 180Khz.
- **Sampling Rate** – The sampling rate is the number of outgoing laser pulses per second. Higher sampling rates produce higher point densities.
- **Scanning Mode** – Two modes and scan patterns are supported, Repetitive, and Non Repetitive. Repetitive provides lower point densities but higher quality data and is recommended for topographic and forestry surveys. Non Repetitive is best for façade scanning or applications where accuracy is not as important.
- **RGB Coloring** – RBB Coloring when turned on will use color lidar returns using the built in camera. This is recommended to be turned on.

Terrain Follow



Other Considerations

- Sighting launch and recovery location
- Are flightline lengths manageable – consider splitting into two overlapping blocks and two launch recovery locations?
- Ground Control Targets are visible and within mapping area

Video Tutorials

Four video tutorials were created for the project. These video presentations provide a more in-depth and audio-visual way to follow the step-by-step detailed workflow guide, which is provided later in this document. The videos feature live screen recordings of each step for each of the different data types individual processing method, along with a voice-over explaining what is happening and why at each step.

The videos which were created:

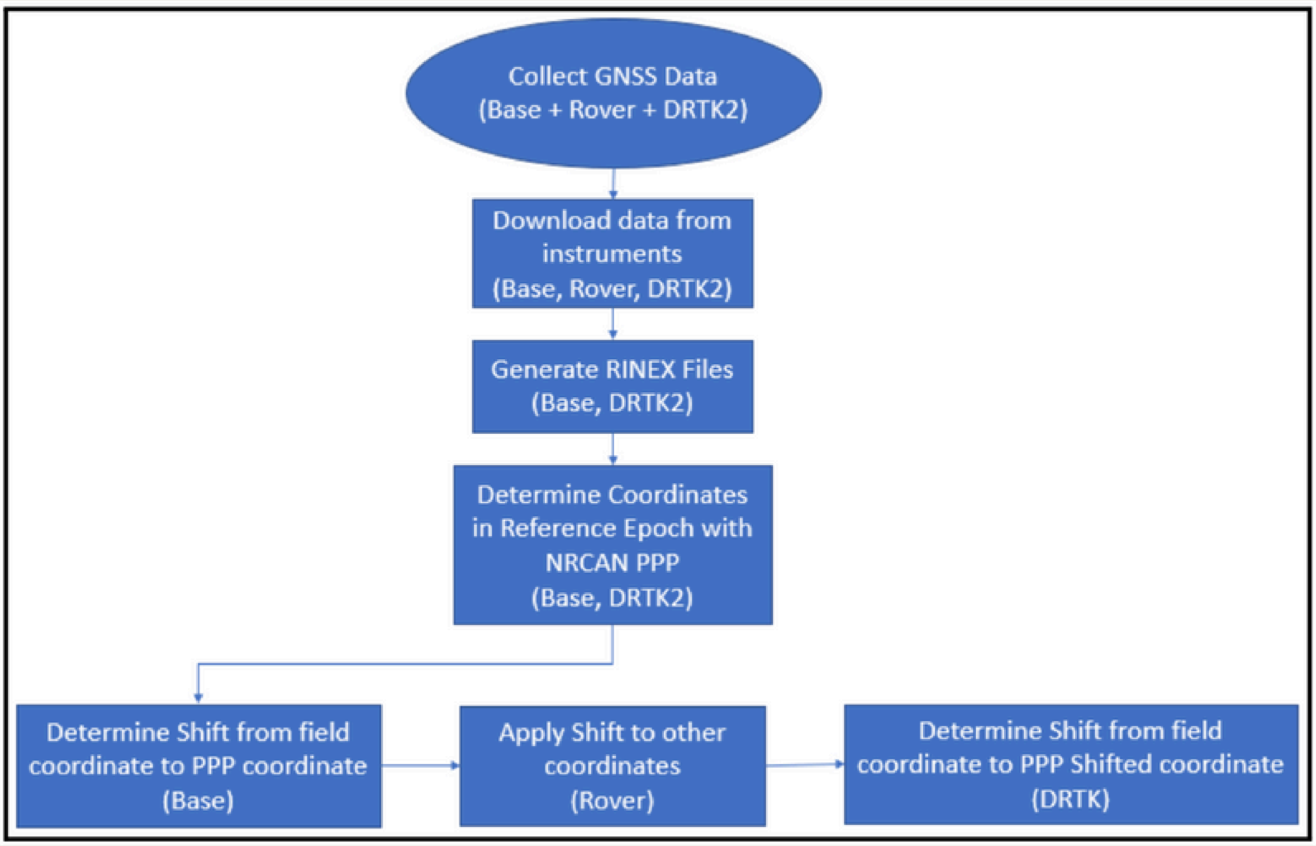
1. GNSS Data Processing Training
2. Thermal (H20T) Data Processing Training
3. LiDAR (L1) Data Processing Training
4. Photogrammetry (P1) Data Processing Training

GNSS Processing

Why do we need to process the GNSS data?

Coordinate reference systems provide the ability to describe a position on the earth's surface using latitude, longitude, and ellipsoidal height, in Canada we commonly use the Canadian Spatial Reference System version of the North American Datum 1983 (NAD83(CSRS)). As tectonic movement happens over time a coordinate representing a feature on earth's surface will also move (mm/year). To account for this and minimize positional errors between repeat surveys, we need to convert coordinates collected on a particular day into a standard epoch. On the mainland of BC, the standard is to use NAD83(CSRS) with the 2002.0 epoch. For more information about the Canadian Spatial Reference System **see this webpage.**

General Workflow:

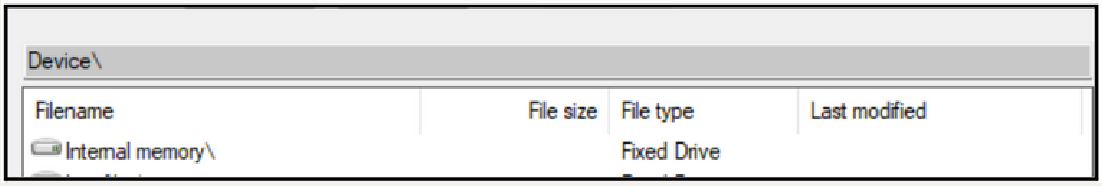


Detailed Workflow Steps:

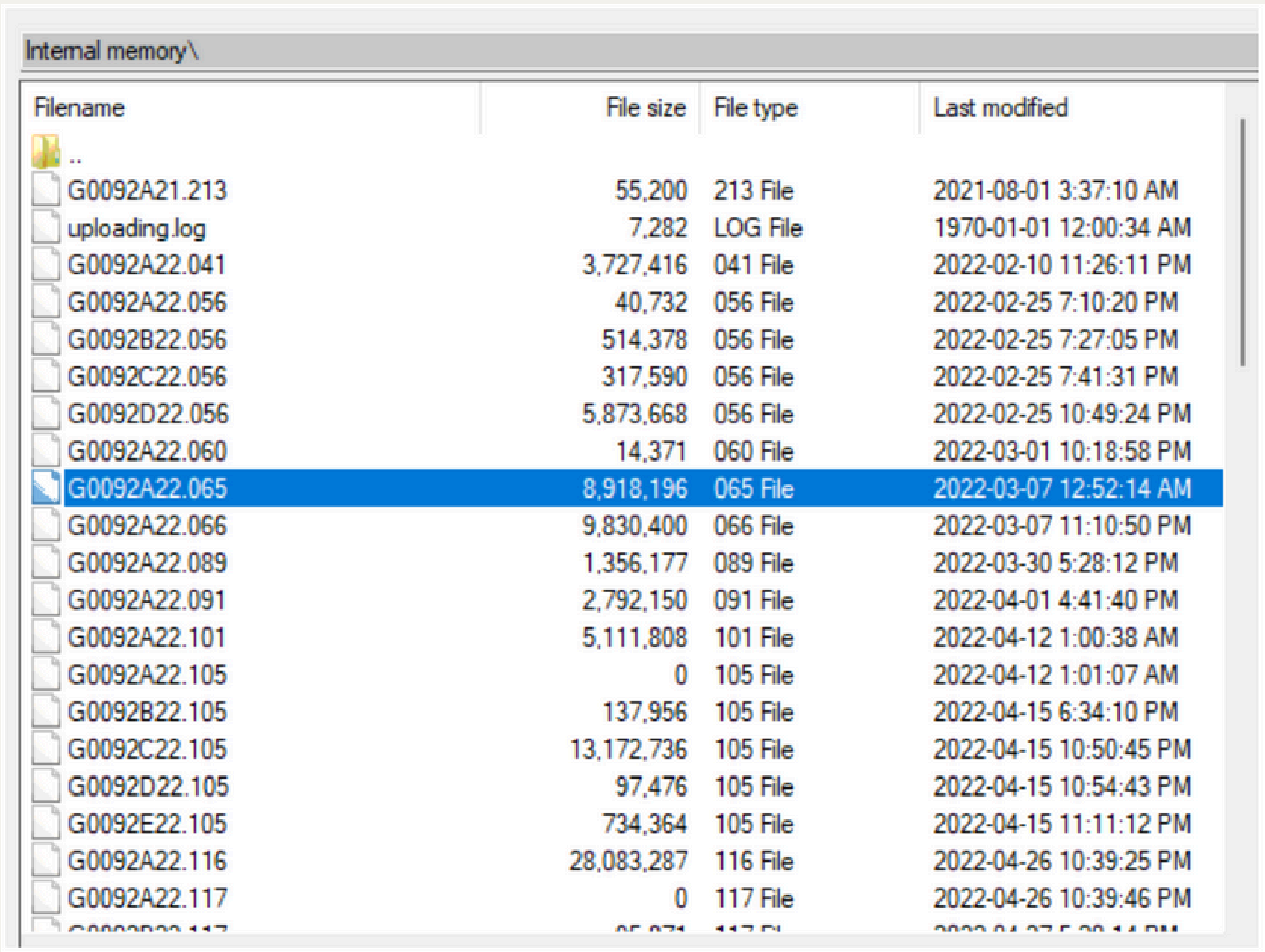
1.0 Retrieving Data

1. Get base files off SP85 head unit
    a. Connect USB to base head
    b. Power on unit
    c. Open Spectra File Manager
    d. Search for the port that shows the USB connection

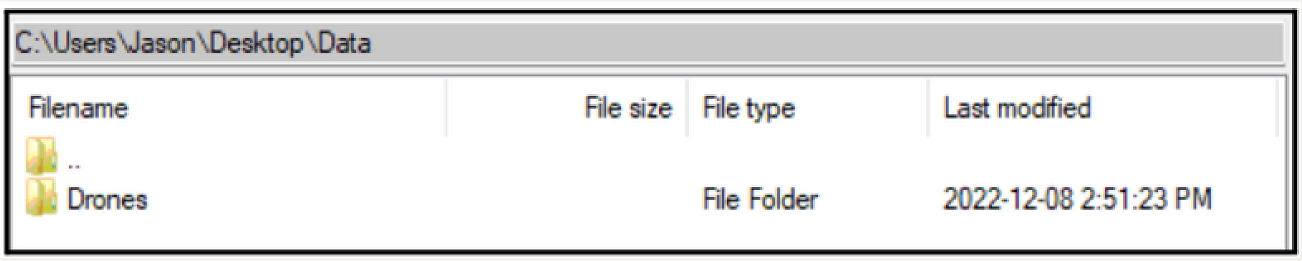
e. In the Device window navigate into internal memory



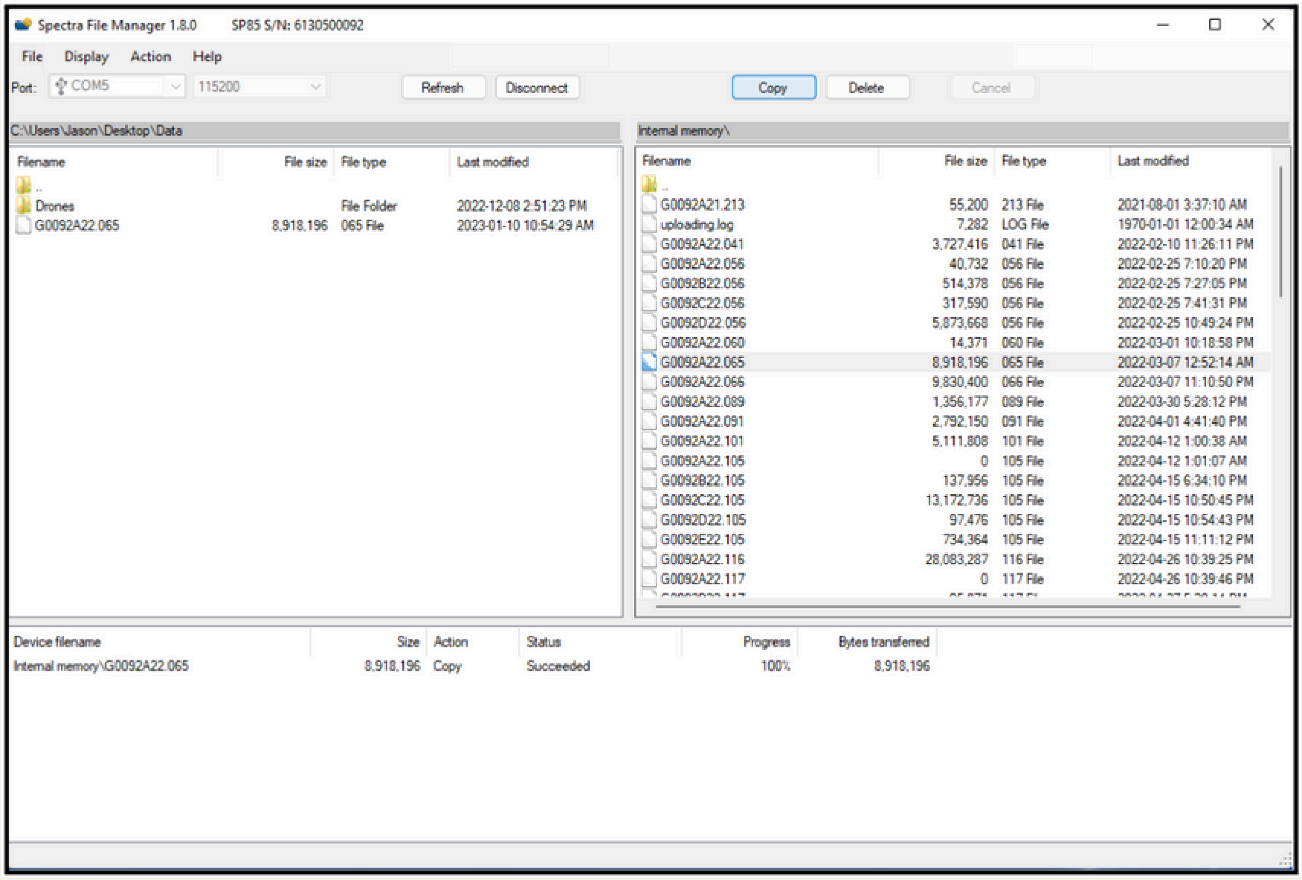
f. Search for the file(s) ending with .### where ### is the day of the year for the survey (check day of year **here**)



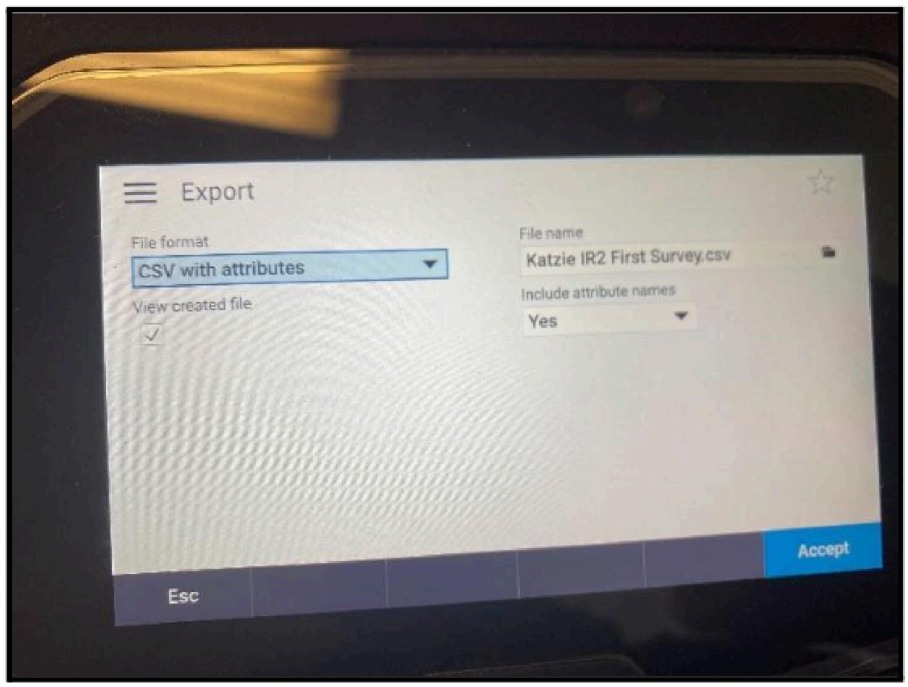
g. On the computer side navigate to the folder where you want to copy data to.



h. With the selected sp85 files highlighted click copy and the files will be copied off the base unit.

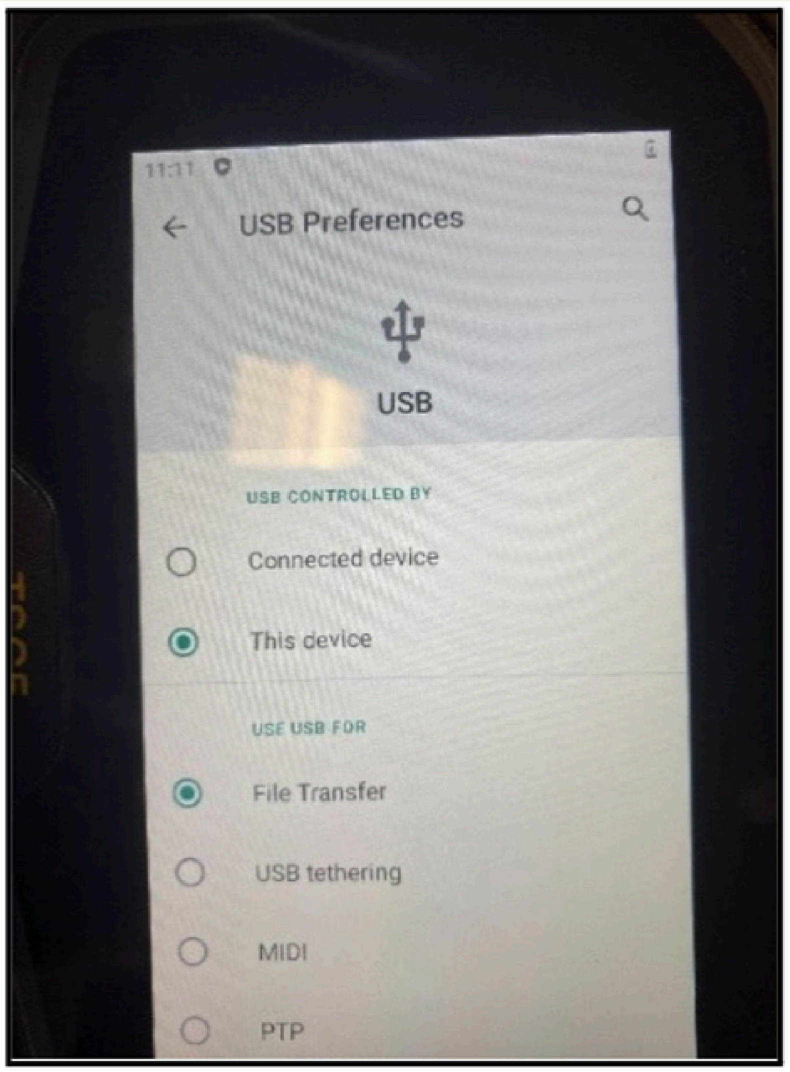


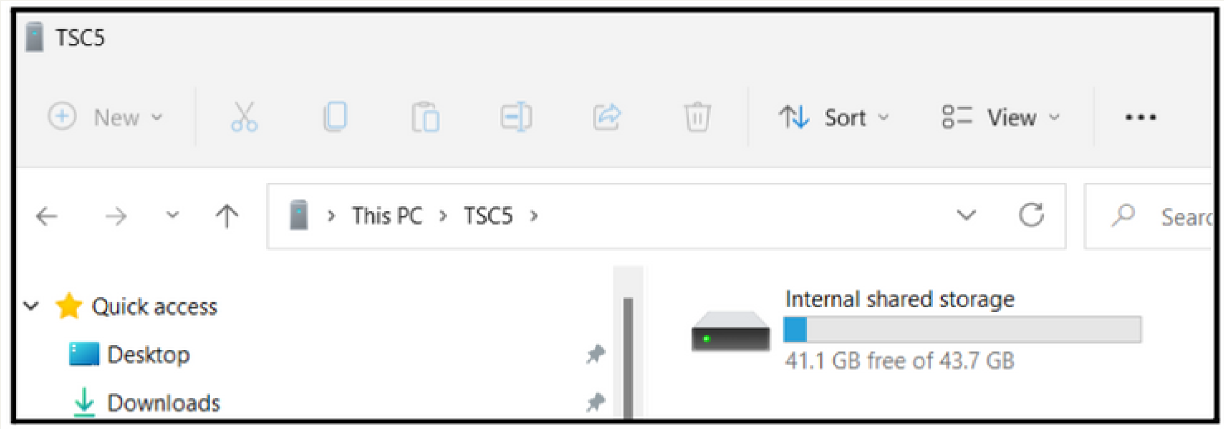
2. Get rover files off TSC5
   a. Power up TSC5 and open Trimble Access
   b. Navigate to the appropriate project folder
   c. Select the job
   d. Select export



