Zenmuse L1 Course Workbook

Version 1.1

heliguy™

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ACRONYMS AND ABBREVIATIONS

Abbreviations	
CORS	Continuously Operating Reference Station
D-RTK2	Differential Real Time Kinematic 2
DSM	Digital Surface Model
DTM	Digital Terrain Model
FOV	Field Of View
GCP	Ground Control Point
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GSD	Ground Sample Distance
IMU	Inertial Measurement Unit
KML	Keyhole Markup Language
LIDAR	Light Detection And Ranging
NTRIP	Network Transport of RTCM via Internet Protocol
ODN	Ordnance Datum Newlyn
OS NET	Ordnance Survey Network
OSGB36	Ordnance Survey Great Britain 1936
PPK	Post Processing Kinematic
RAM	Random Access Memory
RGB	Red Green Blue
RINEX	Receiver Independent Exchange Format
RTK	Real Time Kinematic
TIN	Triangulated Irregular Network

DEFINITIONS AND KEY WORDS

Aerotriangulation – Term used to describe the determination of horizontal / vertical coordinates of points on the ground, from measurements taken using overlapping aerial photographs + already known coordinates of points on the ground

Diffuse reflectance – Reflection of light or other waves from a surface so that a ray incident is scattered at many angles

Digital Terrain Model – Elevation surface representing the bare earth surface referenced to a common vertical datum

Digital Surface Model – Elevation surface that captures both the natural and built features on the earth's surface

DJI Pilot – Flight app on the M300 smart controller for mission planning and manual flights

ETRS89 – Three dimensional geodetic reference system used as a standard for highly accurate GPS georeferencing in Europe

Gimbal – Pivoted support that permits rotation of an object around an axis

GNSS Baseline – Distance between a base station and a rover station. For high accuracy applications, the distance between the rover and the base station should be less than 10km

LAS – Industry standard binary format used for storing airborne LiDAR data

LiDAR – Light Detection and Ranging. Technology introduced in the late 1970s that uses light in the form of a pulsed laser to measure ranges or variable distances to the earth's surface

ODN – Benchmark in the UK that is selected to represent zero heights on maps in Britain. So the heights of hills, buildings and mountains are measured as their elevation above ODN

OSGB36 – System of geographic grid references commonly used on site engineering / survey projects across Great Britain. National grid coordinate system of Great Britain

Photogrammetry – Process of making reliable measurements through the use of photographs. Photogrammetry software stitches overlapping images together to create either a 2D or 3D model

Point Cloud –Dataset including millions of data points that can be used to represent a 3D object or space. Each point has its position located as a set of cartesian coordinates

Specular Reflectance – Reflection of light or other waves from a surface at the angle of incidence. Can be thought of as mirror reflectance

WGS84 – Earth fixed terrestrial reference system that has applications in cartography, geodesy and satellite navigation

INTRODUCTION

Welcome to the Zenmuse L1 complete geospatial course workbook. This course develops your understanding of the L1 sensor, and the steps needed to successfully complete your mapping mission.

This course provides LMS video content, informative video demonstrations and detailed screen recordings to help take you from drone data capture through to the final GIS output. Throughout this course we will outline the best parameters to conduct your autonomous flight mission, introduce the concept of RTK positioning, and finally provide tutorials on processing your drone data using a combination of both DJI Terra, and Terrasolid software.

Throughout this course the GIS team is on hand to assist you in any way, and answer any questions you may have. Beyond the course they are also available via telephone and email to assist with any queries. Please email either:

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For any other queries please email either info@heliguy.com, or the technical support team at tech@heliguy.com

Course Structure

2.1 - Sensor Characteristics and Sensor Technical Information

The first stage of this course goes over what's in the box with the DJI Zenmuse L1 Kit. It provides a breakdown of what's included in the L1 box, and includes a technical overview of the key components on the L1 sensor. DJI also provides a list of specifications for the L1 payload, all of which will be discussed later in this module. Upon completion you should be confident with the applications of LiDAR technology, and when it should be used over photogrammetry.

2.2 - GNSS Positional Correction Workflow Guide (NTRIP, D-RTK2 and PPK)

This section introduces the different workflows that can be used to obtain positional corrections on your drone. Following this chapter you should be confident with the fundamentals of GNSS and RTK. Post Processing Kinematic (PPK) will also be outlined as an alternative workflow, for those who didn't receive the RTK corrections.

2.3 - Introduction to LiDAR Parameters and Mission Planning Configurations (DJI Pilot)

This module covers the fundamental aspects of LiDAR and mission planning. This section will cover Linear, Oblique, Topographic and Waypoint mission planning, and verify the real-world applications for each mission type. The L1 system also includes an IMU, so this section will introduce the IMU calibration process for the different mapping missions.

2.4 - Data Capture and Flight Monitoring

Data capture and flight monitoring will cover the fundamental points needed to safely conduct a mapping mission when out on site. You will learn how to conduct a survey reconnaissance, how to establish ground control, and understand what parameters need to be checked before engaging the autonomous flight. It will also provide a breakdown of some of the factors that could go wrong when out on site, and how to fix them.

2.5 - Data Management and Processing (Generation of Point Cloud in DJI Terra)

DJI Terra is used to process your raw LiDAR dataset to the WGS84 coordinate system. By the end of this section you will have an understanding of the RTK and PPK processing workflows using DJI Terra Processing, and how to set up the software on your device.

2.6 - Data Processing (Terrasolid and Classification of Point Cloud)

Terrasolid has recently partnered with DJI to make the system compatible with the L1 sensor. You will gain an understanding of the Terrasolid wizard, and understand how this can be used to georeference the point cloud to OSGB36. We will then learn how to classify your dataset and remove all elements of noise from the LAS file. The final output from this module will be a cleaned point cloud file ready for export to mapping or surveying software's such as QGIS or LSS.

2.1 - SENSOR CHARACETRISTICS AND TECHNICAL INFORMATION

This section covers the sensors characteristics, and provides a breakdown of the Zenmuse L1s technical information. By the end of this section you should understand:

- What's included in the L1 box
- Understand the components part of the L1
- Understand the L1 technical information

What's in the box?

The first part of this section will cover what's in the box of the Zenmuse L1 sensor. These are listed as follows:

- DJI Zenmuse L1 sensor
- 6 month DJI Terra Free Trial
- Lens cleaning wipe
- User Manual
- Waterproof Hard Case
- SanDisk Extreme 64GB MicroSD Card
- Product certification

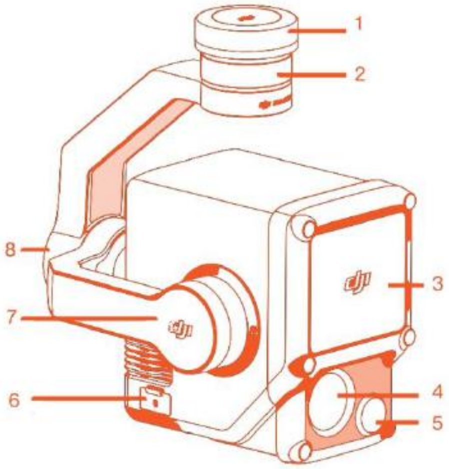
The MicroSD card will already be stored within the SD card reader on the L1. It's important to activate the DJI Terra licence on the PC you wish to complete your data processing on. Once the licence has been bound, it cannot be undone. Further information on this will be provided in section 2.5.