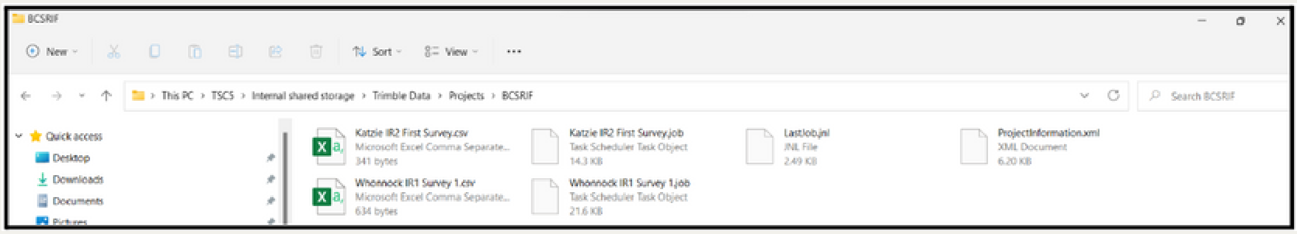
e. Connect TSC5 to computer

f. Enable file transfer



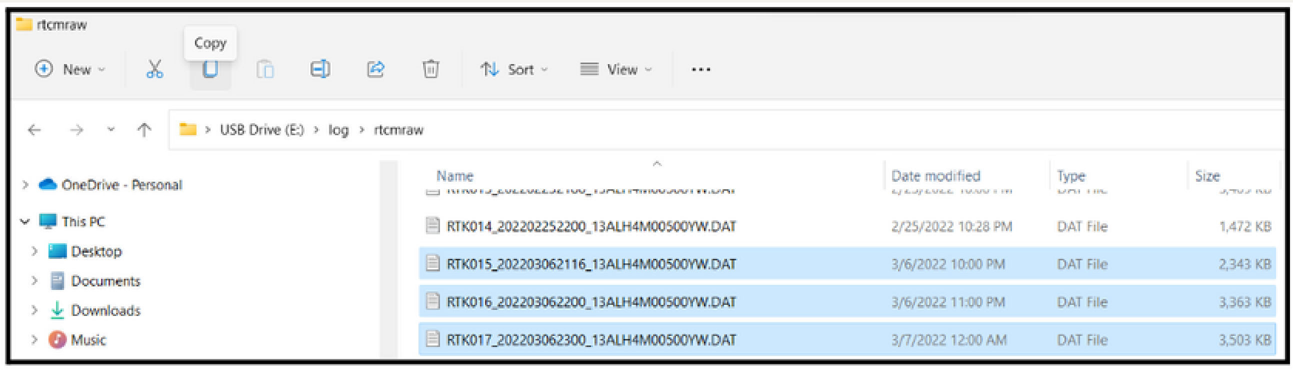


g. Navigate into TSC5 files



h. Copy rover csv files

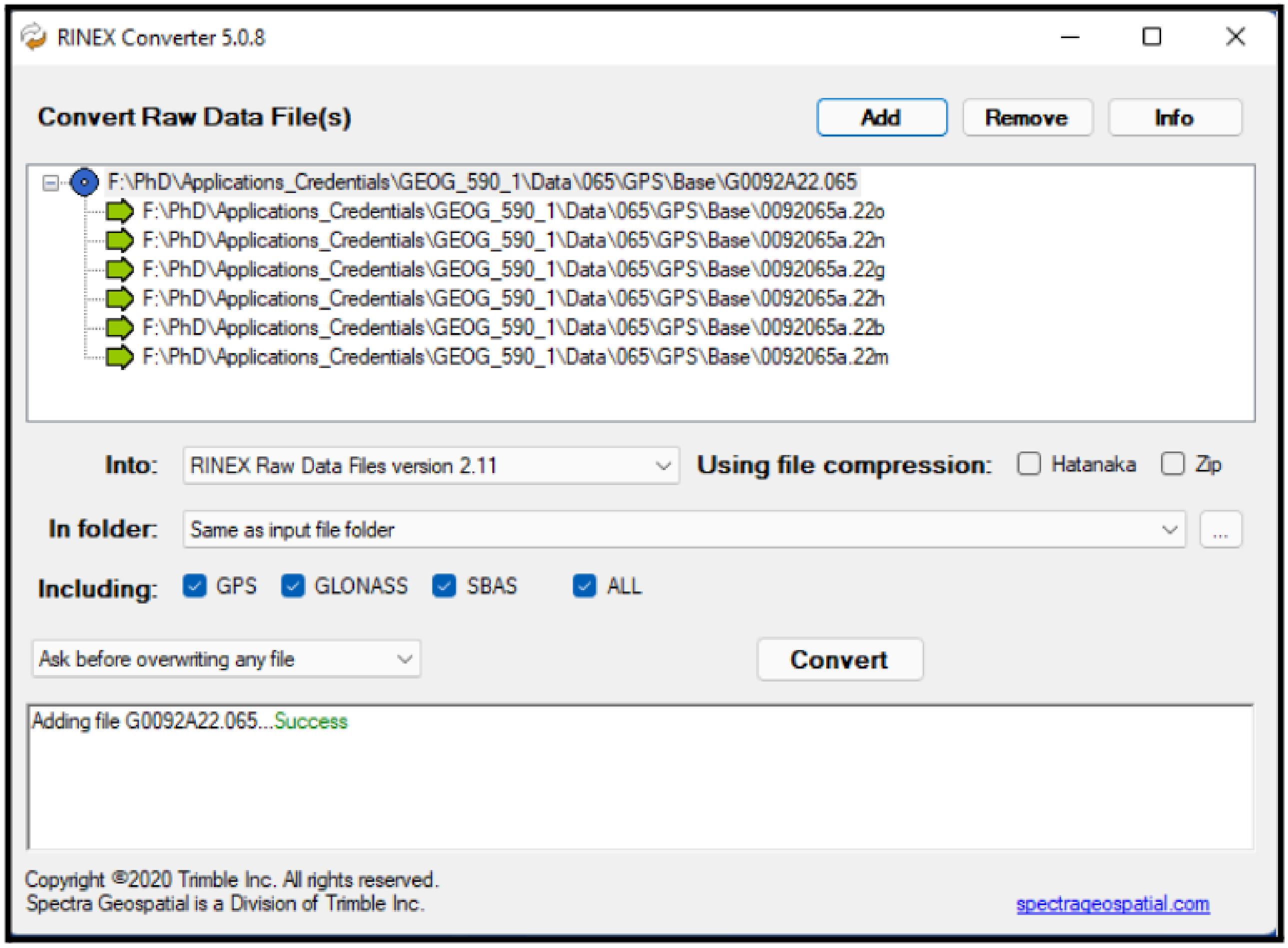
3. Get base files off DRTK2
   a. Power up DRTK2 and connect to computer
   b. Navigate to folder/log/rtcmraw



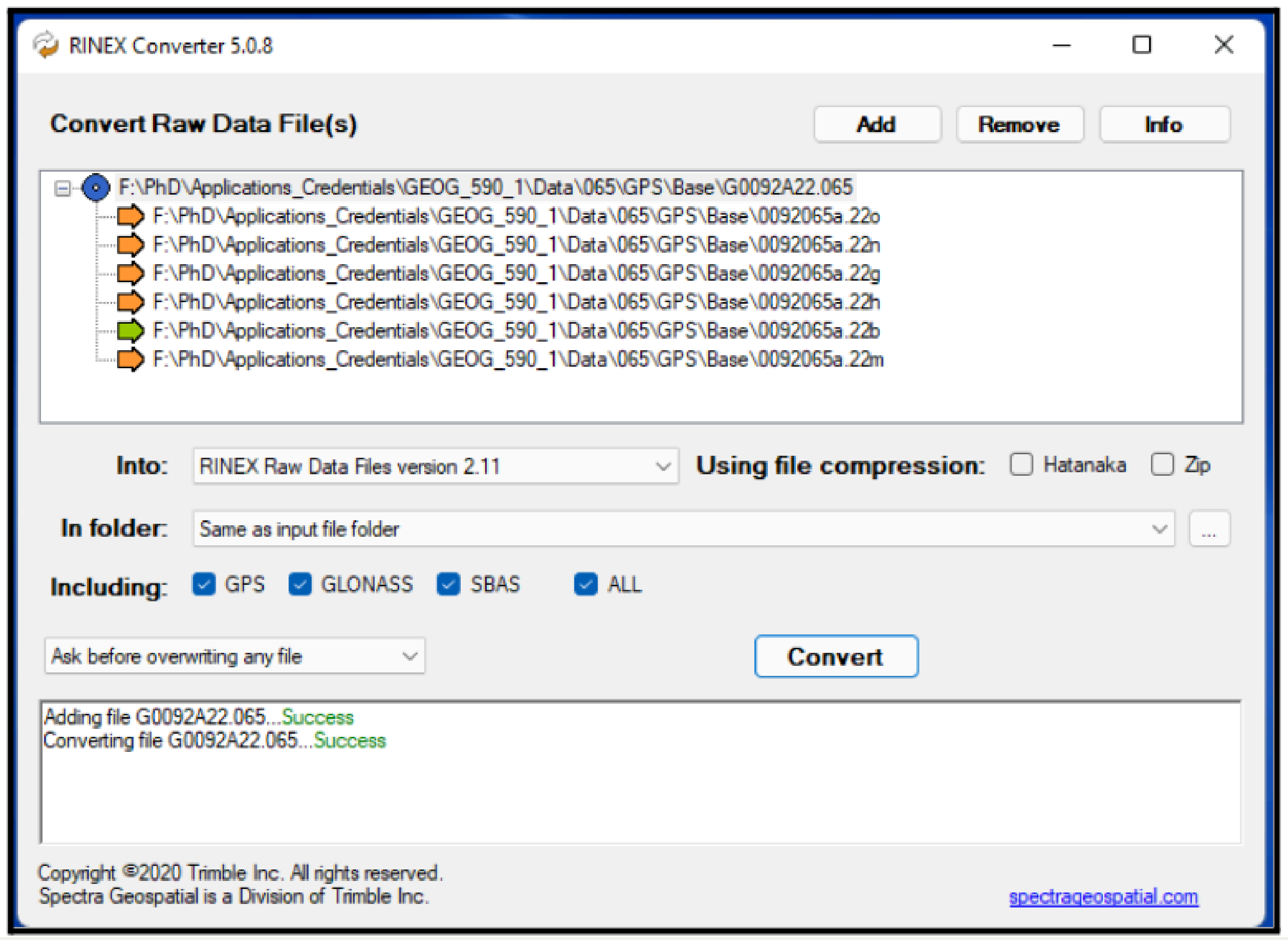
c. Select the files with the appropriate date and copy to computer

2.0 Creating RINEX Files

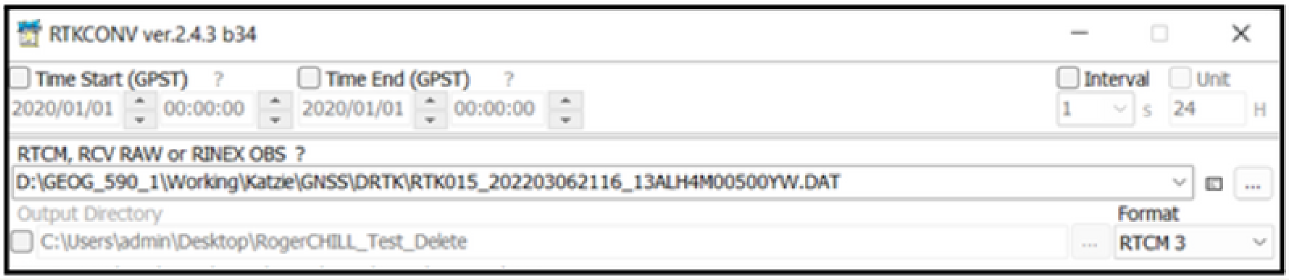
1. SP85 Base
    a. Open SP85 RINEX converter
    b. Add file(s) downloaded from SP85



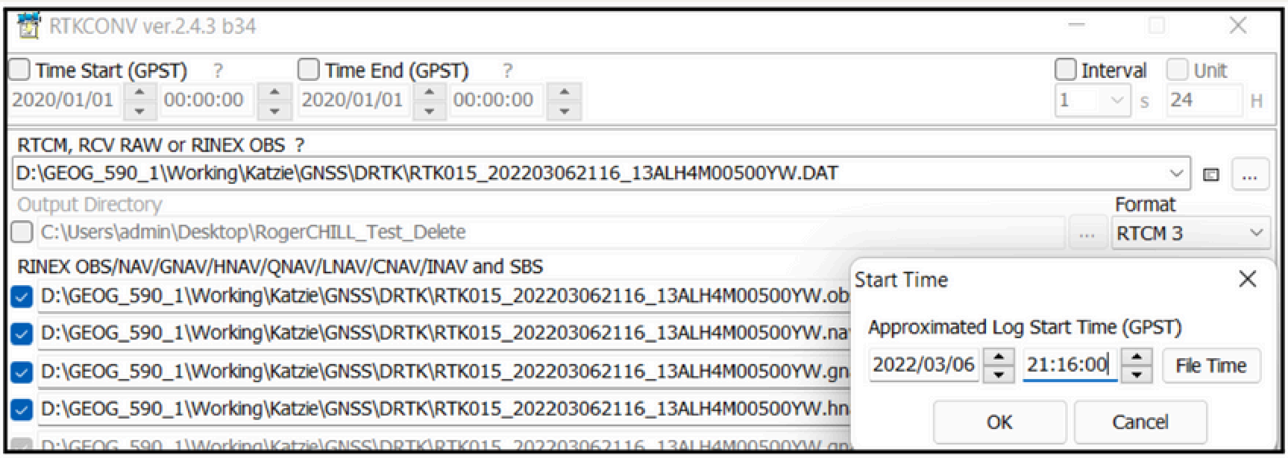
c. Convert into RINEX files



2. DRTK2
    a. Open RTKLib:rtkconv
    b. Navigate to .DAT file from DRTK2
    c. Change format to RTCM3

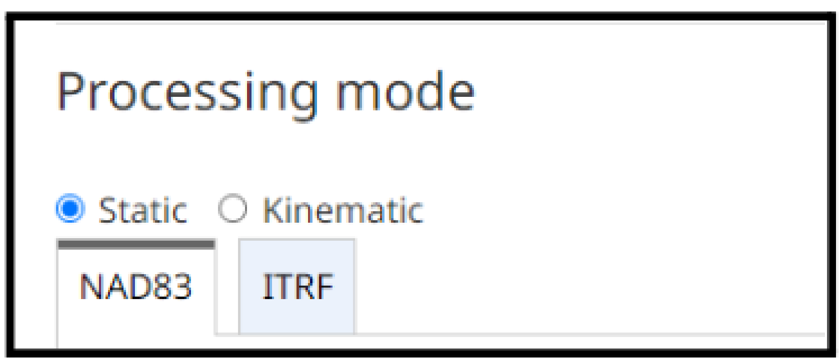


d. Click convert and set log start time to the same in the .dat file name

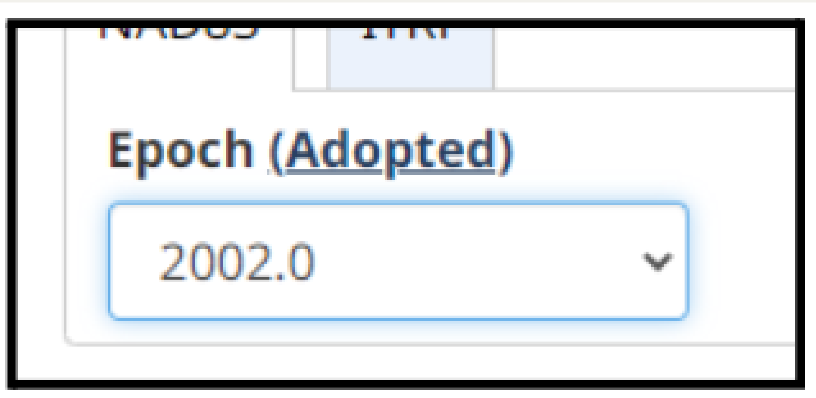


3.0 Creating RINEX Files

1. SP85 Base PPP
    a. Navigate to NRCAN **Precise Point Positioning (PPP)**
    b. Once logged in start a static processing upload using NAD83 datum

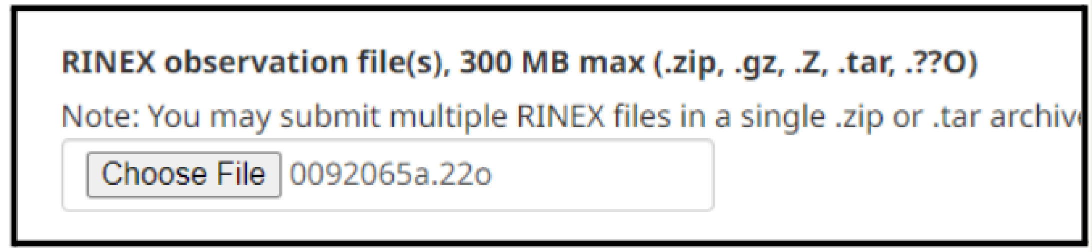


c. Choose a standard reference frame (epoch) to use for the coordinate. (Note: The standard epoch for work on the mainland of BC is 2002.0, and for work on Vancouver Island is 1997.0)



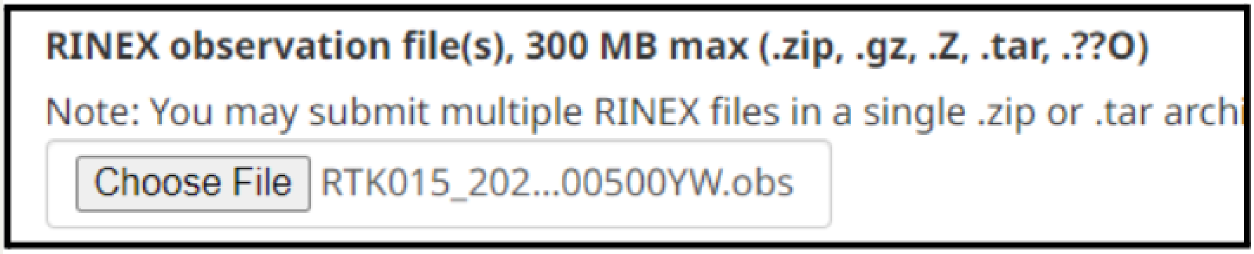
d. Set the vertical datum for orthometric heights (common is CGVD2013)

e. Upload the RINEX file (.22o) that was produced by the SP85 RINEX converter



f. Submit to PPP and wait for the report to be emailed back

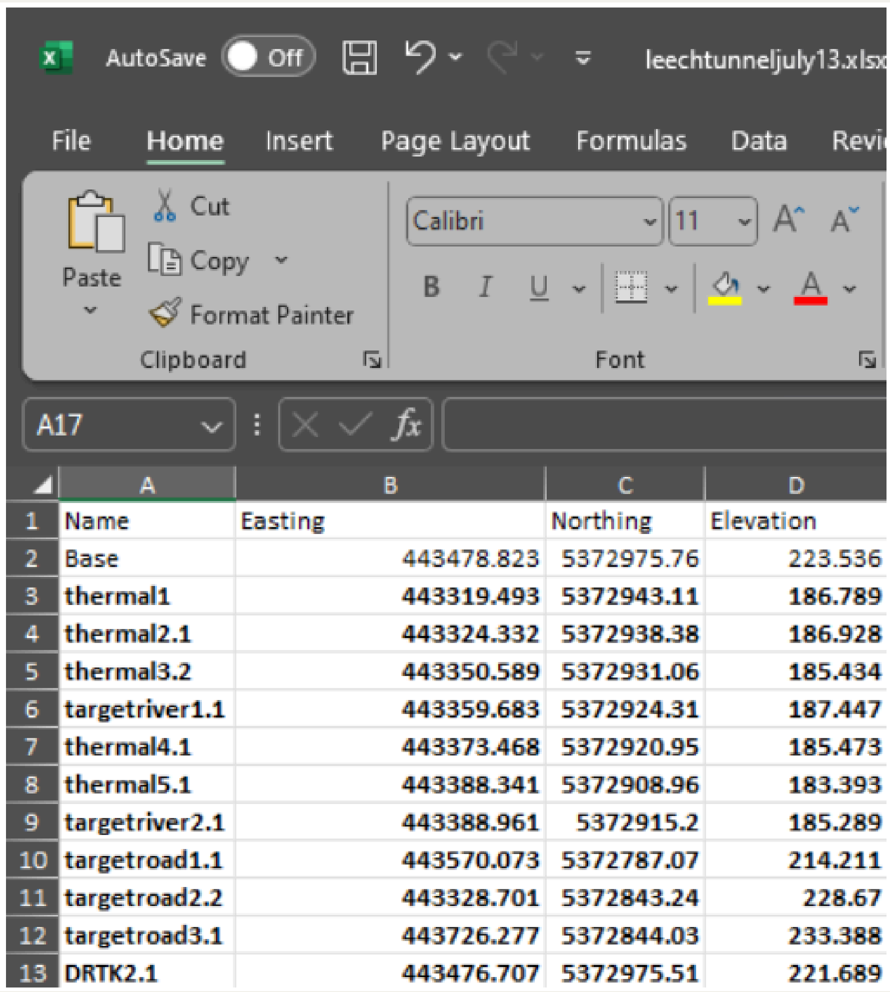
2. DRTK2 base PPP
    a. Repeat the PPP process using the same settings but instead upload the converted DRTK2 RINEX File (.obs)



    b. Submit to PPP and wait for the report to be emailed back

4.0 Create Shift Vectors

1. SP85 shift vectors
    a. Open the .csv file that contains the Rover data exported from the TSC5 and save as .xlsx



	A	B	C	D
1	Name	Easting	Northing	Elevation
2	Base	443478.823	5372975.76	223.536
3	thermal1	443319.493	5372943.11	186.789
4	thermal2.1	443324.332	5372938.38	186.928
5	thermal3.2	443350.589	5372931.06	185.434
6	targetriver1.1	443359.683	5372924.31	187.447
7	thermal4.1	443373.468	5372920.95	185.473
8	thermal5.1	443388.341	5372908.96	183.393
9	targetriver2.1	443388.961	5372915.2	185.289
10	targetroad1.1	443570.073	5372787.07	214.211
11	targetroad2.2	443328.701	5372843.24	228.67
12	targetroad3.1	443726.277	5372844.03	233.388
13	DRTK2.1	443476.707	5372975.51	221.689

b. Add row for DRTK APC (Note: DRTK offset is 1.801m)

DRTK2.1		443476.707	5372975.51	221.689
DRTKAPC		443476.707	5372975.51	223.49

c. Copy the initial recorded base coordinates in preparation for the shift calculation.

	Easting	Northing	Elevation
Emlid Rover Base	443478.823	5372975.756	223.536

d. Open the PPP report for the SP85 base.

CSRS-PPP 3.54.2 (2022-11-10)

reach-base_raw_20230713175057.23O

Data Start	Data End	Duration of Observations
2023-07-13 17:51:43.00	2023-07-13 21:54:15.01	4:02:32.010
Processing Time		**Product Type**
21:05:32 UTC 2023/07/17		NRCan Rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.54 %	14.23 %	1.00 sec

Antenna Model	APC to ARP	ARP to Marker
EML_REACH_RS2 NONE	L1 = 0.135 m L2 = 0.137 m	H:0.000m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for reach-base_raw_20230713175057.23O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997.0)†	48° 30' 26.47334"	-123° 45' 54.76642"	223.302 m
SIG_PPP(95%)‡	0.044 m	0.024 m	0.183 m
SIG_TOT(95%)‡	0.049 m	0.028 m	0.184 m
A priori*	48° 30' 26.44498"	-123° 45' 54.74157"	225.601 m
Estimated – A priori	0.876 m	-0.510 m	-2.299 m

Orthometric Height CGVD2013 (CGG2013a) (1997.0)	95% PPP Error Ellipse (cm)	95% TOT Error Ellipse (cm)	UTM (North) Zone 10
	semi-major: 5.6 cm semi-minor: 2.9 cm semi-major azimuth: -6° 41' 59.72"	semi-major: 6.1 cm semi-minor: 3.4 cm semi-major azimuth: -7° 55' 37.5"	

e. Confirm the data start time (UTC), end time (UTC), and duration make sense

f. Confirm the type of PPP product (Ultra rapid/Rapid/Final)

g. Add the corrected base coordinates (highlighted in yellow) to the excel sheet

Estimated Position for reach-base_raw_20230713175057.23O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997.0)†	48° 30' 26.47334"	-123° 45' 54.76642"	223.302 m
SIG_PPP(95%)‡	0.044 m	0.024 m	0.183 m
SIG_TOT(95%)‡	0.049 m	0.028 m	0.184 m
A priori*	48° 30' 26.44498"	-123° 45' 54.74157"	225.601 m
Estimated – A priori	0.876 m	-0.510 m	-2.299 m

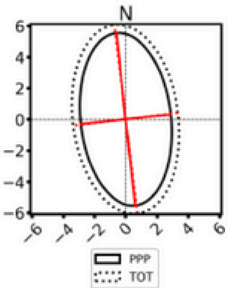
Orthometric Height CGVD2013 (CGG2013a) (1997.0)

240.351 m

(click for height reference information)

95% PPP Error Ellipse (cm)
semi-major: 5.6 cm
semi-minor: 2.9 cm
semi-major azimuth: -6° 41' 59.72"

95% TOT Error Ellipse (cm)
semi-major: 6.1 cm
semi-minor: 3.4 cm
semi-major azimuth: -7° 55' 37.5"



UTM (North) Zone 10

5372975.694 m (N)
443480.687 m (E)

Scale Factors
0.99963925 (point)
0.99960426 (combined)

Emlid Base Rinex PPP Rapid	**443480.687**	**5372975.694**	**223.302**

h. Subtract the updated coordinates from the original coordinates to get the coordinate shifts.

N	O	P	Q
	Easting	Northing	Elevation
Emlid Rover Base	443478.823	5372975.756	223.536
Emlid Base Rinex PPP Rapid	**443480.687**	**5372975.694**	**223.302**
delta (Rover Base - PPP)	**-1.864**	**0.062**	**0.234**

i. Apply coordinate shift to all rover positions

Station	northing	easting	height	n_final	e_final	z_final
Katzie Base	5449197.384	525101.651	-14.982	5449196.62	525103.501	-14.416
Photo Target 1	5448882.63	525028.362	-13.563	5448881.866	525030.212	-12.997
Photo Target 2	5449126.994	524977.465	-15.049	5449126.23	524979.315	-14.483
Photo Target 3	5449177.307	525033.297	-15.199	5449176.543	525035.147	-14.633
Photo Target 4	5449201.716	525094.418	-15.718	5449200.952	525096.268	-15.152
DRTK	5449203.911	525099.186	-14.752	5449203.147	525101.036	-14.186
DRTK APC	5449203.911	525099.186	-12.951	5449203.147	525101.036	-12.385

2. DRTK Shift Vector
   a. For each of the P1 and H20T sensors find the appropriate DRTK file for each session.

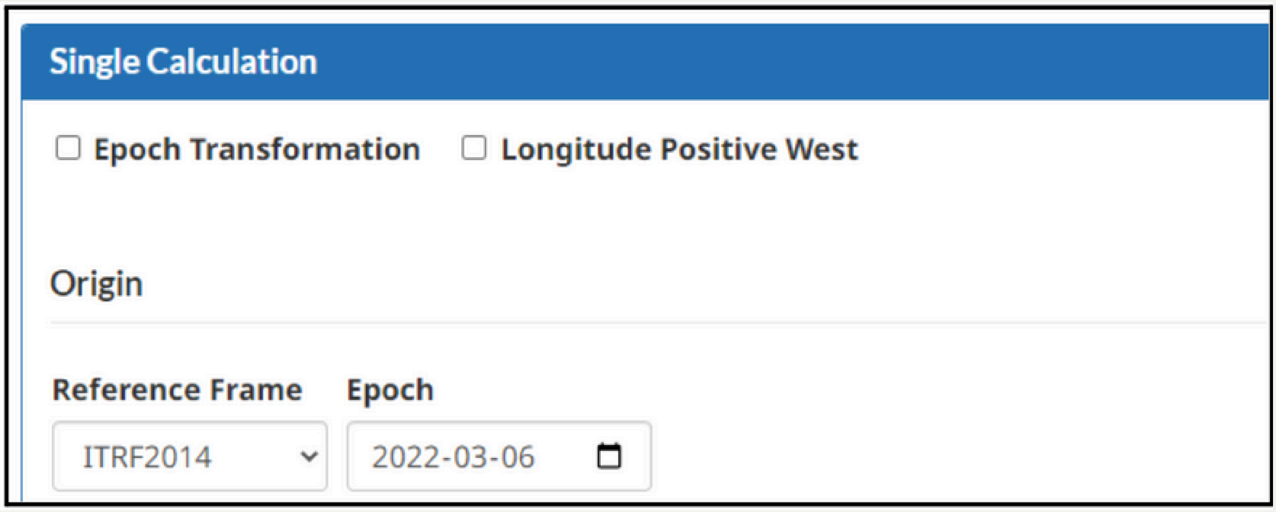
Location	Sensor	Time	DRTK File
Katize	H20T	2022-03-06 16:00	RTK018_202203070000_13ALH4M00500YW
Katzie	P1	2022-03-06 13:00	RTK015_202203062116_13ALH4M00500YW

   b. Open the PPP reports for each file and record the A priori positions (highlighted in yellow) (Note: the height coordinate needs to have 1.801 subtracted from it)

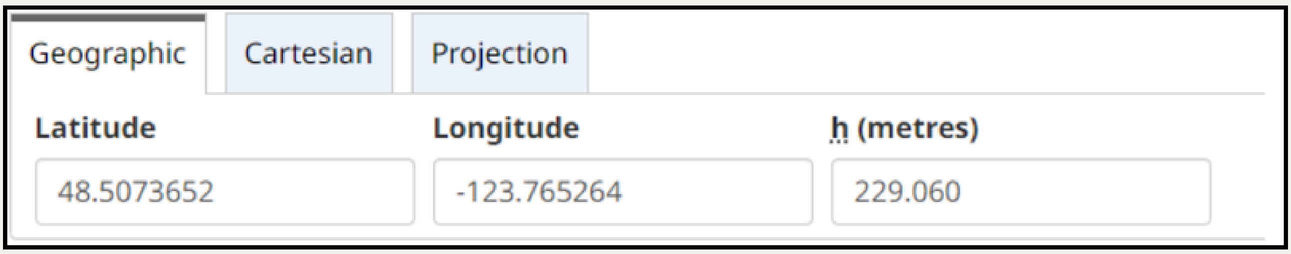
Estimated Position for RTK174_202307131929_13ALH4M00500YW.obs

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997.0)†	48° 30' 26.46294"	-123° 45' 54.86056"	223.566 m
SIG_PPP(95%)‡	0.236 m	0.253 m	0.658 m
SIG_TOT(95%)‡	0.237 m	0.254 m	0.658 m
A priori*	48° 30' 26.51449"	-123° 45' 54.94979"	229.060 m
Estimated – A priori	-1.592 m	1.831 m	-5.494 m

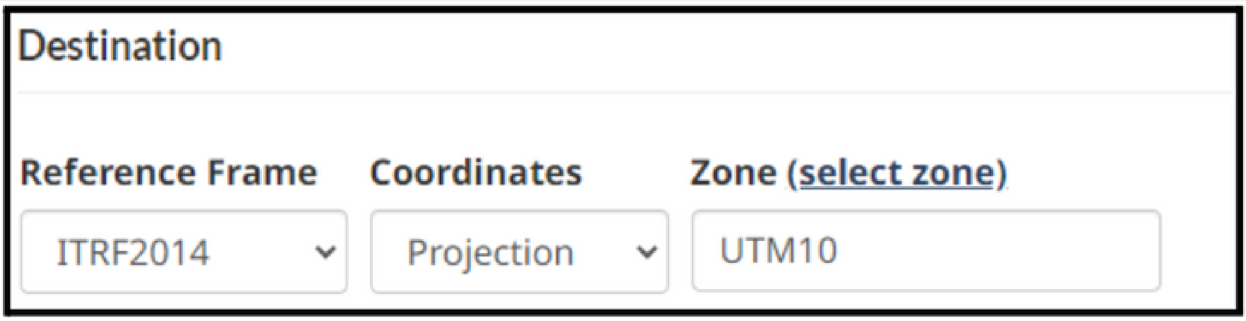
   c. Navigate to the **NRCAN TRX site**
      i. Start a single calculation with the reference frame being ITRF 2014 and the epoch being the date of data collection



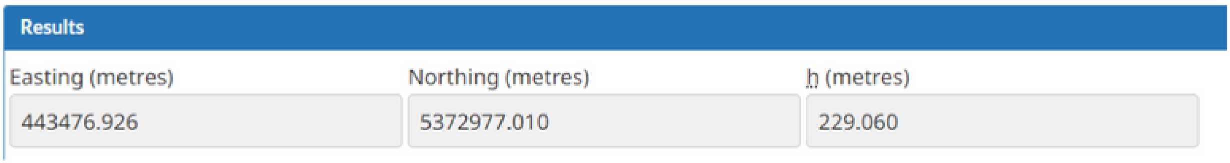
      ii. Enter the coordinates after converting to decimal degrees.
         1. 48° 30' 26.5149"
         2. To calculate the minutes = 30 + (26.5149/60) = 30.441915
         3. To calculate the decimal degrees = 48 + (30.441915/60) = 48.5073652



iii. Select the same reference frame and set the projection to the appropriate UTM zone



iv. Select Calculate and record the results into the excel sheet



DRTK AP	443476.926	**5372977.01**	**227.259**

v. Copy the updated DRTK (NOT APC) coordinate from the rover sheet and subtract from the TRX coordinate

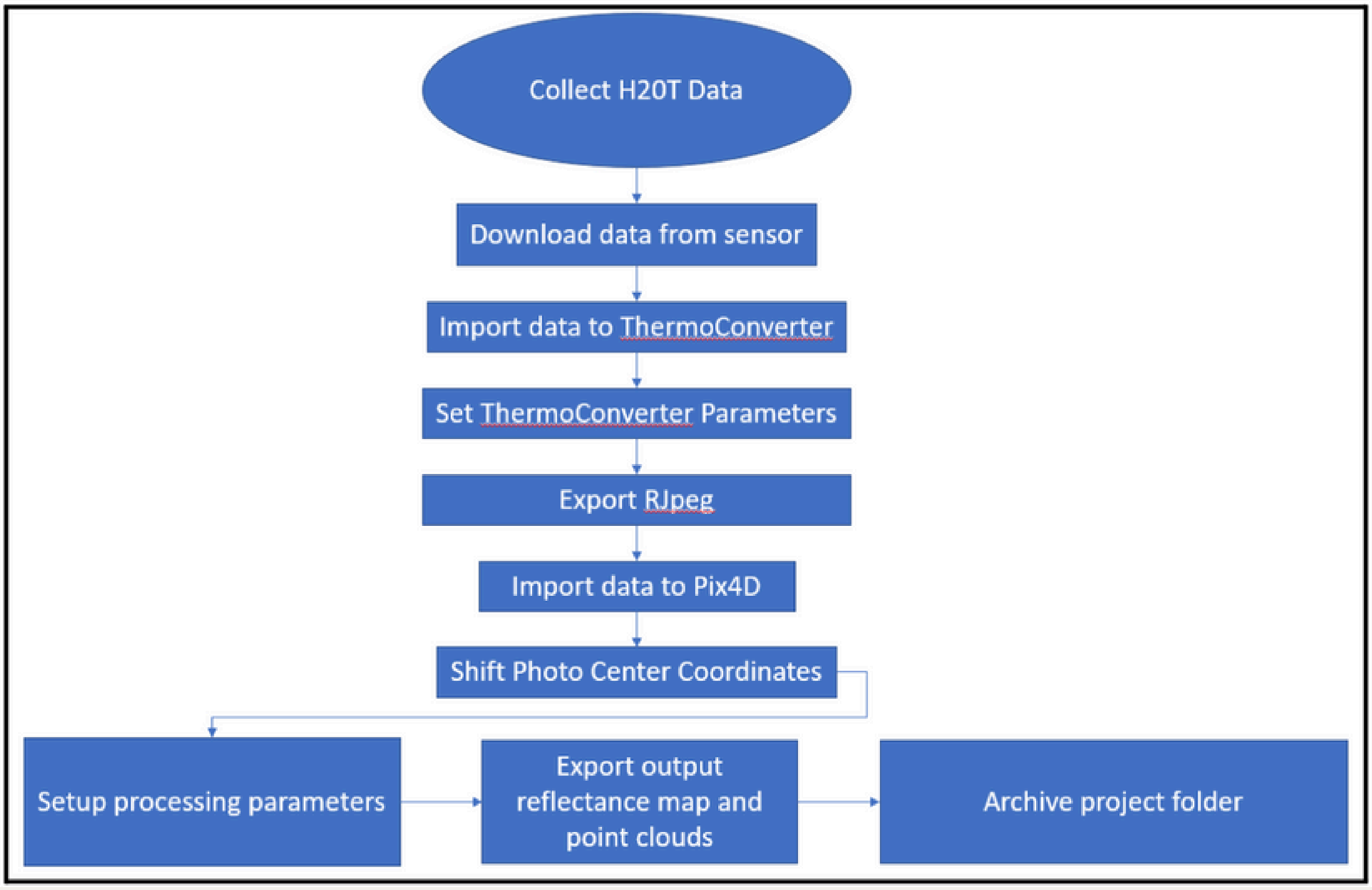
DRTK AP	443476.926	**5372977.01**	**227.259**
DRTK PPP	443478.571	5372975.443	221.455
	-1.645	1.567	5.804

Thermal (H2OT) Processing

H2OT Processing Overview:

When capturing thermal imagery, we are relying on detecting energy outside of the visible range of the electromagnetic spectrum in an area known as the infrared range. Every object will emit some amount of infrared energy and with a thermal camera as well as appropriate collection and processing methods we can detect and measure this energy and relate it to temperature. Before we move further into the processing, we will first define some key terms: 1) Emissivity: a measure of the effectiveness of a material in emitting thermal energy (i.e. the ratio between a target object's emission and that of a perfect emitter at the same temperature); 2) Reflected temperature: thermal energy originating from other objects (i.e. sun) that reflects off the target (less impactful with high emissivity objects like water); 3) Ambient temperature: Air temperature of the environment.