The Zenmuse L1 comes as part of a 3-axis gimbal, allowing for greater usability in enclosed environments. The sensor can rotate freely on this system when not connected to the aircraft - this is normal. A lot like other DJI gimbals, the L1 also uses a Skyport connection that is directly integrated with the corresponding gimbal connector on the Matrice 300 RTK. To protect the Skyport, a gimbal connector is also provided.

Likewise, the front of the gimbal also has a rubberized lens protector used to further protect the sensor itself. As the L1 reflective sensor is made of glass, it is important to always place the lens protector back onto the unit when data capture has finished. Upon unboxing the L1 for the first time, there is also a protective sticker on the reflective sensor. This needs to be removed in preparation for the first flight. This sticker may be kept and replaced for further and ongoing protection. However, the main protection comes from the rubberized lens cover itself, so if the sticker becomes unusable, this will not pose a major risk to the payload.

The L1 sensor is a part of the Livox sensor range, specifically, the Livox Mid-70 repacked into an accurate surveying solution. The sensor acquaints a 70-degree field of view. Beneath the LiDAR sensor, there's a 1-inch CMOS sensor, which matches the technical specification of the DJI Phantom 4 RTK. This can be used as a standalone photogrammetric or photography solution, or can be used to colourise the LiDAR point cloud. The third sensor, located to the bottom right of the payload, is a camera used specifically for vision positioning and helps maintain a high degree of accuracy if there is no GNSS signal. However, this is for failsafe only and it is recommended that you operate with a GNSS signal. Inside of the unit itself there is an IMU which helps to form the fully integrated surveying LiDAR unit DJI has developed.

Zenmuse L1 Component Parts



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

The image above provides a diagram of the Zenmuse L1 and the components that make up the integrated mapping solution. A breakdown of each component will be provided below:

Gimbal Connector: This uses the DJI Skyport connector. It is important to keep this connector in good condition to ensure there is a stable link between the payload and M300. Information is fed back to the controller via the OcuSync transmission system. Similar to other DJI payloads the Skyport is connected to the aircraft through a quarter turn until the two red dots align.

Pan Motor: This is used to orientate the gimbal from left to right. Whilst there is a definitive extent to which the payload can pan, you can fully orientate beyond 180 degrees either way. This means you have visibility around a full 360 degrees.

LiDAR Sensor: The LiDAR sensor is a green glass sensor on the front of the payload that is used to emit and receive rapidly firing laser beams that are used for direct point measurements in the area of interest. The time difference between emittance and received is measured in order to calculate the distance travelled, and in turn the elevation of the point cloud.

RGB Mapping Camera: The sensor also holds a standard RGB camera that represents the same specification as the Phantom 4 RTK and can be used for photogrammetric purposes. However, in tandem with the LiDAR sensor, it can be used to generate colourised point clouds.

Auxiliary Positioning Vision Sensor: This is used to assist the drone when GNSS systems are not recording to full effect. It is also used to help position the aircraft when landing.

MicroSD card slot: As standard, you will receive a 64 GB micro SD card with the L1 for data capture purposes. All LiDAR and photogrammetry data from the mapping mission will be saved to this SD card. It may be necessary to wipe data from the SD every so often so you do not reach max storage, and prevent data from recording to the card. If you wish to use a larger SD card, you need to ensure the SD can write quick enough for L1 data capture.

Tilt Motor: The tilt motor is found on both the right and left hand side of the payload. The tilt motor is the second axis of the three-axis gimbal and allows the payload to tilt forward and backward which is especially useful for nadir and oblique data capture.

Roll Motor: This allows the gimbal to rotate left and right. In combination with a tilt motor, this also can assist with operating the payload at oblique angles.

Inertial Measurement Unit (IMU): The IMU is not visible in the diagram, however it has a crucial role in defining the accuracy of the final dataset. An IMU is an electronic device that uses accelerometers and gyroscopes to measure the angular rate and rotation of the drone. It is located inside the sensor, and requires calibration before, during and after the flight.

Sensor Technical Specification

Technical Specification – Key Information	
Dimensions	152x110x169mm
Weight	930 (+/- 10g)
IP Rating	IP54
Aircraft	Matrice 300 RTK
Operating temperature	-20 to 50 degrees Celsius 0 – 50 degrees Celsius when using RGB camera
System Accuracy	Horizontal – 10cm @ 50m Vertical – 5cm @ 50m
Laser Safety	Class 1 (IEC 60825-1:2014)(Eye Safety)
Field of View	Non repetitive scanning pattern: 70.4 degrees (horizontal) and 77.2 degrees (vertical) Repetitive scanning pattern: 70.4 degrees (horizontal) x 4.5 degrees (vertical)
Sensor Size	1 inch
Effective Pixels	20 MP
Gimbal Axis	3-axis (tilt, roll, pan)

For a detailed overview of the technical specifications of the Zenmuse L1, please refer to either the LMS video footage, or the DJI website for further information using the link below:

https://www.dji.com/uk/zenmuse-l1/specs

Recommended SD Cards

The Zenmuse L1 requires a certain specification of SD card for the system to write the data at a quick enough speed. DJI specifies a sequential writing speed of 50 MB/s or above and UHS-I Speed Grade 3 rating or above. The maximum capacity of the SD card would be 256GB.

DJI Recommendations
SanDisk Extreme 128GB UHS Speed Grade 3
SanDisk Extreme 64GB UHS Speed Grade 3
SanDisk Extreme 32GB UHS Speed Grade 3
SanDisk Extreme 16GB UHS Speed Grade 3
Lexar 1066x 128GB U3
Samsung Evo Plus 128GB

Standardised Point Cloud Formats

Once the data has been processed, DJI Terra allows you to export the data in a variety of standardised formats. These file types are outlined below, and will again be covered in the Data Management and Processing stage of the course.