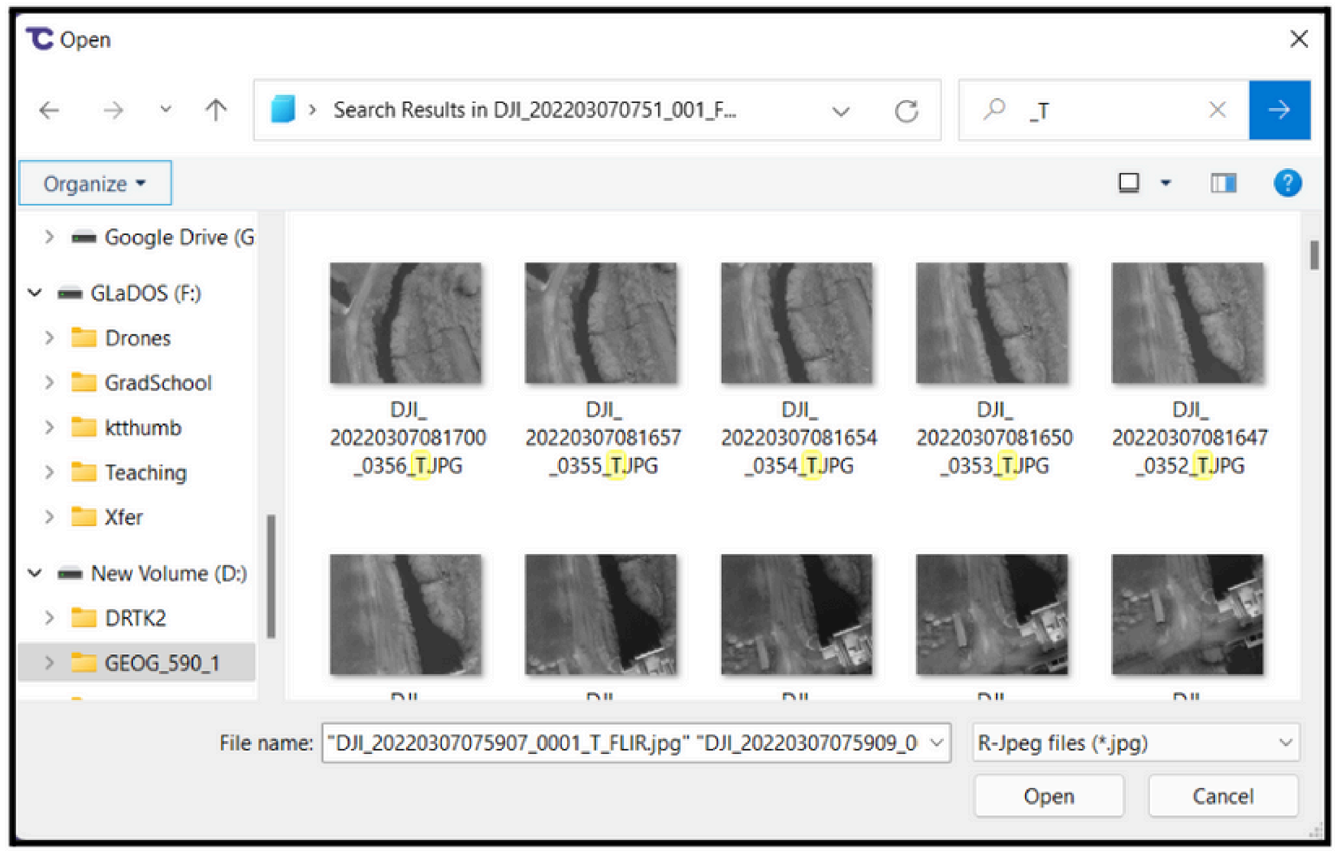
General Workflow:



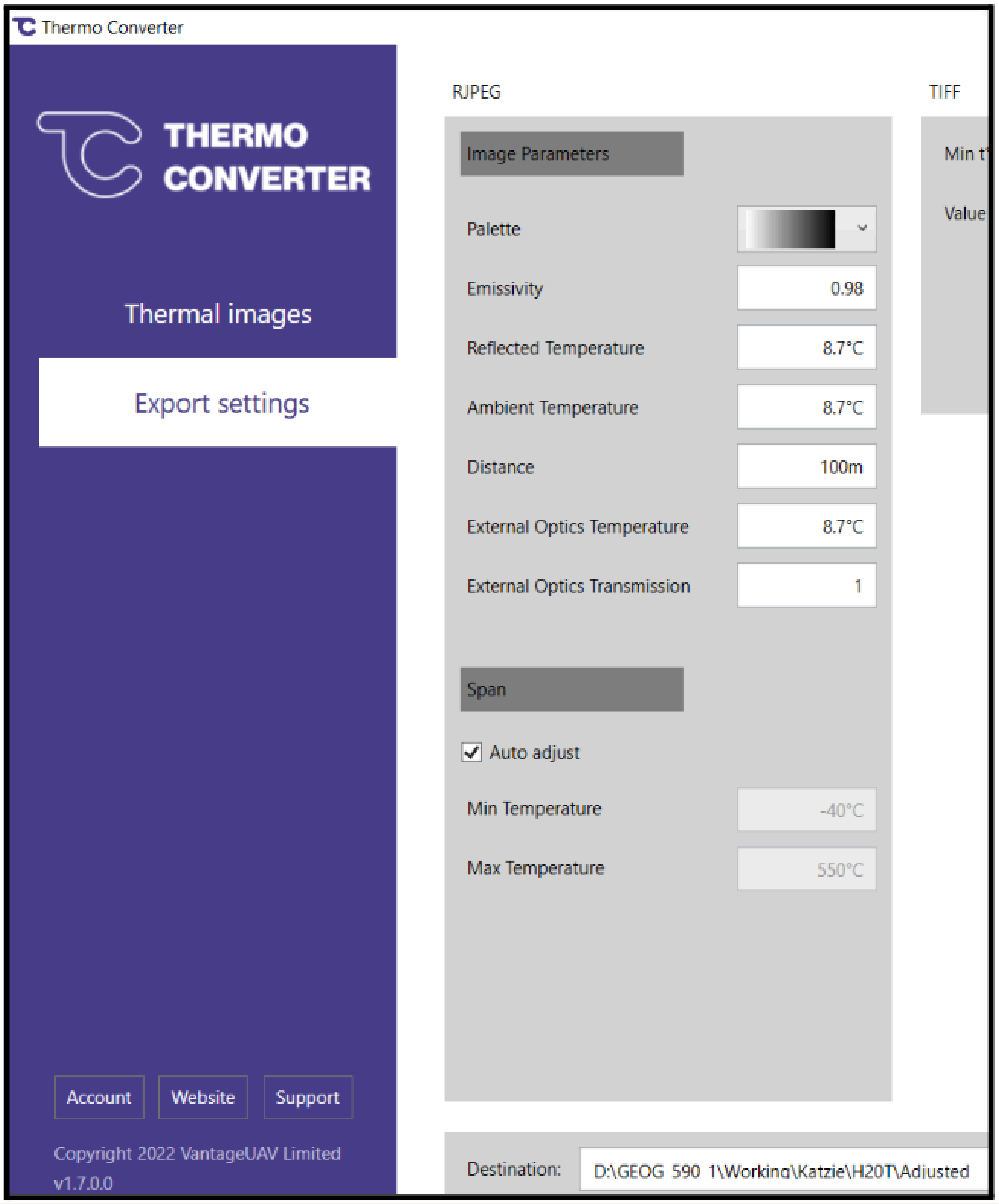
Detailed Workflow:

1. Download photos
2. Open thermo converter
3. Click upload and navigate to the folder with thermal images

4. Search for "_T" to filter only the thermal images



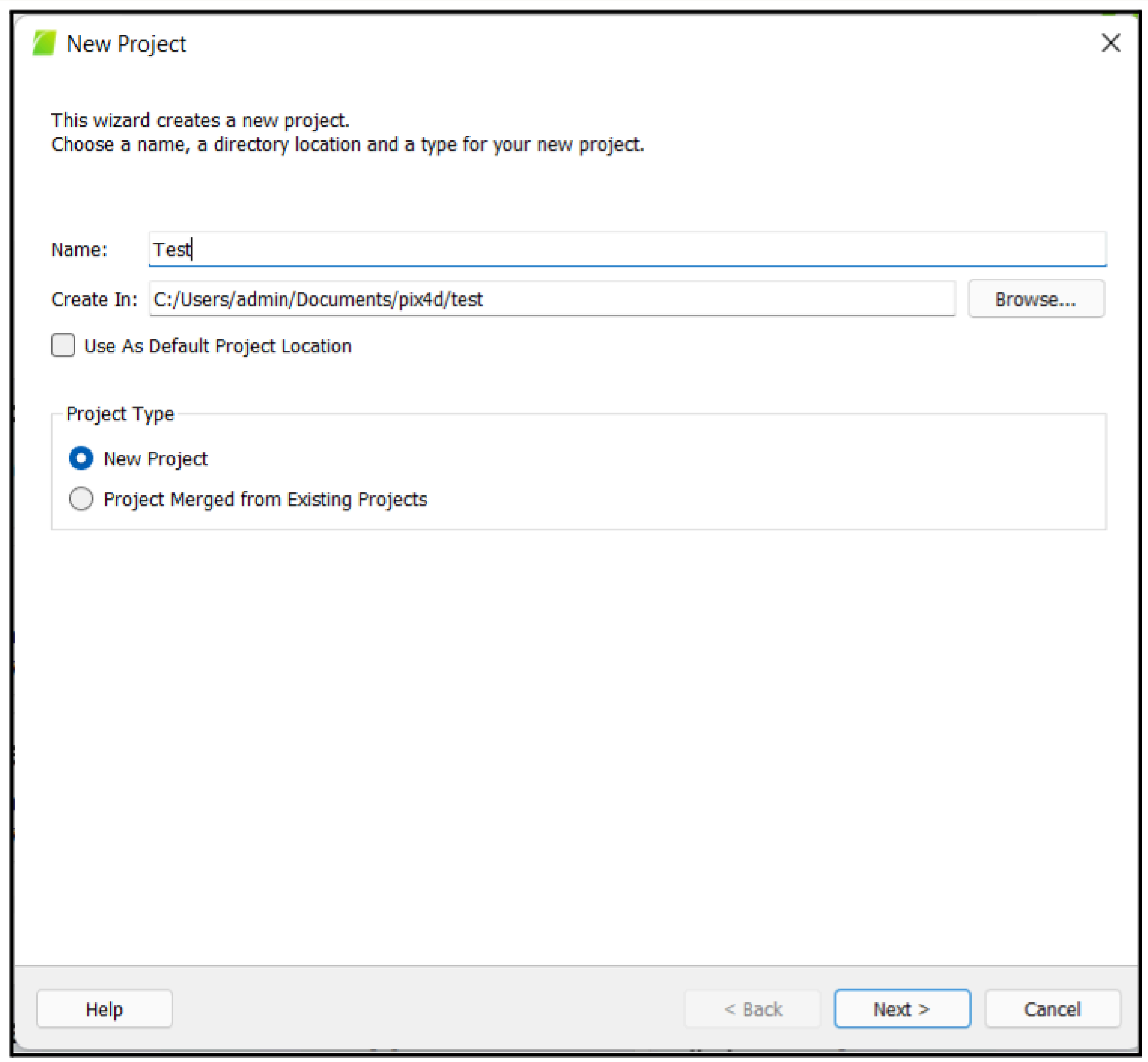
5. In the Export settings tab set the emissivity value of target feature (water generally 0.95-0.98) and aircraft height (distance). Also set temperatures to best available temperature during flight.



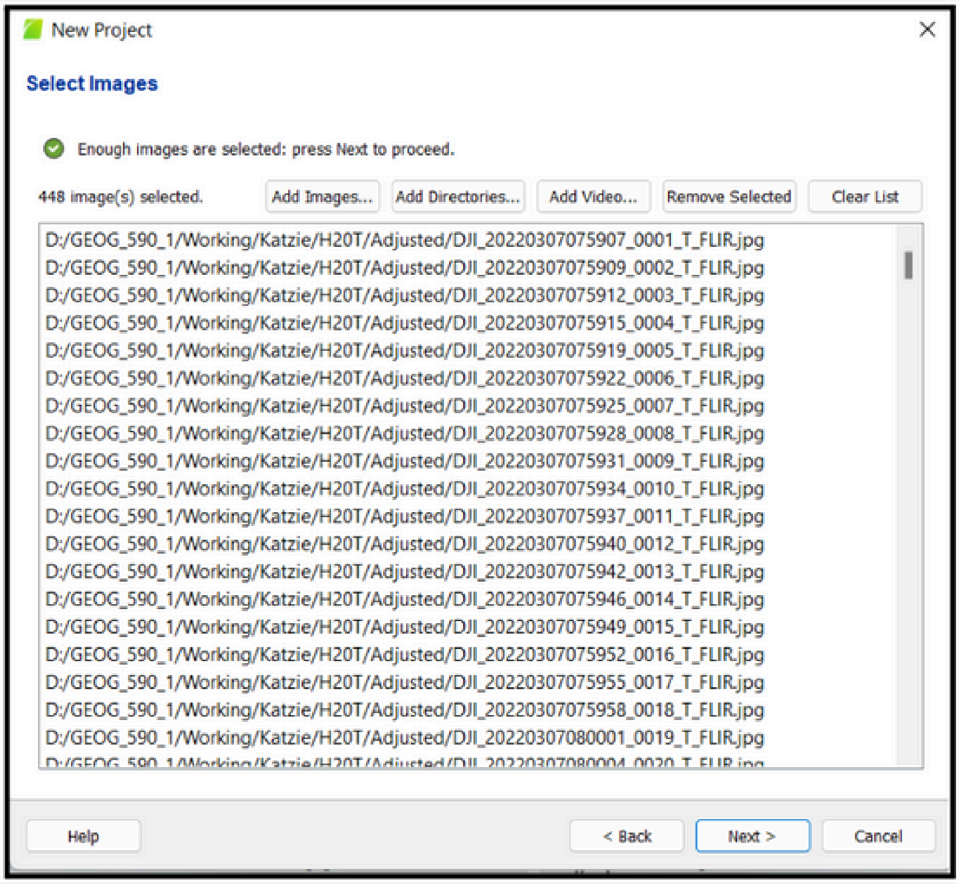
6. In the thermal images tab click select all and then Export RJPEG

7. Open Pix4d mapper

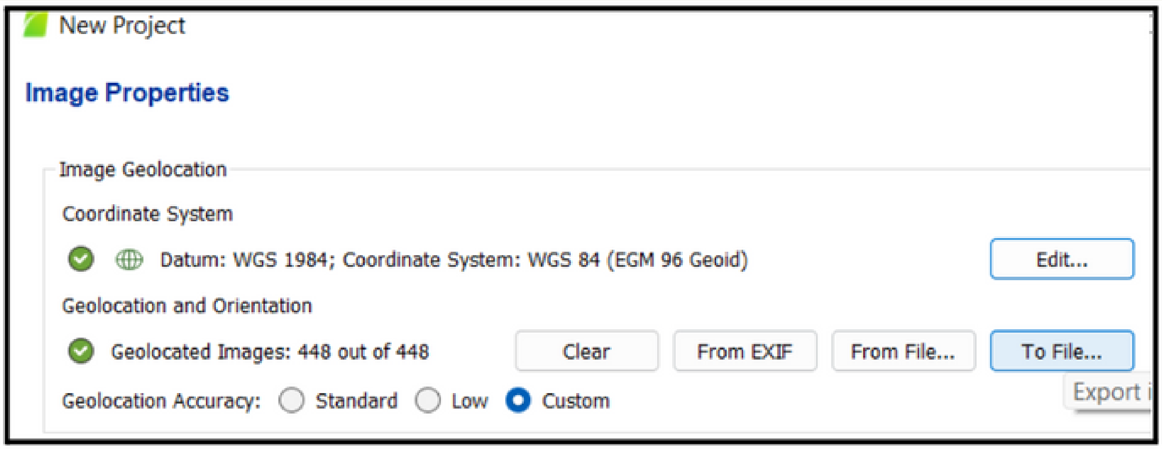
8. Start a new project

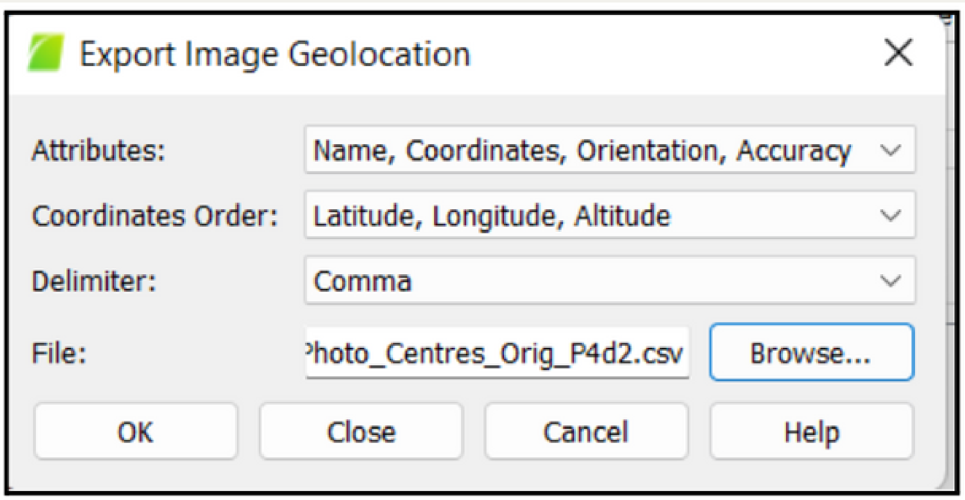


9. Add converted thermal images



10. Export photo centers as a .csv with the name, coordinates, orientation, and accuracy



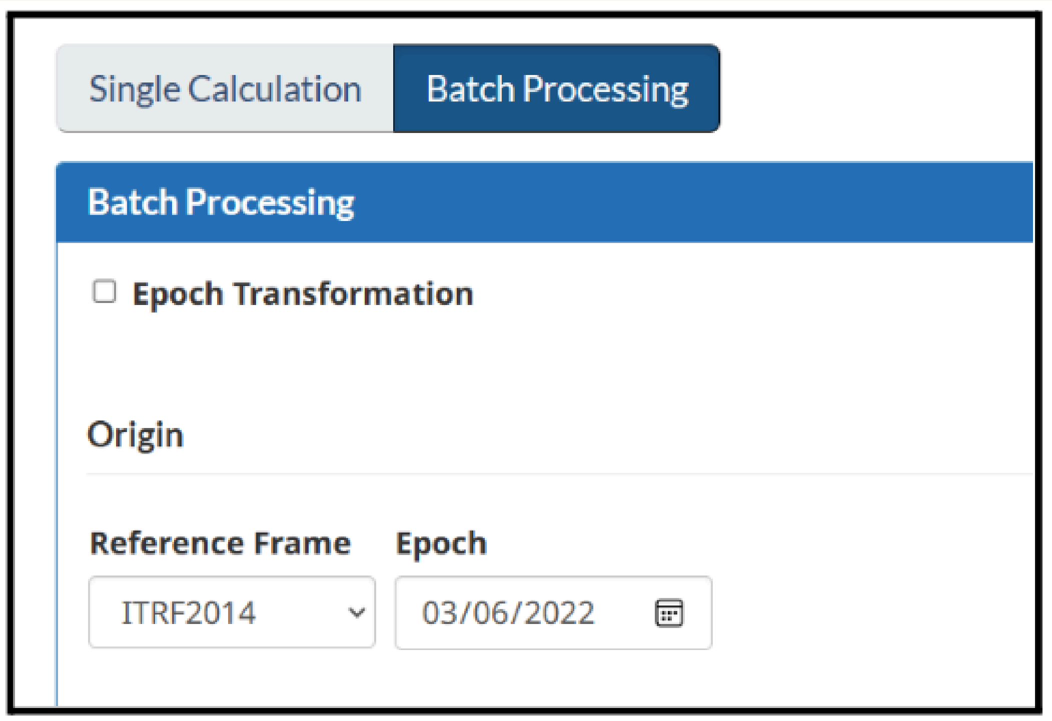


11. Make a copy of the csv named TRXin and keep only the photo name, latitude, longitude, and height columns

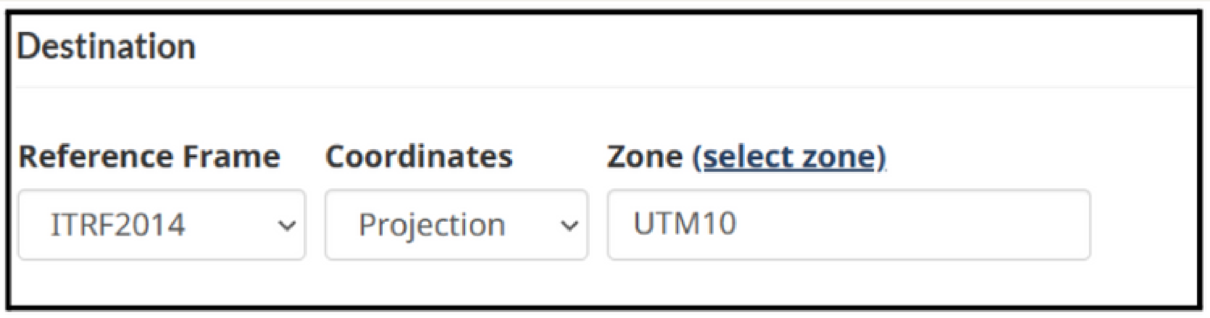
12. Open TRXin.csv and label the columns as: Station, latitude, longitude, height