Formats in DJI Terra
PNTS
LAS
PLY
PCD
S3MB

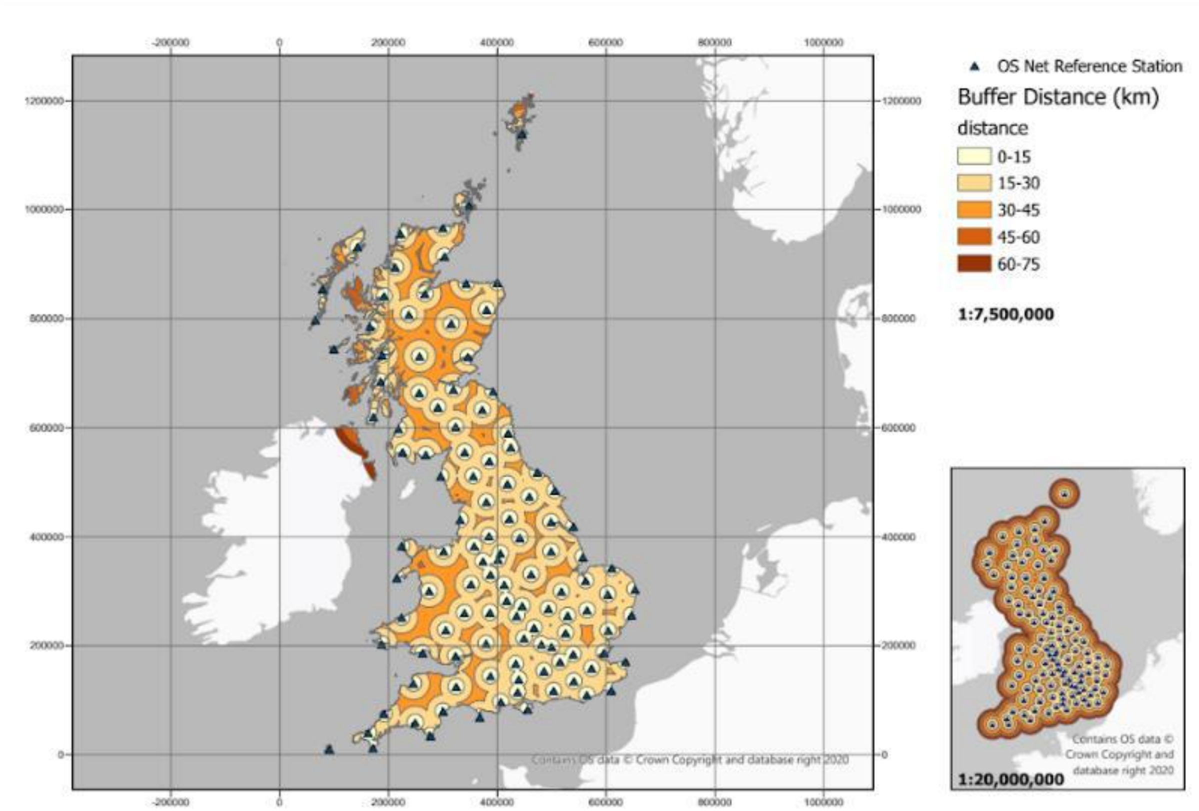
2.2 - WORKFLOW CUSTOM NETWORK, D-RTK2, PPK

This section is designed to introduce the RTK and PPK workflows that can help achieve cm level accuracy across your LiDAR + Photogrammetry datasets. By the end of this section you should be able to:

- Become familiar with both RTK workflows (custom network + D-RTK2)
- Understand how to collect data using a PPK workflow
- Understand how to establish a CU link to an NTRIP RTK network
- Understand how to assemble the DJI D-RTK2 base station
- Be able to connect the D-RTK2 base station to the M300 drone
- Be aware of the process used to provide the D-RTK2 with a known coordinate and achieve a high absolute accuracy
- Use the D-RTK2 base station as a part of a third party PPK workflow
- Understand how to use a third party station or CORS to post process LiDAR data

RTK and PPK Workflows

There are 3 GNSS positioning techniques that can be integrated into your Zenmuse L1 workflow. NTRIP stands for Network Transport of RTCM via Internet Protocol, and enables the GNSS rover (Matrice 300 Drone), to access data over the internet from a network of RTK base stations and achieve a sub 5cm accuracy. There are a variety of NTRIP formats and streams that can be used to derive your GNSS corrections. 24/7 Continuously Operating Reference Stations (CORS) are carefully positioned so you can access corrections from anywhere across the UK. A map of the different Ordnance Survey CORS stations based in the UK has been provided below. If you wish to find more information on this you can refer to the Ordnance Survey website for more information on the OS Network of base stations.



Custom Network RTK

To receive your NTRIP corrections for your custom network, an NTRIP account with a third party provider will be required. RTK Fix is one such service that can be used to derive your GNSS corrections, and can be purchased as a daily, monthly or yearly subscription. RTK Fix works on the principle of VRS Now, and uses a Virtual Reference Station to generate the highly accurate positional corrections. Multiple RTK base stations are used to create a virtual reference station closer to the drone, which has the added benefit of shortening the GNSS baseline to boost the accuracy of the results. Upon purchasing your custom network licence a series of login details will be provided entailing information on the mount point, password, IP address, username and port number.

D-RTK2 Base Station

Alternatively your corrections can be derived in real time from the D-RTK2 base station. The D-RTK2 base station is particularly useful if you're working in a remote area that has weak phone connectivity as the drone communicates to the Matrice 300 via a radio link, rather than receiving signals over the internet. This product supports the use of the 4 GNSS satellite systems: GPS, GLONASS, Galileo and Beidou, and stores the GNSS data in the standardised RINEX format.

PPK Workflow

The PPK workflow adopts a process that means no connection is needed between the RTK base station and the drone. It is recommended that the GNSS baseline or the distance between the drone and the base station is kept to as short a distance as possible; ideally less than 10km. Following the flight, the base station file corresponding to the same time slot can be downloaded from the Ordnance Survey website as an observation file in RINEX format. Alternatively, a third party base station (Leica Geosystems or Trimble Static receiver) can be used as a base station. Once the base station file is added to the same directory as the LiDAR data it can be processed in Terra. For the L1 photogrammetry data, EzSurv software can be used to mark the photo-centres of each photo to a cm level of accuracy. A full overview of PPK processing will be provided at the end of this section.

Establishing a CU Link between the Drone and Custom RTK Network

To establish the CU link between the drone and the NTRIP service, RTK needs to be enabled on the smart controller. Select custom network RTK for the NTRIP service type. Log in to the NTRIP service using the details received when the NTRIP account (RTK Fix, Leica Smartnet or Trimble VRS) was set up. This includes details of your NTRIP host, Port, Username, Password and Mountpoint.

Once these points are saved, the RTK network should connect automatically. The RTK Network needs to be showing that it's a fixed connection. If the smart controller states the RTK connection is converging, it will only be providing a float solution. The

RTK network must be fixed as this ensures that no ambiguity errors propagate to the end result. Failure to account for these ambiguities means the network has not established the integer number of wavelengths between the base station and the satellite, which can translate to poor positional error.

The smart controller provides details of the standard deviation being recorded by the drone. If the measurements are at the cm level of accuracy, this is further evidence that the GNSS corrections are at a survey grade level / the connection is fixed.