13. Navigate to the **NRCAN TRX site**

14. Start a batch processing calculation with the reference frame being ITRF 2014 and the epoch being the date of data collection



15. For destination select the same reference frame and set the projection to the appropriate UTM zone



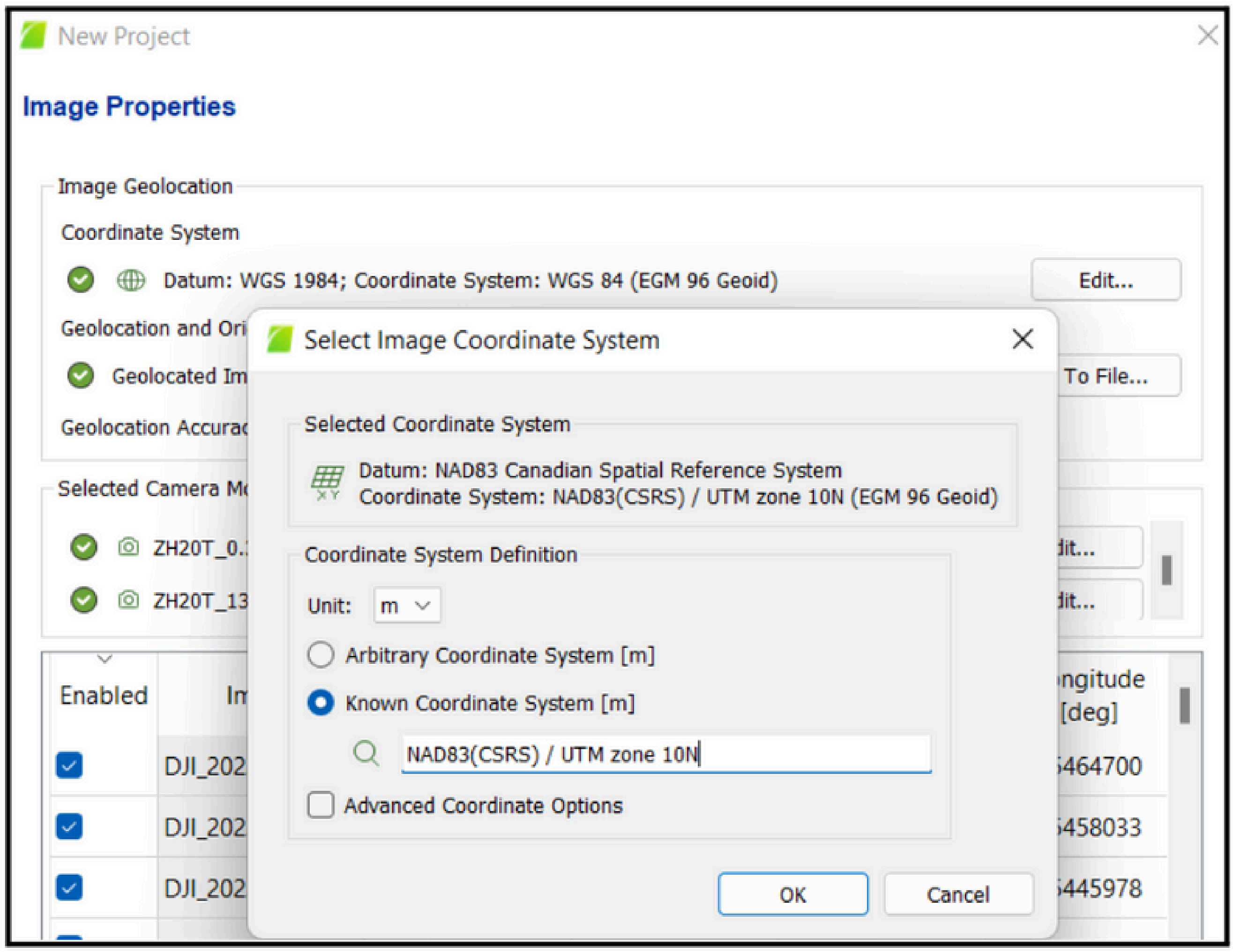
16. Upload the photo center .csv file and click send to download the results

17. Make a copy of the photo center .csv file and change the coordinates to the projected coordinates downloaded from TRX (Note: ensure the same order of photos as the original file)

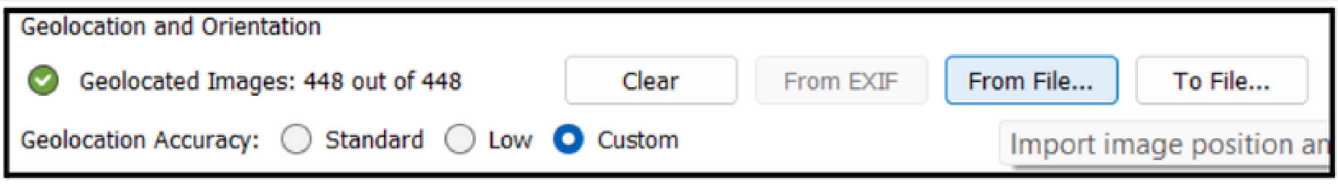
18. Apply the DRTK shift vector for the northing, easting, and height coordinates to the projected photo coordinates

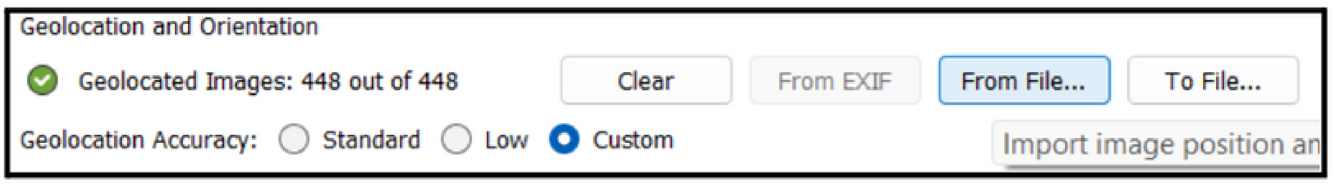
19. Add the accuracy, kaapa, phi, and omega columns back from the original export from pix4d ensuring the same order

20. In Pix4d edit the coordinate system to NAD83(CSRS) with an appropriate UTM zone



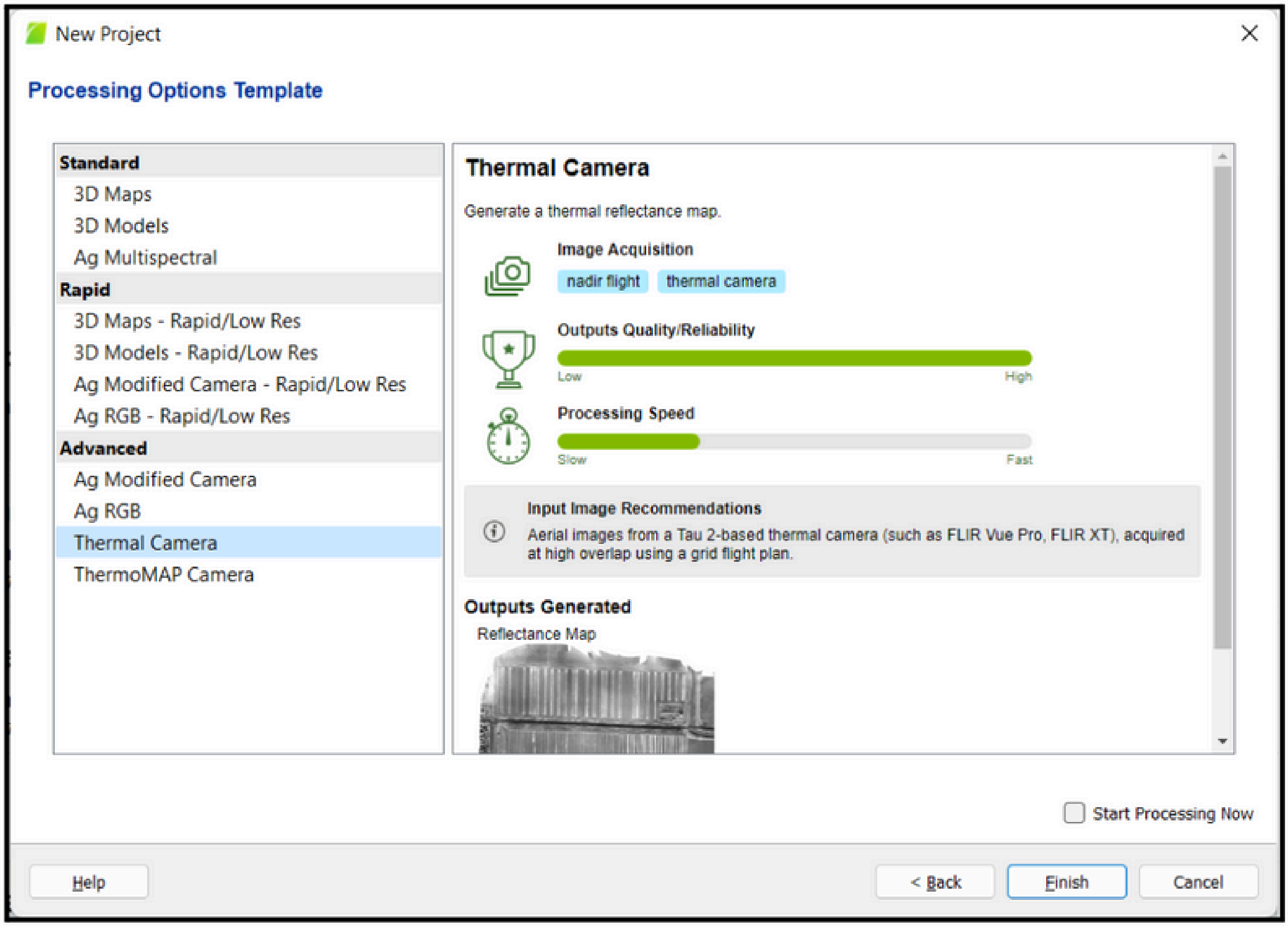
21. Import the shifted coordinate .csv



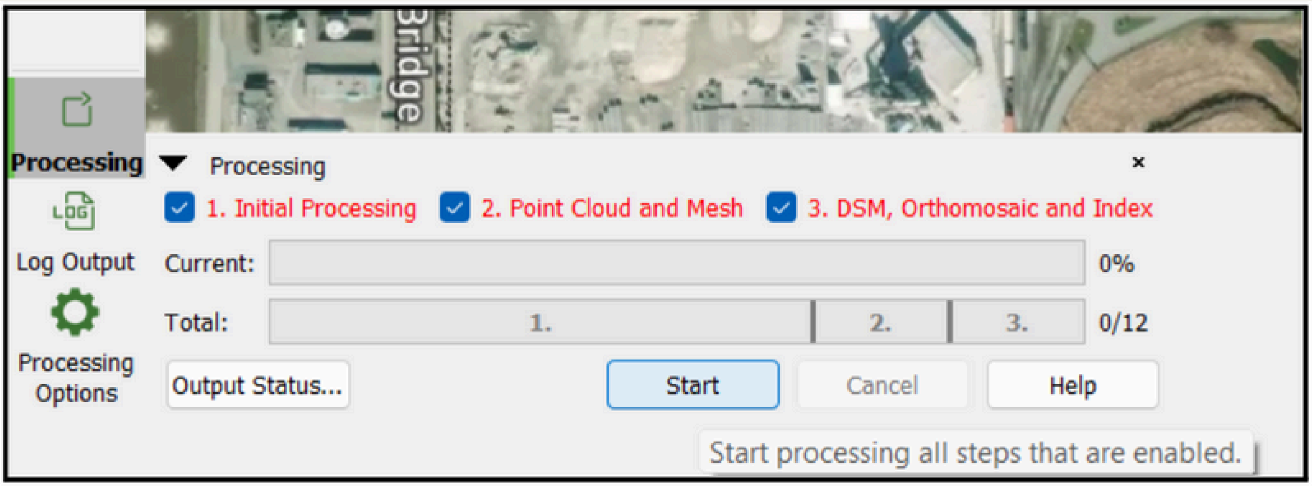


22. Set the output coordinate system to also be NAD83(CSRS) with the appropriate UTM projection

23. Select the thermal camera pix4d template



24. Select start to process with the default options.

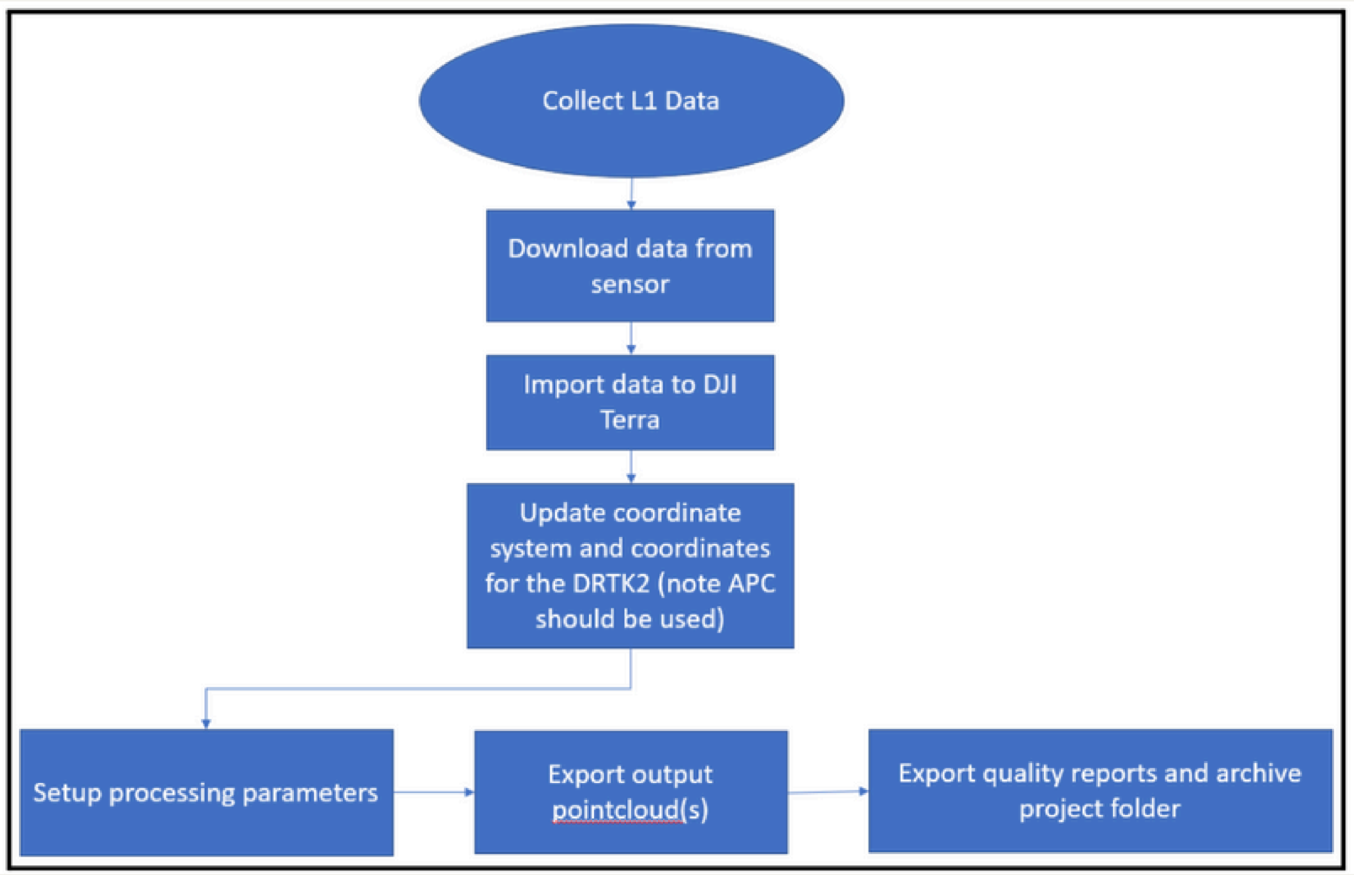


LiDAR (L1) Processing

L1 Processing Overview:

For a brief overview of how LiDAR works and what it can be used for please watch this short video from Open Topography (**https://youtu.be/chSywRqgIGY**). As mentioned in the video, we can use the GNSS system to know with very high accuracy the relative position between the DRTK2 and the UAV throughout the whole LiDAR collection. Once we complete the GNSS processing we will then have an updated coordinate representing the antenna of the DRTK2. The software (DJI Terra) will then use this updated coordinate to determine the trajectory of the UAV during the mission. Next from each position of the trajectory the software uses the distance and orientation of each laser return to determine the coordinates for each point. This process where a coordinate can be directly translated from a point on the ground to a point on the aircraft and back to a point on the target surface is known as direct geo-referencing and is different from how geo-referencing is done with photogrammetry.

General Workflow:

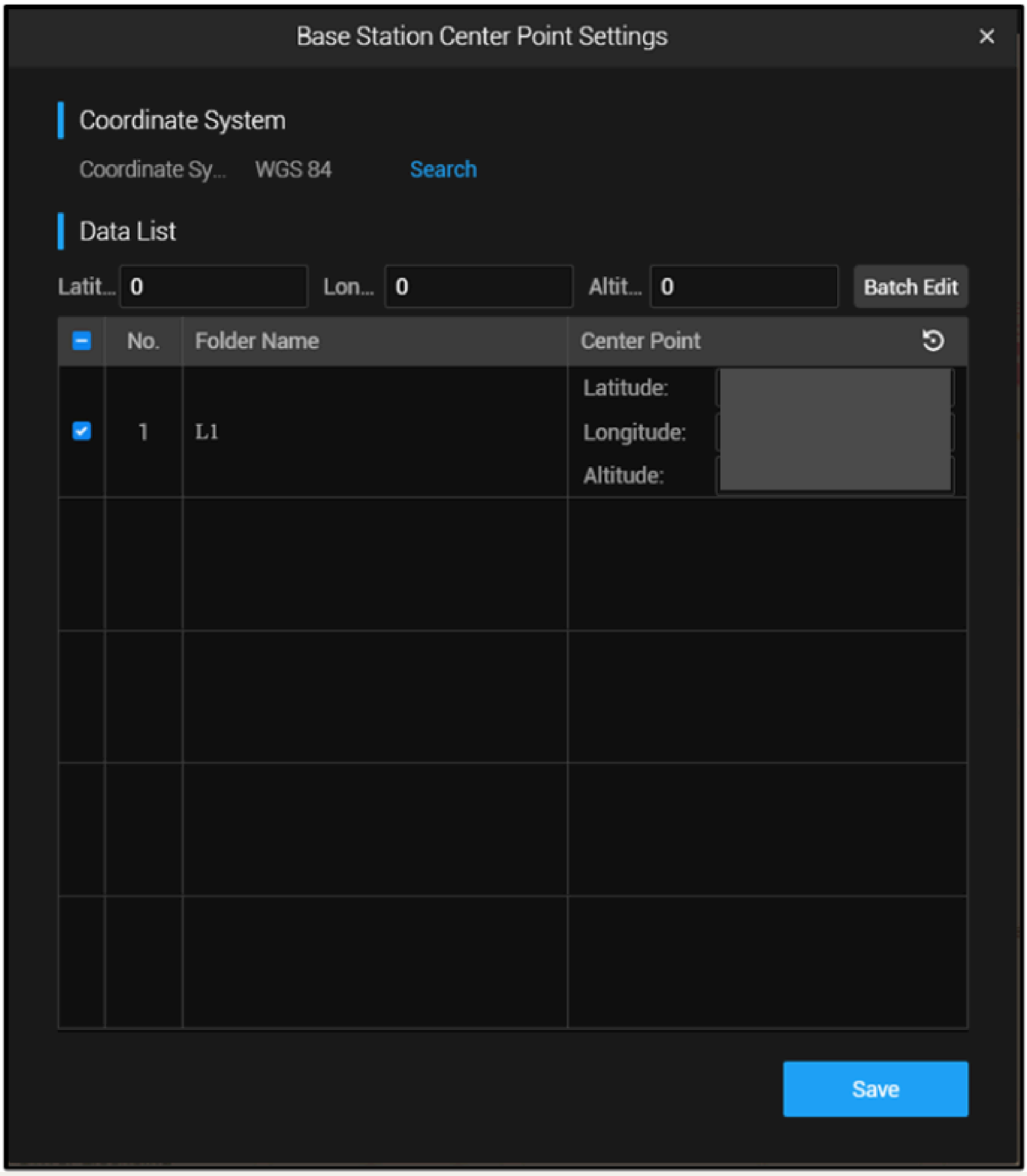


Detailed Workflow Steps:

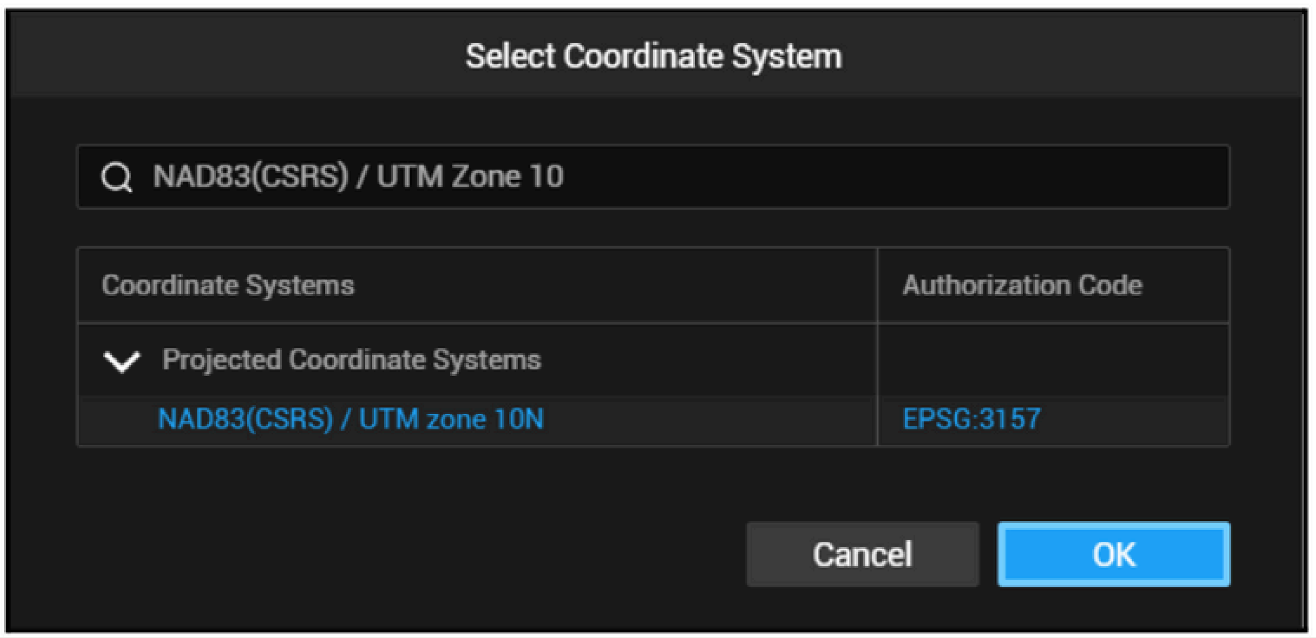
1. Download data
2. Open DJI Terra and select New reconstruction mission
3. Select LiDAR Point Cloud
4. Give a name to the project

5. Select the folder icon, navigate to the L1 Data and select the whole folder

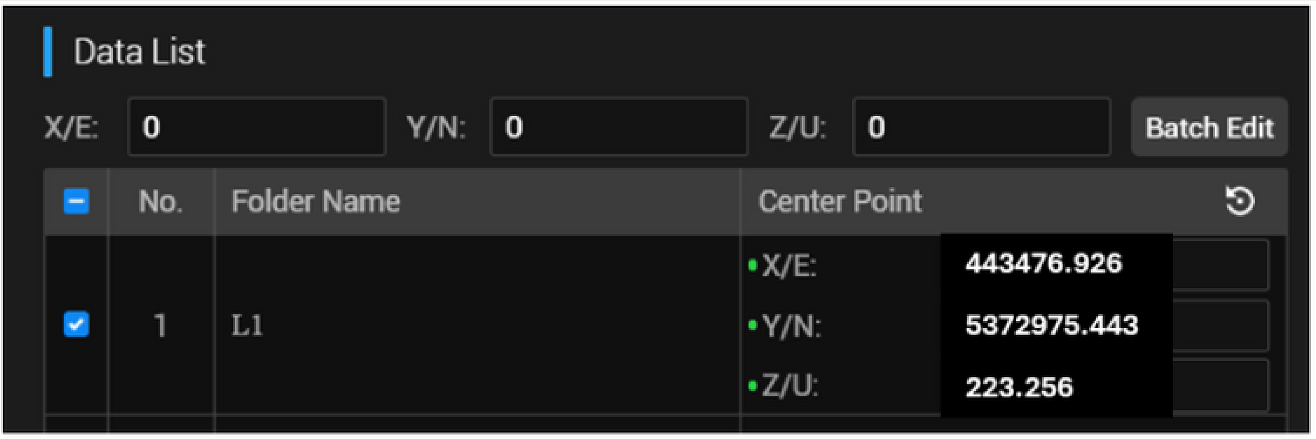
6. Enter the Base Station Center Point Settings menu



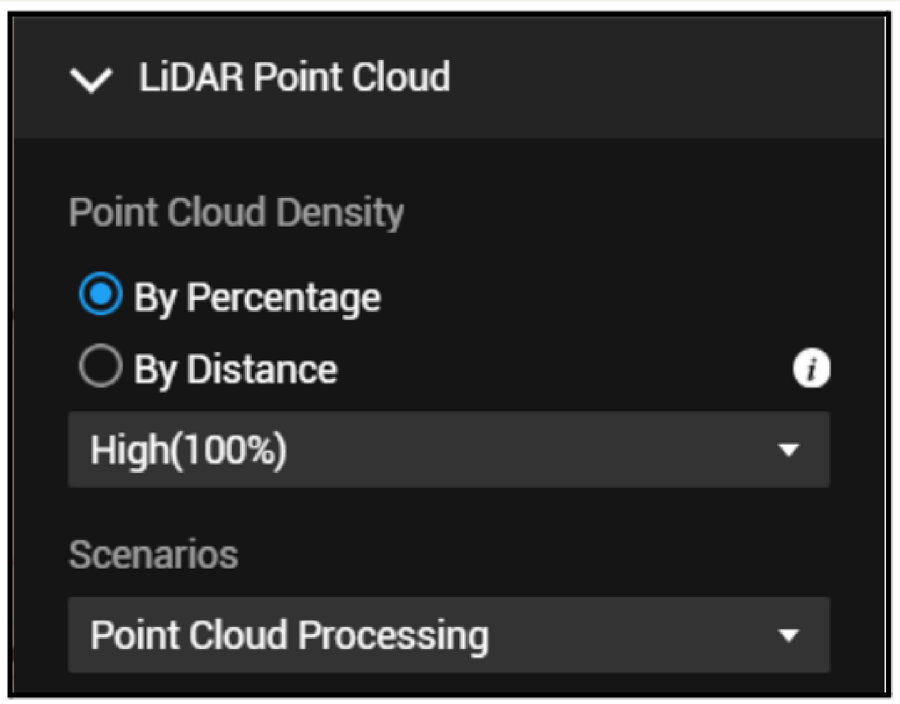
7. Set the coordinate system to NAD83(CSRS) with the appropriate UTM zone



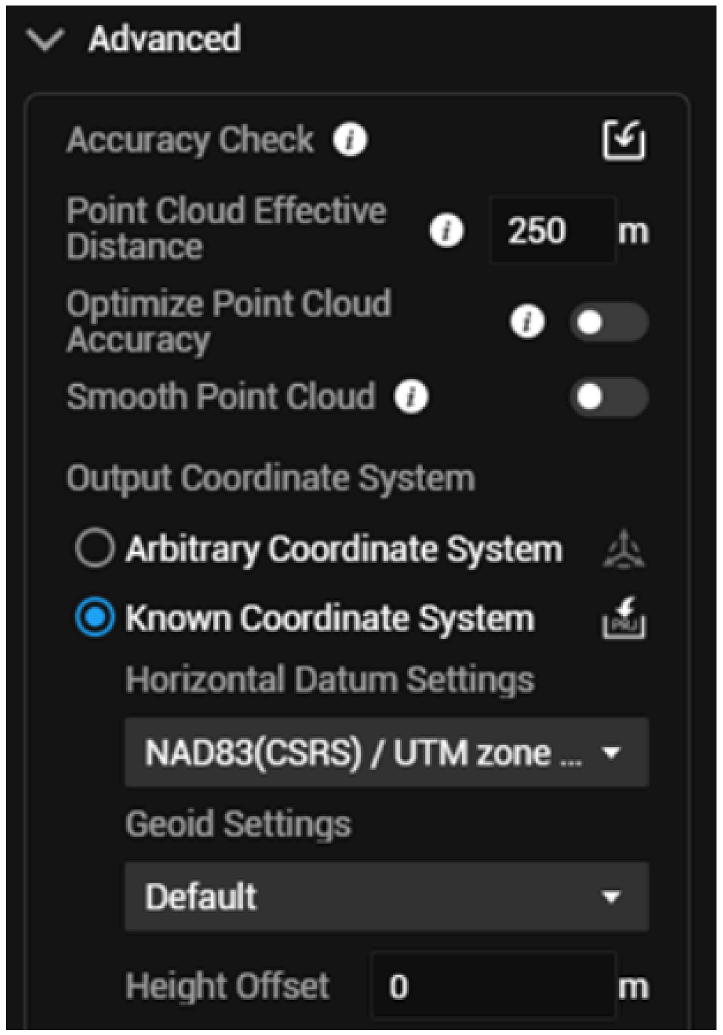
8. Update to coordinate to the PPP adjusted coordinate for the DRTK2 APC



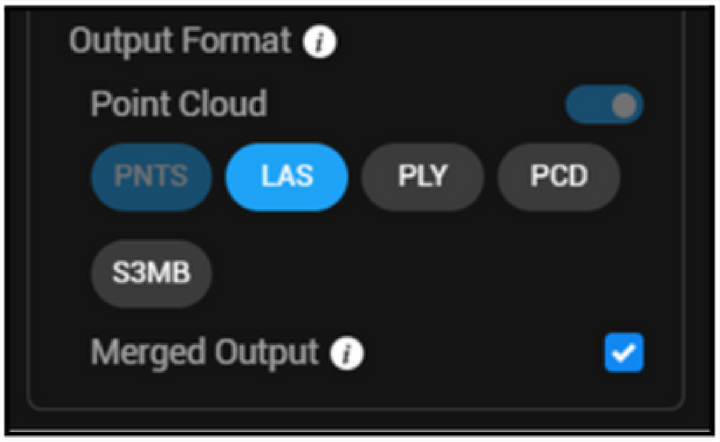
9. Under LiDAR Point Cloud Options set point cloud density and Point Cloud Processing



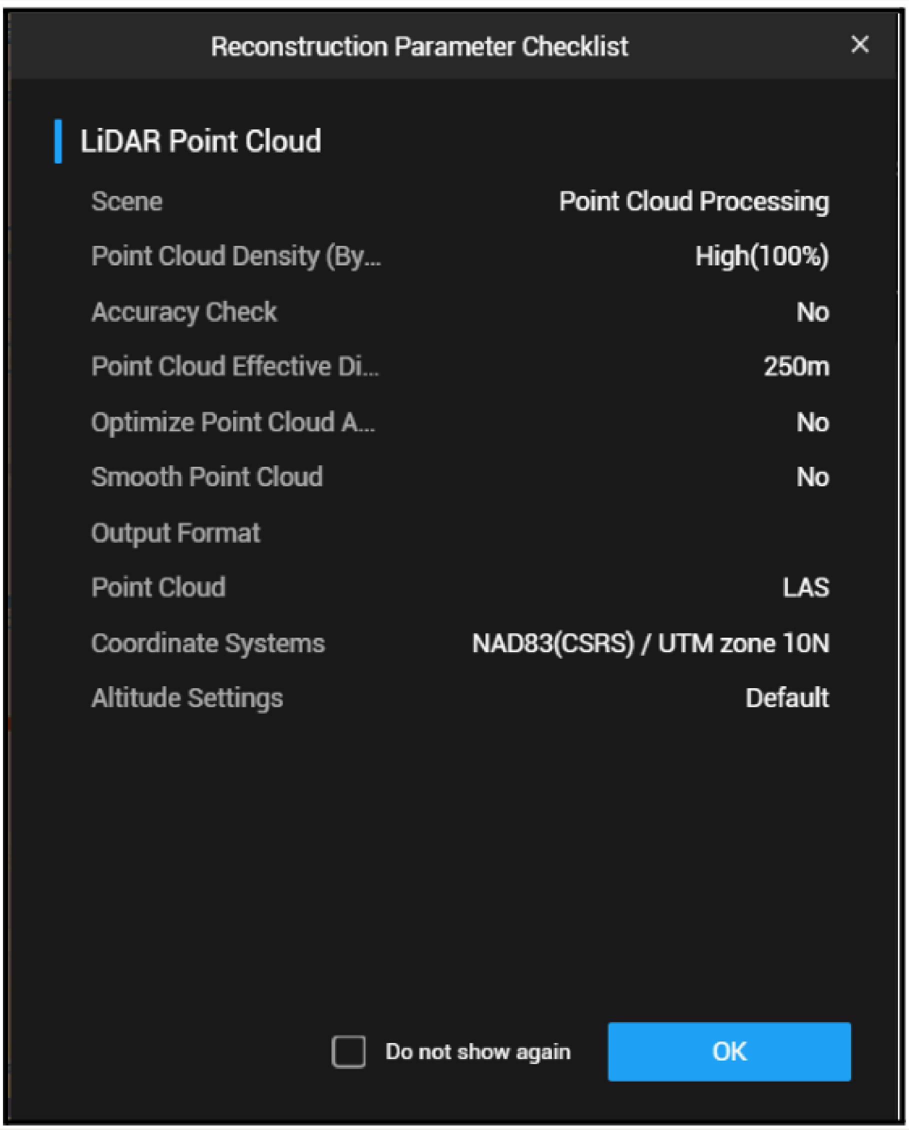
10. In the advanced tab leave default settings and adjust the output coordinate system to NAD83(CSRS) and the appropriate UTM zone



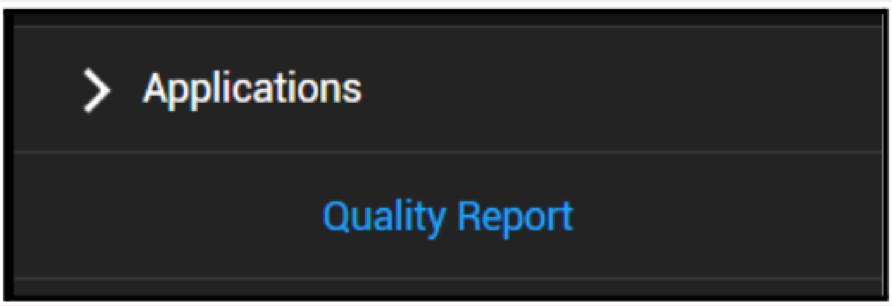
11. Set the output point cloud be LAS with merged output



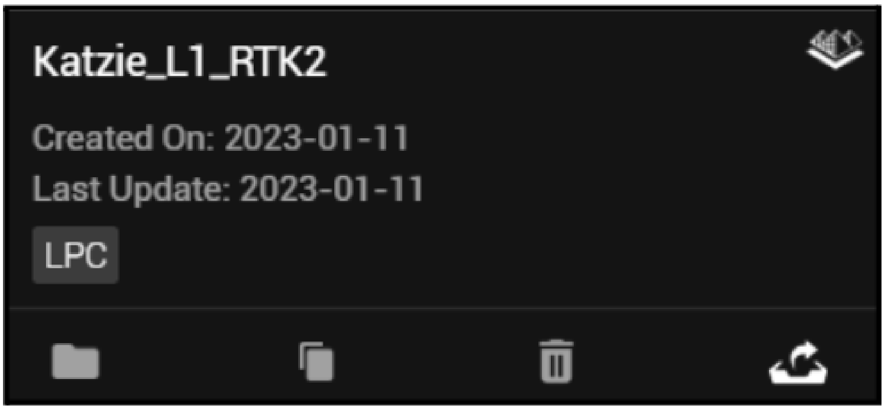
12. Confirm reconstruction parameters and run

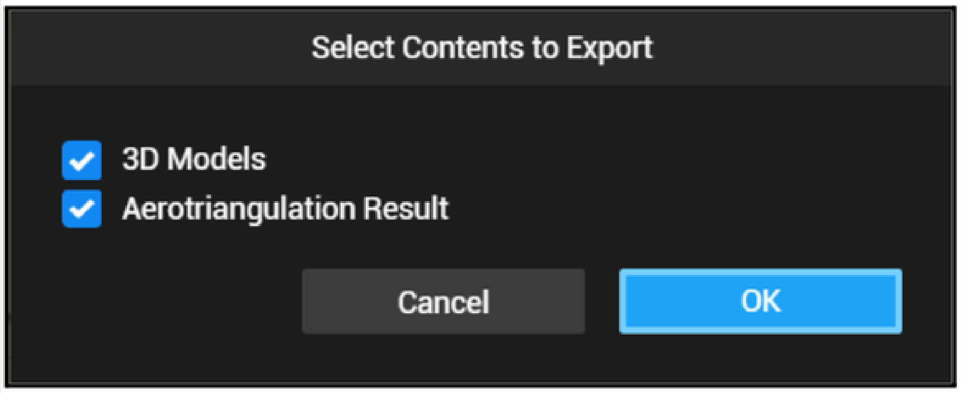


13. After the run is complete generate quality report



14. Export a copy of the mission for long term storage





15. Copy the mission folder from the DJI terra folder to a "working" drive for further processing and analysis

16. Inside the folder the quality report is in the report folder and point cloud results in the lidars folder (lidars/terra_las/***.las)