Key parameters with custom network RTK:

- Connection via 4G hotspot – Receive highly accurate GNSS corrections by selecting your mobile hotspot under the Wi-Fi settings
- Connection via 4G LTE Dongle – Insert a data sim card with data allowance into the 4G dongle. Plug the dongle into the back of the smart controller enterprise to receive the GNSS corrections

- Maintain Positioning Accuracy Mode – Enhanced flight positioning if RTK is lost during flight

D-RTK2 Connection

The second form of RTK connectivity is to use the DJI D-RTK 2 base station with direct connection to the Matrice 300 RTK during flight. Using the D-RTK 2 base station is especially useful when working in a remote area that has weak phone signals, preventing the use of an RTK Network connection. The D-RTK 2 supports the use of all 4 GNSS satellite constellations including GPS, GLONASS, Galileo and Beidou; storing the GNSS data in the standardised RINEX format. Unlike an RTK custom Network, the D-RTK 2 requires a physical set up on site in order to receive positional data that is accurate to a coordinate reference system. In real time, the D-RTK 2's observations are then transmitted via radio link to the Matrice 300 RTK to enable RTK positioning.

The D-RTK2 base station can be set up either arbitrarily or over a known survey point. To establish a radio link between the drone and the M300, the base station needs to be switched to mode 5. The mode button on the right hand of the base station needs to be pressed 5 times so the green light flashes five times. This confirms the D-RTK2 is set-up as a Matrice 300 static base station. Under RTK service type, select D-RTK2 base station as the RTK provider so the drone is linked to the base and receiving the GNSS corrections.

For applications demanding a high absolute accuracy, the D-RTK2's known coordinates need to be modified to that of a known survey point. The static convergent coordinates of the DRTK-2 have an error at the metre level, and will propagate into the end result. For those working to OSB36/ British National Grid or a coordinate reference system, it is necessary to set the tripod over a known survey point. The D-RTK2 collects its data in ETRS89, so ensure the coordinates have been converted to this coordinate system before inputting them into the smart controller.

If your survey work only demands a high relative accuracy and does not need to be georeferenced to a coordinate system, the base station can be set over any random point as long as the tripod is level. *For a full demonstration on setting up the D-RTK2 base station please refer to the setup video on the Heliguy online portal.*

Post Processing Corrections

Whilst RTK provides an efficient workflow, it may not always be available due its reliance on the internet. In this incidence, RINEX data can be used as a part of a post processing workflow. This method is one that is common amongst surveyors or teams that already have access to GNSS receivers which can be setup to record observations as a base station. Alternatively, this workflow can also utilise any third party corrections available over the internet. If an owner of the D-RTK 2, the system can be used to record RINEX data for post-processing purposes.

Post Processing Corrections - Workflow

The PPK Processing Workflow can be used for both the D-RTK2 base station, and third party static base stations. DJI Terra can be used for processing the LiDAR point data, whereas a third party source such as EzSurv is best utilised to post-process the raw photogrammetry data.

D-RTK2 Base Station PPK workflow

The D-RTK2 can be used in post processing workflow with no real time connection. For this process it is recommended that the GNSS baseline, or the distance between the drone and the receiver is kept below 10km. The D-RTK2 needs to be set up in an area with a clear open skies, to prevent the multipath error propagating into the end result.

It is important to switch the RTK off in the settings so the data records without connection to a base station or RTK custom network. It is also important to ensure that the base station is running across the entirety of the mission so the time stamped LiDAR data corresponds to the time-stamped observation data.

Once the data has finished recording, a type-c cable can be used to connect the D-RTK2 to the PC. The base station file should be copied to the same folder as the L1 result file. The data output provided will be in a format that is directly compatible with the L1, and will be named so DJI Terra recognises the file as a positional corrections file. Verify again that the .DAT file has the same timestamp for both the L1 and the base station. Alternatively, a PPK workflow can be used which uses third party GNSS corrections from the Ordnance survey website.

Third Party Base Station PPK workflow

The third party PPK workflow does not require a connection between the drone and the RTK base station. If using a third party base station (Leica or Trimble), the static receiver will need to be placed in a position with strong horizon coverage, and be placed so that it is within 10km of the flight path. Following data capture, the raw data file stored in RINEX format will need to be placed in the same folder as the L1's raw data. Alternatively, the relevant GNSS files can be directly downloaded from a CORS network online.

Processing with the CORS Network

It is recommended that the GNSS baseline or the distance between the drone and the base station is kept to as short a distance as possible; ideally less than 10km. If your flight has been conducted in the UK, the base station file corresponding to the same time slot can be downloaded from the Ordnance Survey website:

https://www.ordnancesurvey.co.uk/gps/os-net-rinex-data/

Using the OS Map that is on the OS Net website, click on the marker that you believe is closest to your survey area. These coordinates can then be copied into the search parameter box. Alternatively search for your survey area using one of the following parameters:

- ETRS89 Geodetic (Degrees, Minutes, Seconds)
- ETRS89 Geodetic (Degrees, Decimal Minutes)
- ETRS89 Geodetic (Decimal Degrees)

- ETRS89 XYZ
- National Grid Eastings and Northings
- National Grid KM Square

Specify your parameters for at least 2 stations, and make sure the start and end times of the survey span over a 24 hour period. This may take a couple of minutes to download. To speed up the process, download the data so it extends to one hour before, and one hour after the survey. The OS Net CORS network has been carefully designed by the Ordnance Survey so each reference station falls within a 30km radius of one another. One of the stations downloaded should fall within a 10km area of the mission area. If it does not, select the shortest possible baseline. Grid reference finder can also be used to verify distances between the survey area and base station:

https://gridreferencefinder.com/

Finally name the project with something recognisable that relates to your survey data. Once the station closest to the survey area has been downloaded, the resultant file should be stored in a RINEX format, which is a standardised GNSS file for satellite data. The base station file will need to be loaded into the same directory as the DJI L1 Lidar files. If there is an RTB file in the same directory this will need to be deleted to allow for processing. Rename the current base station folder with the name of the RTK folder, and change the file suffix to that of an OBS file. If not using observation data in a RINEX format, the Zenmuse L1 supports the following base station protocols:

Data Format	Version	Message	Rename to
RINEX	V2.1.x	/	DJI_YYYYMMDDHHMM_XXX.obs
	V3.0.x	/	
RTCM	V3.0	1004, 1012	DJI_YYYYMMDDHHMM_XXX.rtcm
	V3.2	MSM4, MSM5, MSM6, MSM7	
OEM	OEM4	RANGE	DJI_YYYYMMDDHHMM_XXX.oem
	OEM6	RANGE	
UBX	/	RAWX	DJI_YYYYMMDDHHMM_XXX.ubx

This concludes the GNSS positional correction guide to the course. If either the PPK or RTK data is missing, the L1 data will not process. If the drone loses RTK connection halfway through flight, the mission will automatically pause to ensure data validity. The next section covers mission planning in the DJI Pilot App.