17. At this point if storage room on the DJI Terra computer is a concern you can delete the project from DJI Terra.

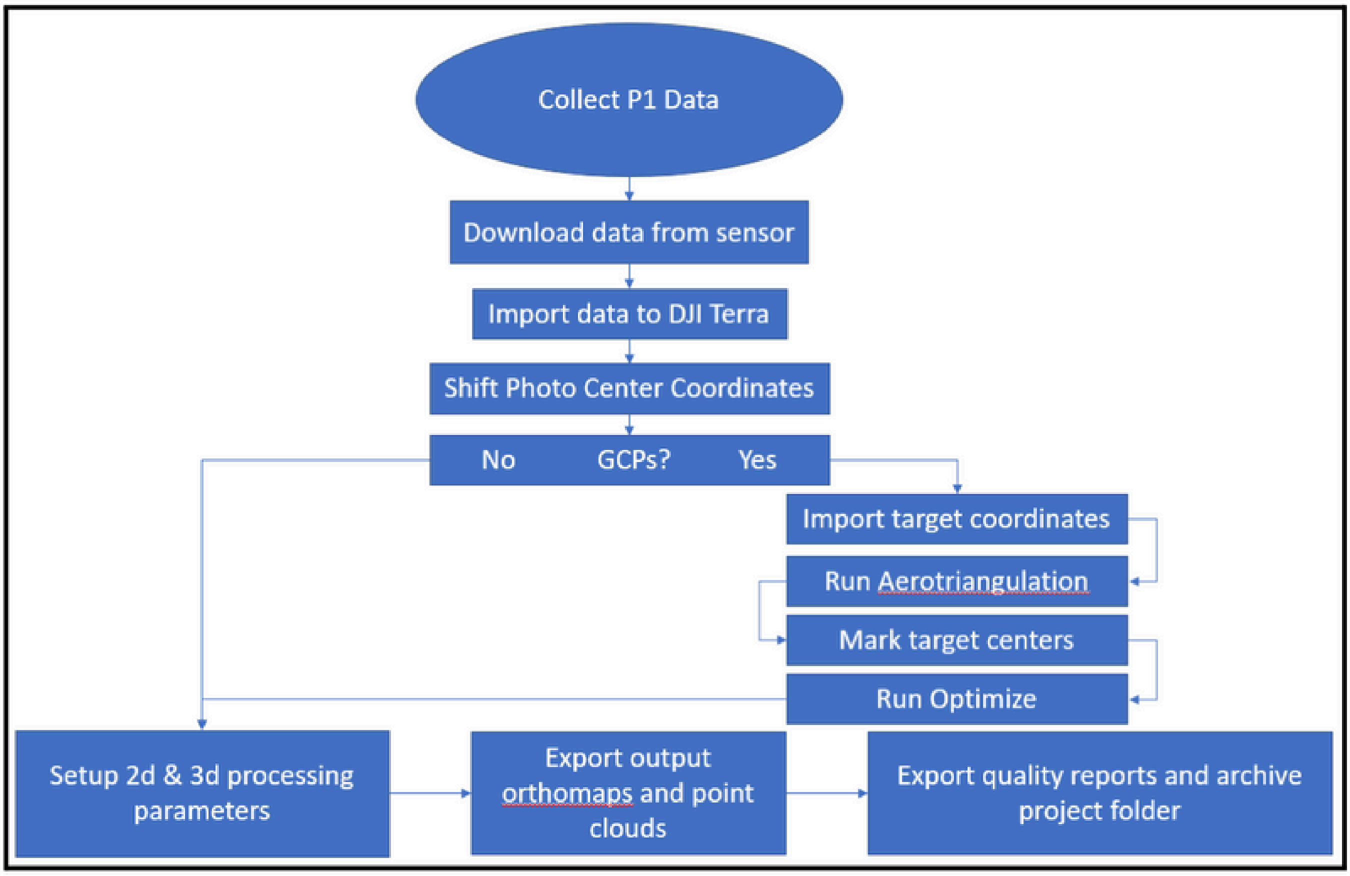
Photogrammetry (P1) Processing

P1 Processing Overview:

Key Points:

- SfM relaxes some of the requirements of traditional photogrammetry
- Advantageous for UAV missions (can incorporate numerous view angles)
- Direct georeferencing only as accurate as onboard GPS system, where indirect georeferencing (including GCPs) can improve accuracy

General Workflow:

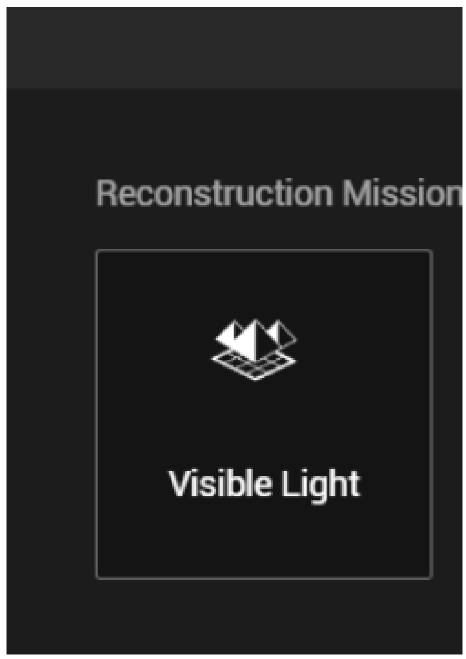


Detailed Workflow Steps:

1. Download data

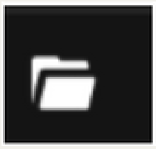
2. Open DJI Terra and select New reconstruction mission

3. Select Visible Light

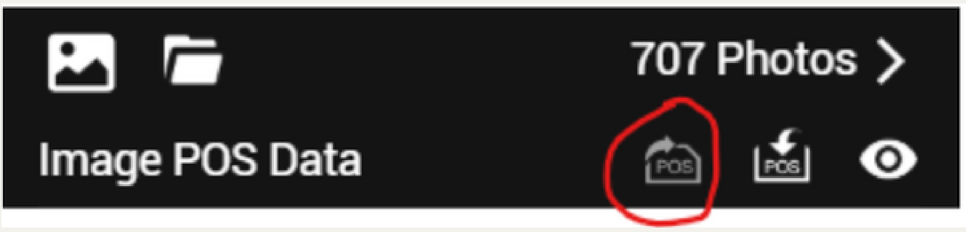


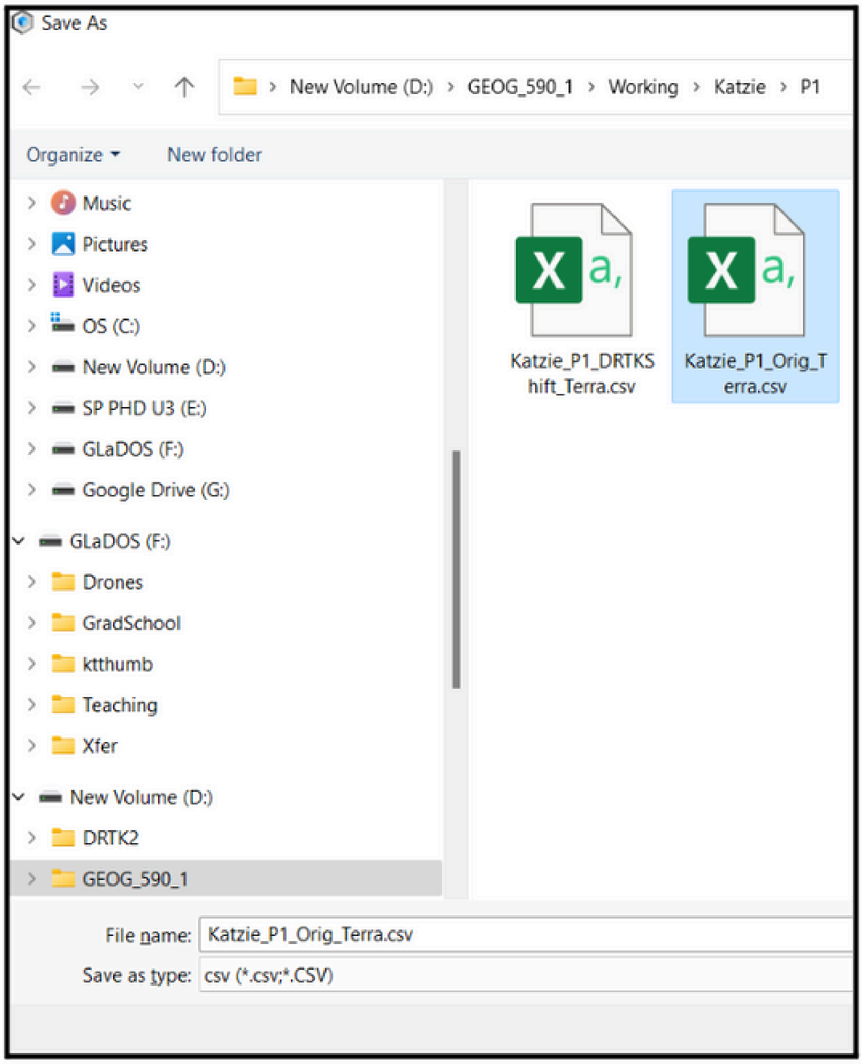
4. Name the project

5. Click on the folder icon to import photos



6. Export the positions of the photos

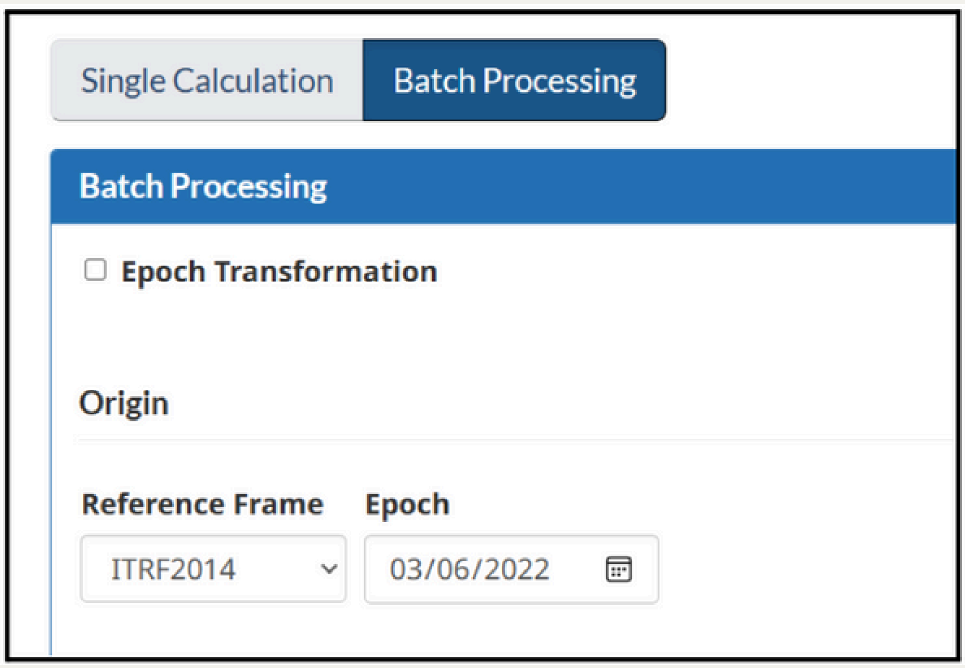




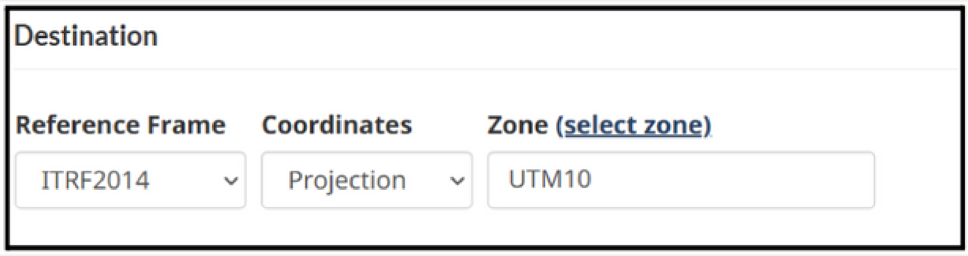
7. Open the .csv and label the columns as: Station, latitude, longitude, height

8. Navigate to the **NRCAN TRX site**

9. Start a batch processing calculation with the reference frame being ITRF 2014 and the epoch being the date of data collection



10. For destination select the same reference frame and set the projection to the appropriate UTM zone

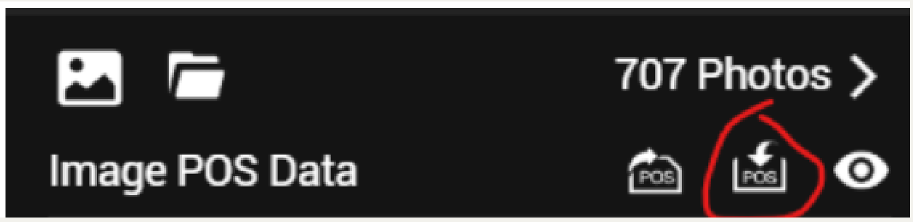


11. Upload the photo center .csv file and click send to download the results

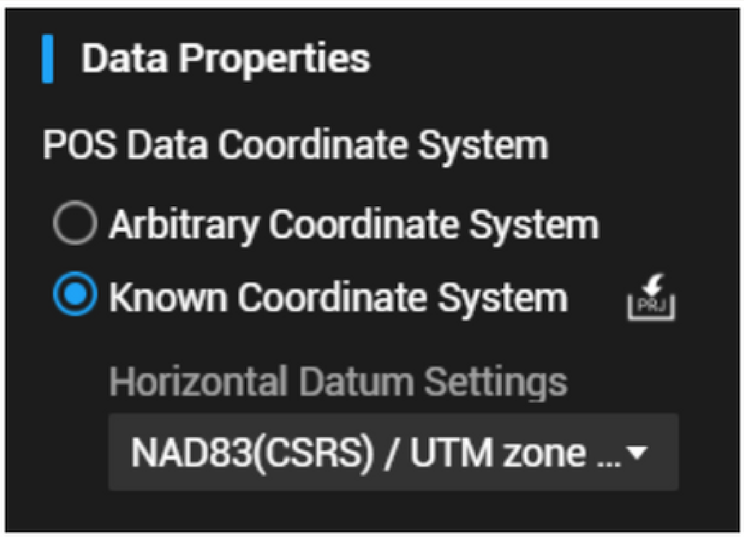
12. Make a copy of the photo center .csv file and change the coordinates to the projected coordinates downloaded from TRX (Note: ensure the same order of photos as the original file)

13. Apply the DRTK shift vector for the northing, easting, and height coordinates to the projected photo coordinates

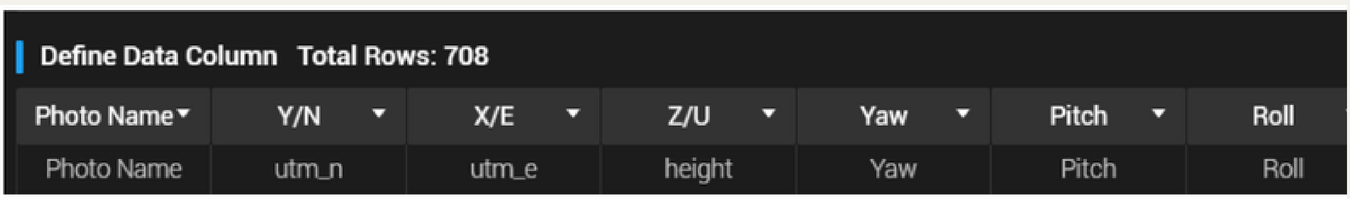
14. In DJI Terra import the new shifted photo coordinates