2.3 - MISSION PLANNING (DJI PILOT)

The aim of Section 2.3 is to introduce the fundamentals of Lidar technology and explain the various mapping missions that can be setup using the DJI Pilot app. By the end of this session you should:

- Understand scan frequency, Lidar type and detection range
- Become familiar with the different types of autonomous flight mission - Linear, Waypoint, Mapping and Oblique
- Understand the recommended mapping parameters for each mission type and the applications these are most applicable
- Recognise the fundamentals of a manual LiDAR mission
- Be able to understand the process for a terrain follow DSM
- Recognise the IMU calibration process on the Zenmuse L1

LiDAR stands for Light Detection and Ranging. Initially, Lidar terrain mapping was introduced to the market in the early 1970s and focused on single beam profiling devices for use in bathymetry. With the development of GNSS technology and Inertial Measurements Systems (IMU), LiDAR soon became an attractive option to engineers and surveyors, as the sensor made it possible to collect highly accurate measurements in areas where terrestrial surveying methods were long and time consuming.

Zenmuse L1 LiDAR Data incorporated into a TIN Model for a coastal survey

Currently, LiDAR has applications in flood monitoring, agriculture and coastal zone mapping. It uses light in the form of a pulsed laser to measure the time difference between the emitted pulse and the return pulse. Knowing the position and orientation of the sensor, this can then be used to determine the XYZ coordinate of the reflected surface. Over a vast area with millions of individual data points, this can be used to generate a 3D point cloud, which can be viewed in terms of intensity, RGB colour or elevation. LiDAR can be integrated into either a satellite, UAV or an airborne flying system such as a Helicopter. DJI has developed the L1 sensor as an easy to use LiDAR system that can measure components of the earth's surface with accuracy, precision and flexibility.

Key Settings

- *Point Cloud Density* – configurable depending on the flight altitude, flight speed, overlap, return mode and scanning mode. Number of points per unit area in the point cloud
- *Ortho GSD* – directly relates to the photogrammetry data. Distance between two consecutive pixel centres measured on the ground. Ortho GSD depends heavily on the flying altitude
- *Altitude* – Can be measured as altitude ALT (above take-off point), or height altitude above sea level (Earth Geoid Model – EGM96 ellipsoid)

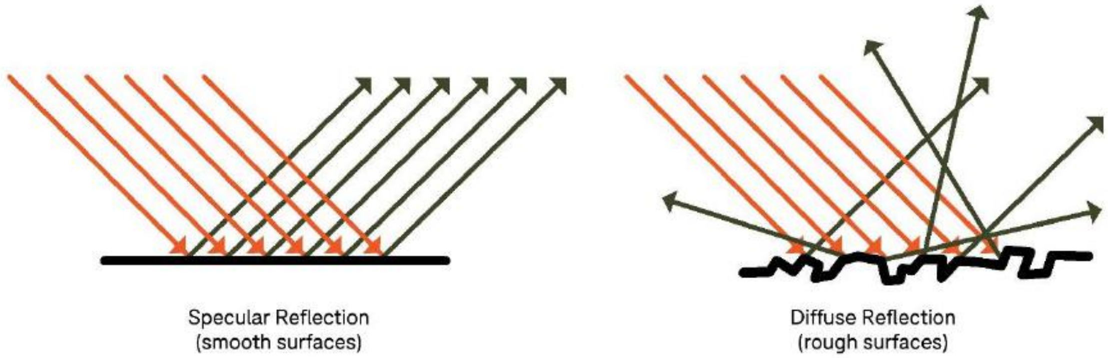
- *Standard Mission Flight Parameters* – Flight route height, Target surface to take-off point, Take-off speed and Speed
- *Course Angle* – How the flight lines are plotted across the survey area. Can be tailored toward the projects requirement
- *Margin* – How far the survey extends over the mission area
- *Elevation Optimization* – Matrice 300 flies to the centre of the survey area following the mission to capture a series of oblique images and increase the elevation accuracy
- *Upon completion of data capture* – How to end the survey following data capture. Hover, Return to Home, Land and Go to Route Start Point
- *Side Overlap* – 50% minimum if there is a requirement for photogrammetry data alongside LiDAR data. 20% overlap if only require LiDAR data
- *Photo Mode* – Timed Interval or Distance Interval. Timed interval collects data roughly every 3 seconds, whereas distance interval continuously collects images over a specific distance

Detection Range

The detection range integrated into the L1 sensor refers to the farthest measurable distance. This factor can vary greatly depending on the environmental conditions at the time of flight. It depends on a variety of factors including the target surface reflectivity, the target shape, and the ambient light interference. DJI has specified the L1's detection range for different illumination and reflectivity parameters:

- 450 m @ 80%, 0 klx - when the solar illuminance is 0 klx and the target's reflectivity is greater than 80%, the L1 has a maximum measuring distance of 450m.
- 190 m @ 10%, 100 klx - when the solar illuminance is 100 klx and the target reflectivity is greater than 10%, the L1 has a maximum measuring distance of 190m.

Klx can also also be thought of as the solar illuminance, or the intensity of illumination on a surface per unit area. DJI has provided the detection range of the sensor in terms of diffuse and spectral reflectivity. Diffuse reflectors are surfaces that are rough in texture reflecting the emitted pulse in a variety of directions. Whereas spectral reflectors return the pulse at a definitive angle. Land types with greater surface roughness, such as an asphalt road, will have a higher reflectivity at 90%. Smooth spectral reflectance surfaces, such as lakes, have a reflectivity closer to the 10% mark. For real world LiDAR applications, most surfaces will be diffuse reflection surfaces.



Point Cloud Data Rate

The point cloud data rate can also be referred to as the sampling or pulse frequency. It refers to the maximum number of laser beams emitted by the laser within a unit of time. Providing there are consistent environmental conditions, a higher point cloud data rate will deliver a higher number of measured points and operate at a higher efficiency.

The sampling frequency relates closely to the echo mode selected. Three echo modes are available on the L1. Single echo, Dual echo and Triple-echo mode are the operating modes available. The point cloud data rate depends on the echo mode selected. In single and dual echo mode, the maximum sampling frequency is 240,000 kHz, meaning that 240,000 laser beams are emitted per second. In triple echo mode, the maximum sampling frequency is 160kHz. In theory 480,000 points should be recorded per second, but in practice there are a much smaller number of measured points.

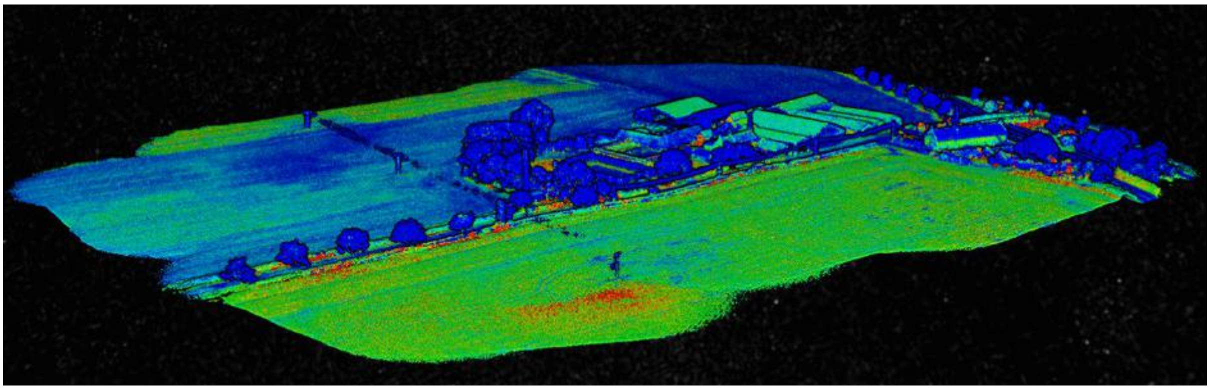
A combination of dual-echo mode and a sampling frequency of 240kHz would derive the highest number of measured points for any given dataset.

Applications

Depending on the application of your work, either one of the echo modes can be selected for your flight mission:

- *Single echo mode* : Oblique mapping missions, and mapping of urban objects/ features
- *Dual echo mode* : Maximising the point density of the final output. Applicable to mapping of both urban and topographic features
- *Triple echo mode* : Topographic mapping and mapping of vegetation / forestry

Selecting triple echo mode ensures that the sensor is measuring multiple returns from the surface. The rays of light can penetrate through the gaps in a sparse forest canopy, however are less effective in areas of dense vegetation.



The Livox LiDAR on board the L1 supports both repetitive and non-repetitive scan mode. As displayed by the diagram below, the sensor emits different shapes towards the earth's surface depending on whether it's repetitive or a non-repetitive scan. The scan shape is also influenced by the terrain, flight direction and speed of the drone.

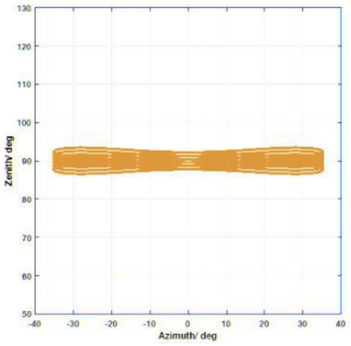


Figure: Scan shapes formed in 0.1s with repetitive scan mode of L1

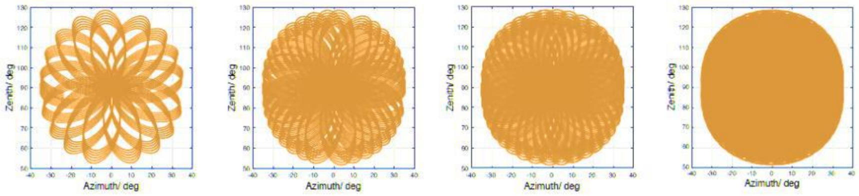
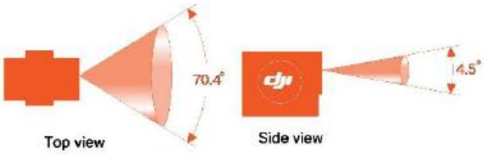


Figure: Scan shapes formed in 0.1s, 0.2s, 0.5s, and 1s with non-repetitive scan mode L1

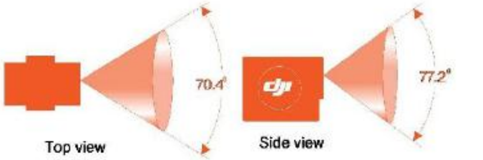
FOV (Field of View) : Also referred to as the scan angle, represents the angle covered by the LiDAR sensor, or the angle at which laser signals are emitted. The FOV varies depending on the scan mode detected.

Repetitive scan: The vertical field of view is narrower, but the accuracy is higher. This scan mode is recommended for high-accuracy surveying and mapping.

Non repetitive scan: The vertical field of view is wider. This mode is recommended for capturing data of complex structures, or building facades, and works well with an oblique mapping mission.

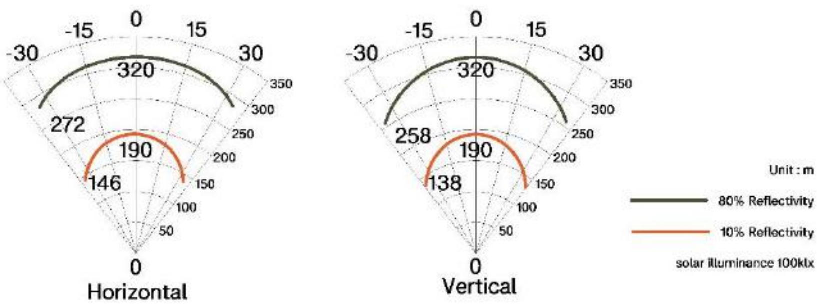


Scan angle in repetitive mode



Scan angle in non-repetitive mode

The closer an object is to the edge of the FOV, the less detailed it will be in the final scan. However, if an object is close to the centre of the FOV, the more detailed it will be in the final point cloud.



Effective range of L1 within the FOV

Beam Divergence Angle : Refers to the diameter of the laser beam on board the L1 which can widen as the laser pulse propagates from the sensor. Generally laser beams are well collimated, however this could introduce light spots into the dataset if the flying height were to increase significantly.

Ranging Accuracy: Discrepancy between the LiDAR measured distance and the actual distance. Ranging accuracy differs from the system accuracy in that the former does not represent the accuracy of the final result.

RGB Colouring Enabled: Colourises the point cloud. Disabling this feature means the point cloud can only be viewed in terms of Elevation, Intensity and Return. Uses the image data that is captured by the RGB sensor on the L1. Also means raw image data is captured which can be used to generate an 2D or 3D models.