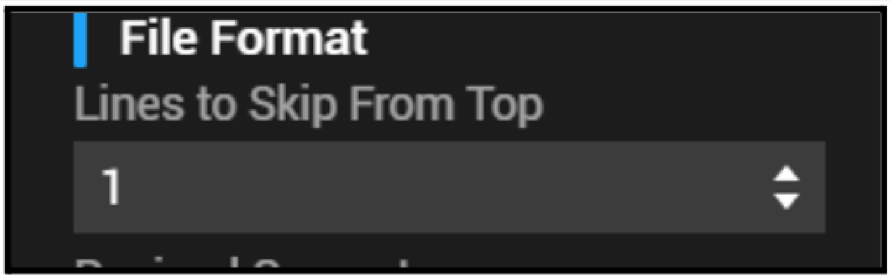
15. Define the coordinate system



16. Match column headers to first row of sheet

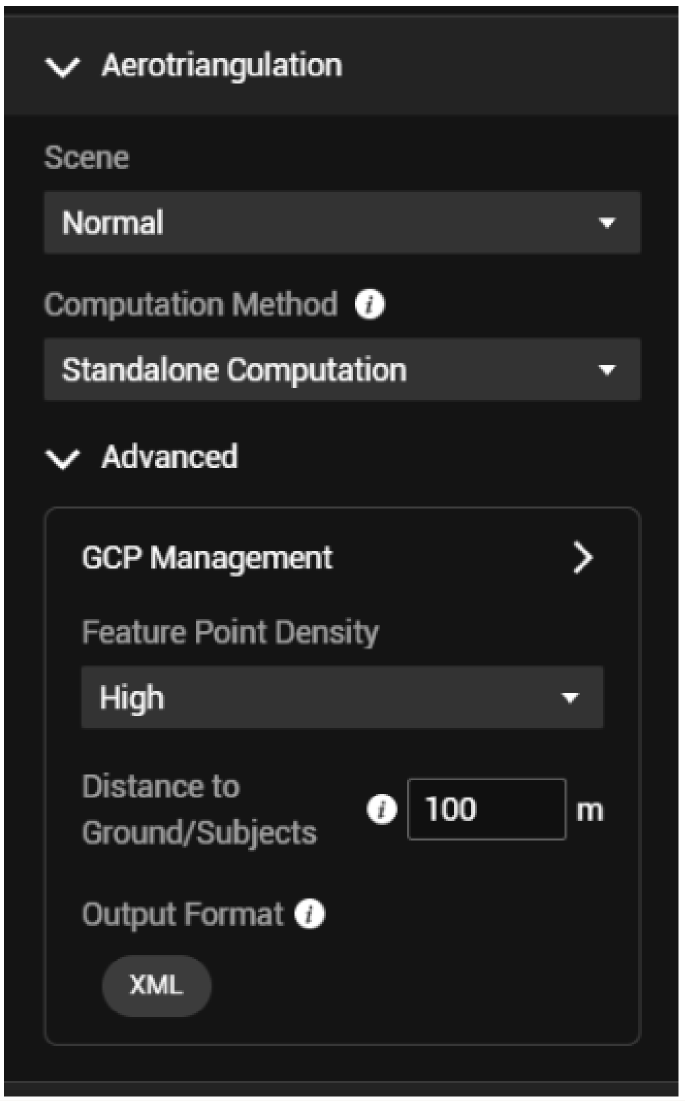


17. Skip the first row to remove the original column headers



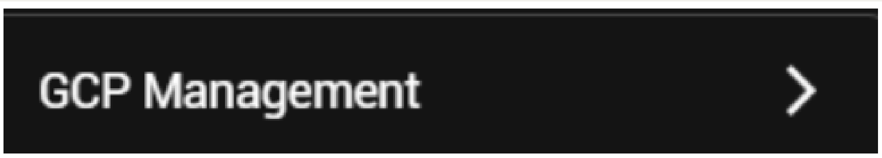
18. Click import

19. In the aerotriangulation section leave the default settings



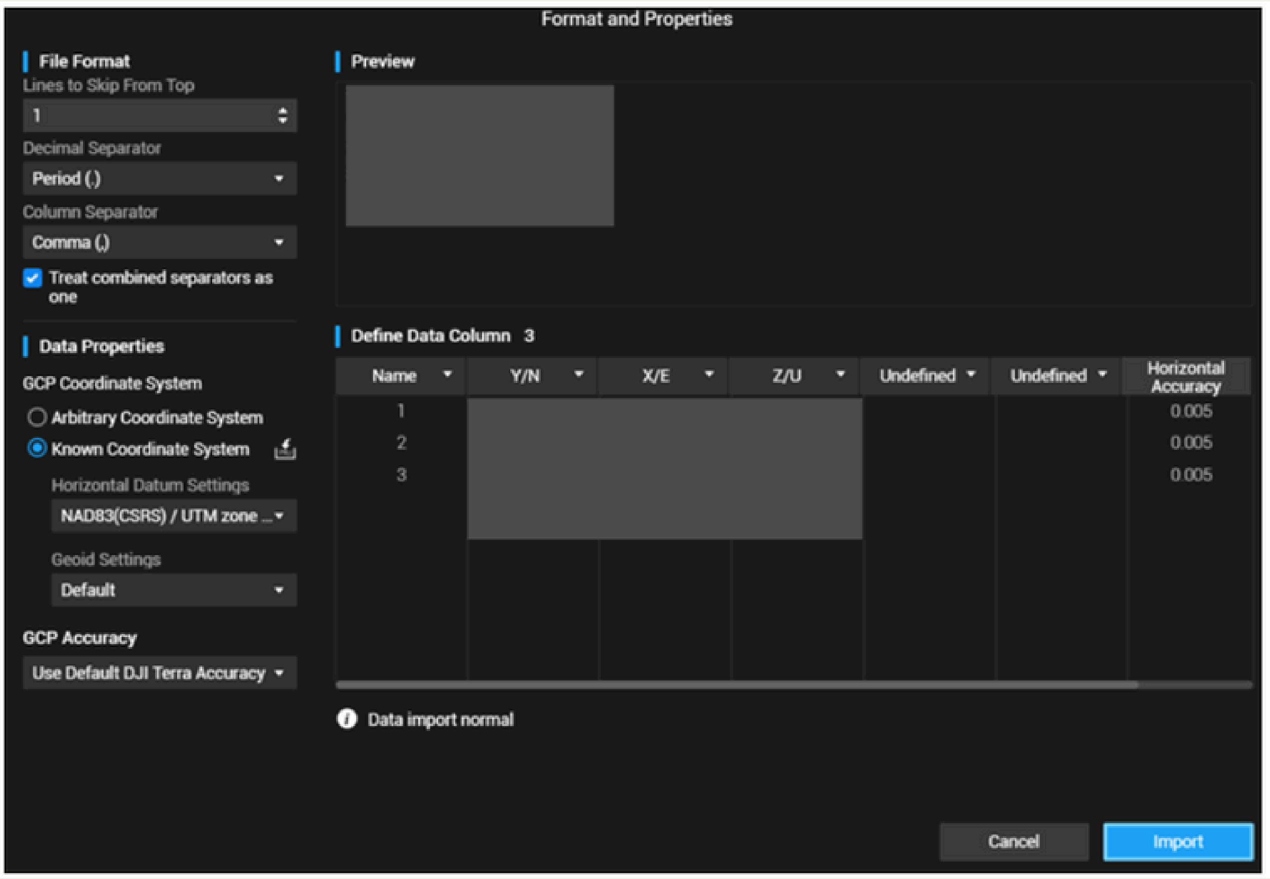
20. If using GCPs

a. Open GCP management

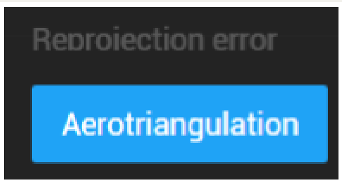


b. Import targets csv 

c. Set target coordinate system and columns



d. Run Aerotriangulation



e. Select each GCP and start marking targets

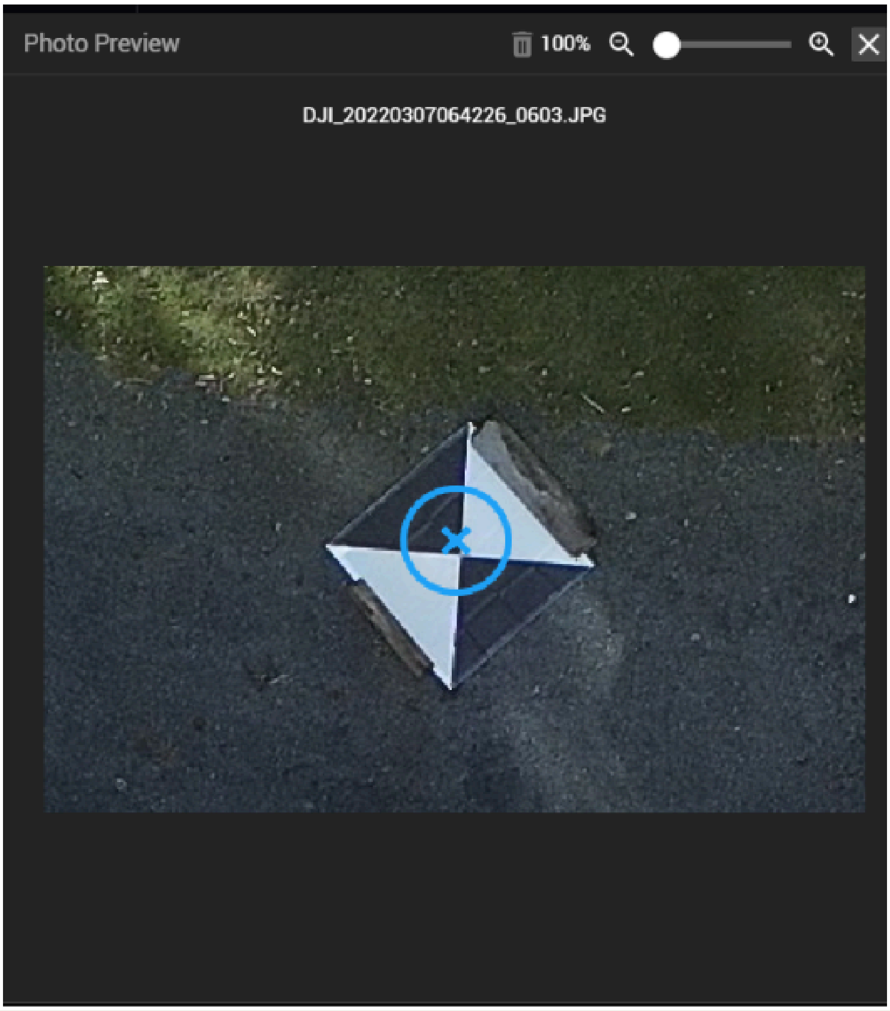
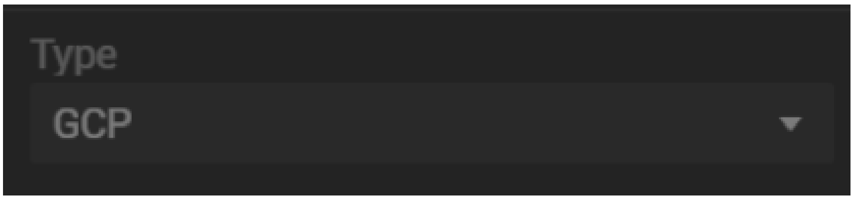


Photo Preview
100%
DJI_20220307064226_0603.JPG

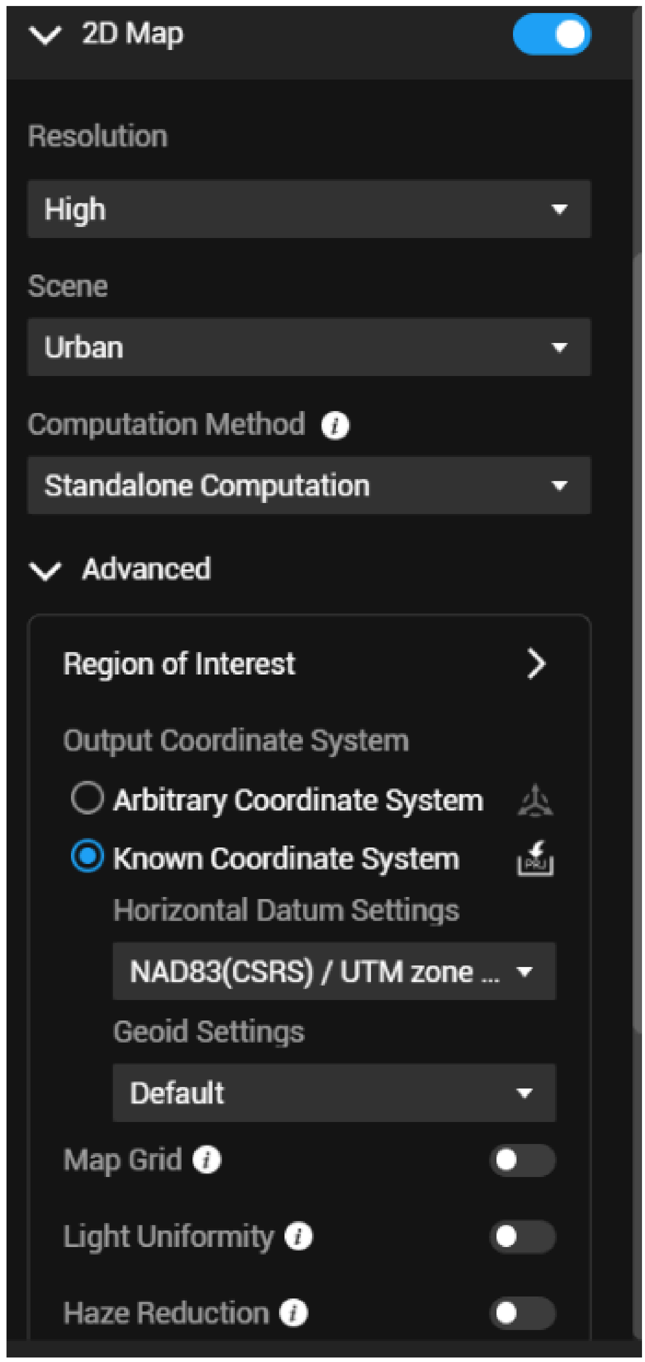
f. Continue marking targets if they have a clear visible center point until all photos for each GCP have been gone through

g. Set each point as either a control point or check point

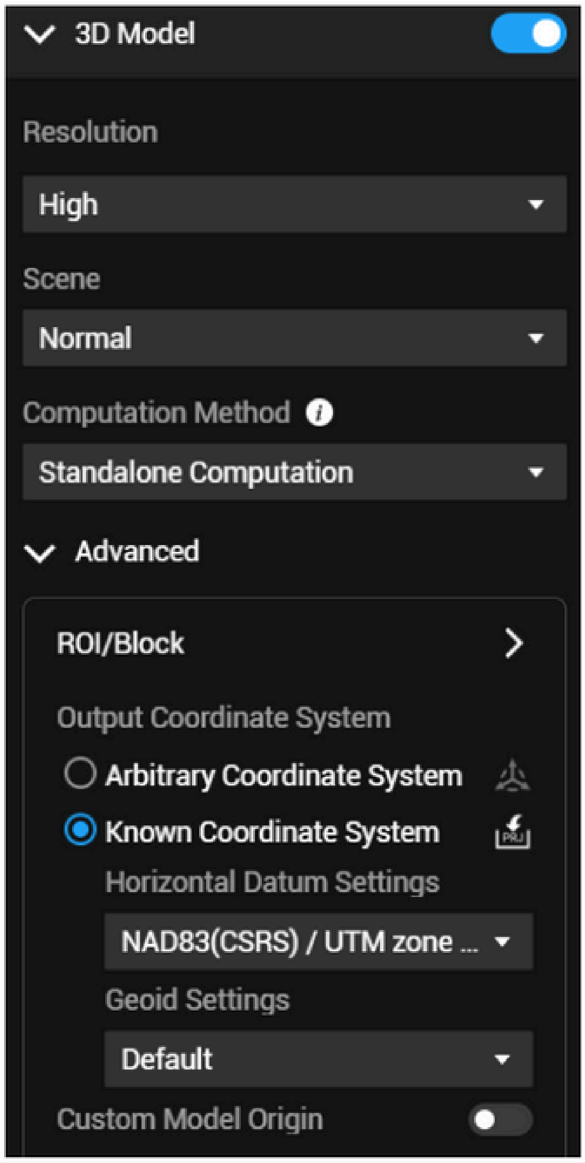


h. Run Optimize

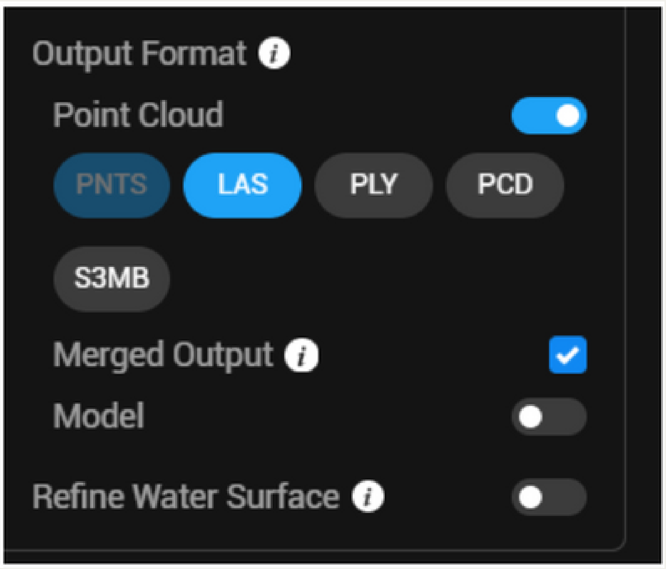
21. In the 2d section leave the default settings except for changing to output coordinate system to NAD83(CSRS) and an appropriate UTM zone



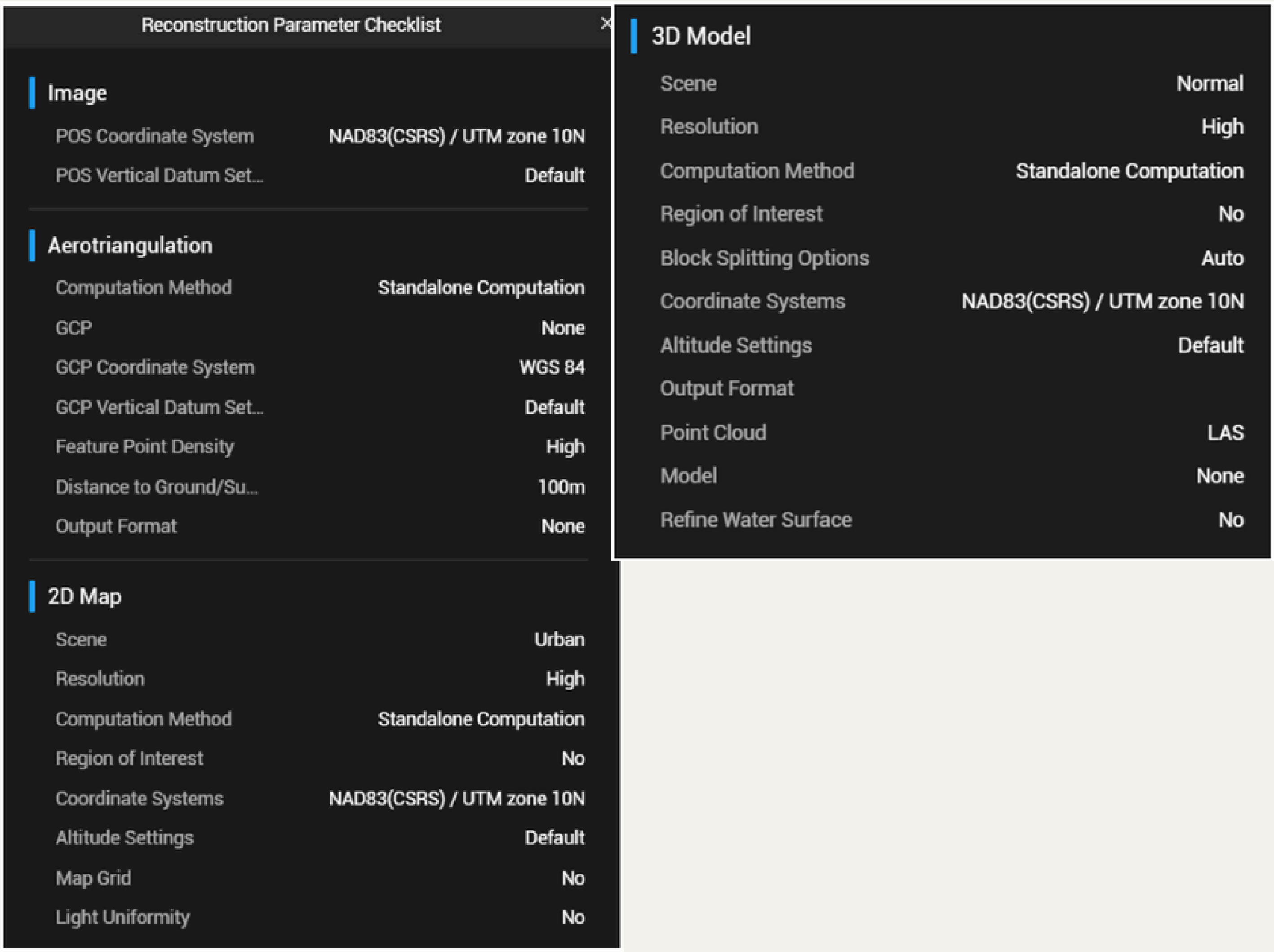
22. On the 3d section also use the default settings and change the output coordinate system to NAD83(CSRS) and an appropriate UTM zone



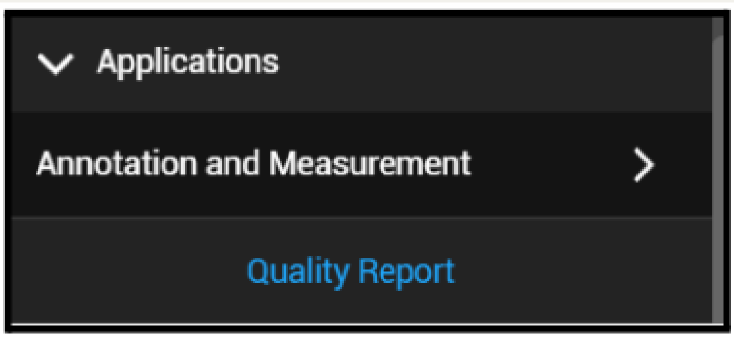
23. In the 3d model output settings set the point cloud output to LAS and turn off the model output and check merge output



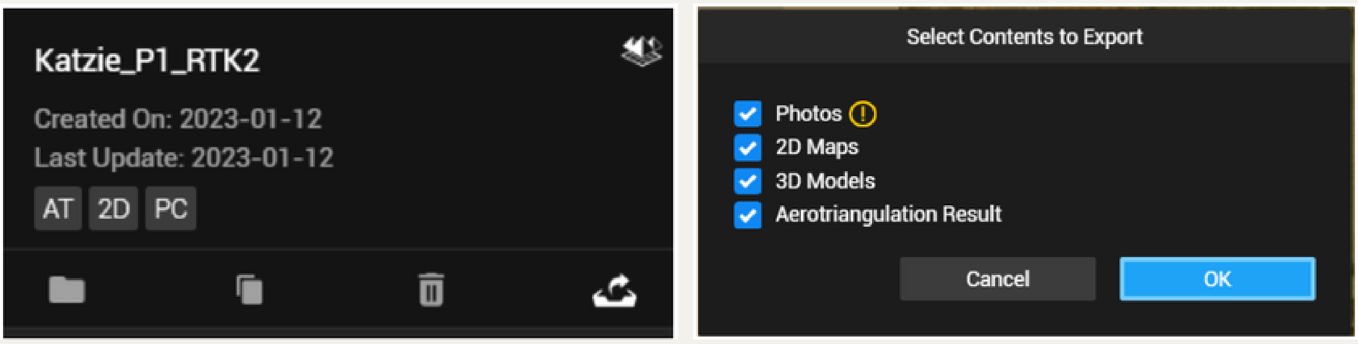
24. Confirm reconstruction parameters and run



25. After run generate quality report

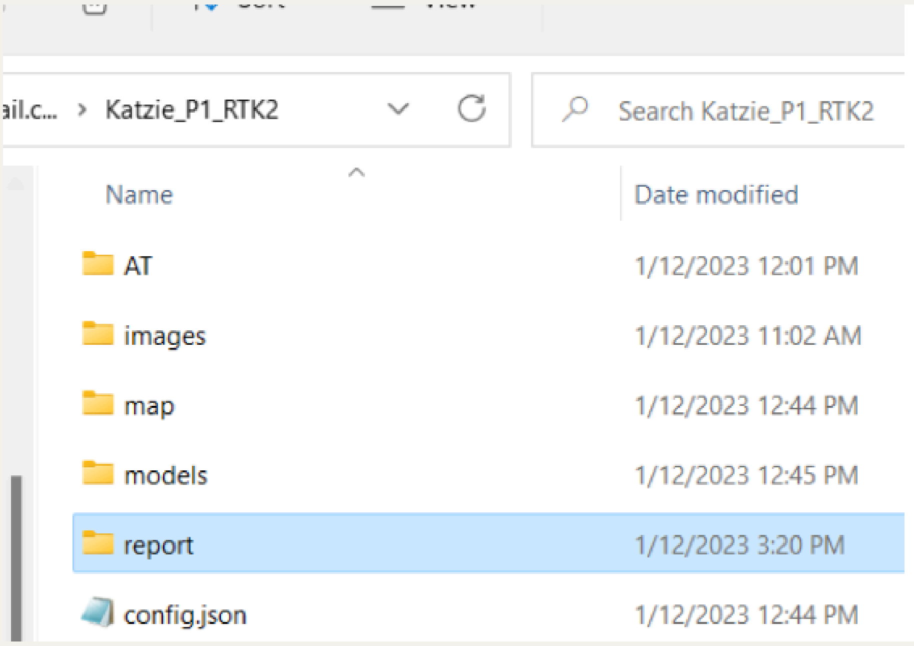


26. Export a copy of the mission for long term storage



27. Copy the mission folder from the DJI terra folder to a storage unit

28. Inside the folder the quality report is in the report folder



29. The ortho map output is in ./Map/result.tif and point cloud results in ./models/pc/..../terra_las/cloud_merged.las

30. At this point if storage room on the DJI Terra computer is a concern you can delete the project from DJI Terra.