Topographical Surveying + Forestry

By the end of this section you should understand what mission parameters are needed to successfully conduct a topographic survey flight. The parameters for this survey mission can also be used for LiDAR missions that need to penetrate the vegetation canopy, meaning this information is also applicable for those involved in forestry . Whilst they are two different applications, their flight planning parameters are very similar. Typically a polygon shaped area, select Mapping as the choice of mission. On the smart controller navigate to the approximate area of interest and tap the screen once - this will bring up the blue data capture box. Using the vertices, reshape the box to cover the area of interest. Once the L1 LiDAR sensor has been selected, ensure IMU calibration is selected. Yellow calibration lines should appear on the edge of the survey area. Please refer to the table below or the LMS video for a breakdown of the other parameters:

Category	Parameter Name	Explanation and recommended value
General	Camera type	Zenmuse L1 LiDAR Mapping
	Point Cloud Density	*Varies depending on flight altitude, overlap ratio, flight speed, scan mode*
	IMU Calibration	Enabled
	Altitude Mode	Default
	Flight Route Altitude	50 meters
	Target Surface to Take Off Point	0 by default
	Takeoff Speed	15 m/s
	Speed	10 m/s
Advanced Settings	Side Overlap	At least 50%
	Course Angle	*Adjusted to projects needs*
	Margin	*Adjusted to projects needs*
	Photo Mode	Timed Interval Shot
Payload Settings	Echo Mode and Lidar Sample Rate	Triple
	Scan Mode	Repetitive
	RGB Colouring	Enabled

Surveying using Oblique Scanning Methods

For environments with significant terrain undulations or with 3D structures, standard nadir data will not provide comprehensive point cloud densities on the sides of facades, therefore, the L1 sensor angle must be set up with an oblique angle.
In DJI pilot, oblique missions are split into five sub-missions. The first of those will provide nadir data capture, directly over the area of interest, whereas the subsequent four sub-missions displace the flight path in each of the four directions; East, South, West and North. This is necessary because an oblique sensor angle would essentially eclipse the area at the closest edge of the survey and with more severe angles, less and less of the area interest will remain inside of the mission's data collection. DJI Pilot considers both the flight height and sensor angle to determine how much of an offset to apply.

Category	Parameter Name	Explanation and recommended value
General	Gimbal	Zenmuse L1
Route Settings	Speed	6-10 m/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	Gimbal pitch rotation at -90 degrees Timed interval shot enabled Start point cloud modelling recording
	Last waypoint	Finish Point cloud modelling recording
L1 Payload Settings	Sampling rate	240 kHz
	Scanning mode	Non-repetitive
	Return Mode	Dual
	RGB Colouring	On

Terrain Follow Feature

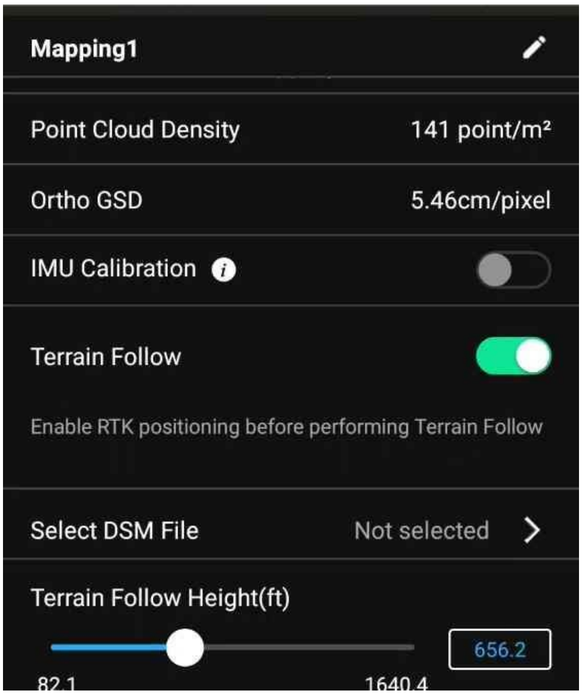
Terrain Follow is particularly useful for areas with sloped or uneven terrain. As standard, the Matrice 300 will fly with a consistent height above the take-off point, therefore, if you take off on the top of the hill, your point cloud density will be far less than what DJI Pilot specifies. Likewise, your GSD's will be a lot larger. Therefore, for the example of a hill, it is best practice to maintain a consistent height from the surface of the earth to obtain the desired point cloud density. To do this, Terrain Follow can be used. It is important to note that Terrain Follow fundamentally relies on RTK connectivity, therefore, it is not possible in a post-processing workflow. Connection to network RTK or the D-RTK 2 is required.

Next select a DSM file, also known as a Digital Surface Model. This data may have been collected from a previous survey or from online national LiDAR resources. Whilst importing a DSM collected using photogrammetry is the most common approach, the UK's online database can also be used:

https://data.gov.uk/dataset/f0db0249-f17b-4036-9e65-309148c97ce4/national-lidar-programme

DJI Terra can also be used to generate a DSM file by collecting 2D data of the target area and performing a 2D reconstruction in DJI Terra with Fruit Tree mode enabled. A *gsddsm.tif* file will be generated in the "map" folder of the mission files which can be imported into DJI Pilot App for terrain following.

A DSM file can be imported using the SD card slot located on the top of the Enterprise Smart Controller. Once selected, the height will then be denoted as 'Terrain Follow Height' as appose to flight route height. The M300 and L1 will then fly with a consistent height above the terrain instead of the take-off point thus improving data consistency.



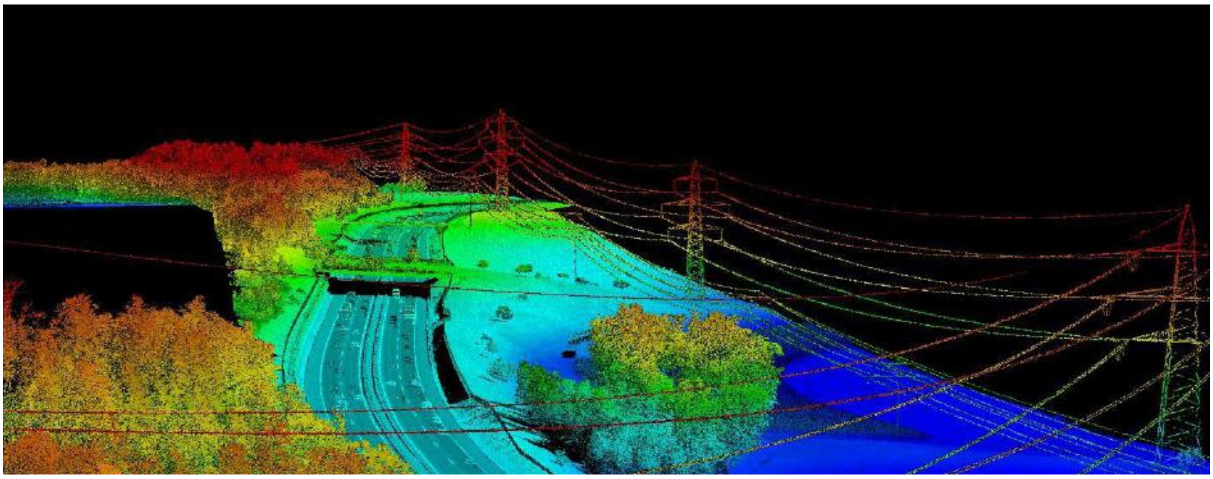
Terrain Follow and calibration flight option cannot be enabled at the same time. IMU calibration needs to be turned off to enable the terrain follow function.

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.

Area of DSM File shown on Map

Surveying for Powerline Inspection Services

Although DJI Pilot's linear flight mission mode seems it would be best suited for powerline inspections, this is actually not the case. Waypoint missions allow for a lot more control, as well as automated calibrations, therefore, data quality is much higher.



When creating a route, DJI Pilot will ask to confirm whether there will be pre- set waypoints on the DJI Pilot app, or if they will be set via live mission record. Live Mission Record is essentially a process of manual flight prior to the automated LiDAR recording, whereby you set accurate waypoints for the aircraft to follow, using the C1 button on the back of the smart controller. This is particularly useful on sites with varied terrain to maintain a consistent height above the powerlines. It also enables close proximity flight which is very important due to the fine nature of a powerline structure. Once you have selected all the waypoints in the manual flight, the drone can be returned to the home point ready for the autonomous flight. An autonomous flight provides a consistent and accurate dataset.

Waypoint Mission Planning Flight Parameters:

Category	Parameter Name	Explanation and recommended value
General	Gimbal	Zenmuse L1
Route Settings	Speed	6-10 m/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	Gimbal pitch rotation at -90 degrees Timed interval shot enabled Start point cloud modelling recording
	Last waypoint	Finish Point cloud modelling recording
L1 Payload Settings	Sampling rate	240 kHz
	Scanning mode	Non-repetitive
	Return Mode	Dual
	RGB Colouring	On

If there are any waypoints that need to be removed, the waypoint of interest can be selected and then the disposal bin icon at the top can be used to remove the waypoint. This finalises our mission. Once the parameters are set towards the projects requirements, save the file and begin the flight mission.

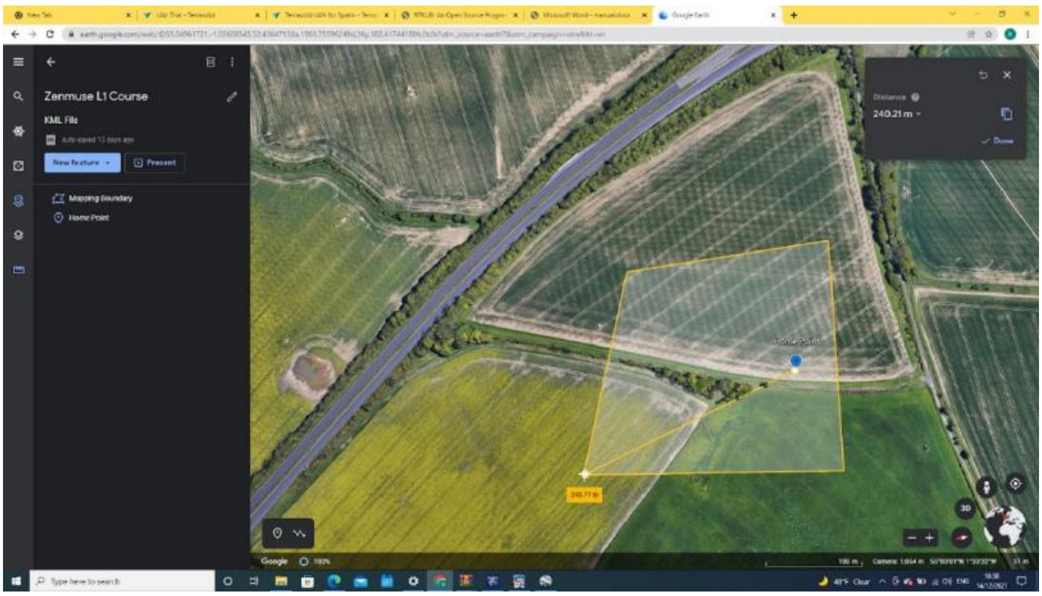
Manual Lidar Data Capture

For more intricate environments, whereby autonomous flight may not be possible, manual flight may be necessary in order to capture data. During a manual flight you will need to manually initiate the calibration procedure every 100 seconds. If the sensor goes beyond 100 seconds without a calibration then the IMU's accuracy will decrease and your data will lose accuracy. The calibration procedure involves a series of forward and backward motions at varied speeds, this should be done at the altitude of data capture.

For this process, the drone will need at least 30 meters open airspace in front. It is recommended that obstacle avoidance is switched on to reduce risk of an incident. Once the IMU calibration is complete, then data capture can begin by using the record button on the right hand side of the interface, very similar to recording a video.

Once 100 seconds is up, the recording should be stopped, a calibration process should be instigated and then the recording can continue. Given the nature of stopping and starting a mission, you will find that you will have multiple files containing each segment of the dataset. These files can be collapsed into one folder to allow DJI Terra to process the one complete point cloud. If the manual flight being conducted consists of many turns and speed changes, it is not necessary to instigate an IMU calibration every 100s. However if your flight path is long and continuous it is recommended that the manual calibration is toggled.

Import a KML into DJI Pilot



Certain operations require a kml file to be imported into the DJI Pilot app. This feature is useful when working across a large survey area. It allows the majority of the planning to be completed prior to going out on site and tailored towards your survey specifications.
Google Earth is used to draw out your kml file/ mapping area. A step-by-step guide for drawing your kml file is illustrated below:

- Type postcode in the top left search bracket to find your area of interest
- Create a new project to draw the perimeter of the survey area
- Under new feature add a placemark for the proposed home point
- Use the draw line or shape tool to verify that the perimeter of the survey area does not exceed the 500m horizontal flying distance. Ensure there is a visual line of sight (VLOS) on the drone throughout the flight.
- Under more actions select export kml file. Save the exported kml file to an sd card
- Once the sd card is in the smart controller select import kml file in the DJI Pilot app for the mapping mission you wish to execute
- Select external sd and import the kml file. The survey area should now be loaded into the DJI flight screen with the default mission parameters, and can be amended to your projects needs

2.4 - CAPTURE / MONITOR

Section 2.5 goes over the practical element of the course. By the end of this section you should:

- Understand how to successfully complete a survey reconnaissance
- Understand what parameters need to be checked before starting the mapping mission
- Be able to establish ground control for quality assessment with the L1
- Understand what variables could go wrong when out on site

Survey Reconnaissance

Before flying your drone, it is worth doing a reconnaissance of the site so you can get a feel for the survey area, and understand what risks there are on site. As well as noticing some of the risks on site, the survey reconnaissance helps you establish what positions are best for the control points.

Using the image above as an example, there are some hazards that need to be recognised before completing the flight. There is a road running along the south side of the survey area, so it is worth putting some spotters out to watch out for oncoming traffic. Secondly, along the east side there is a rail track, so the drone cannot fly below a 60m flying distance. If an oncoming train approaches, and the drone is near the track, switch to manual flight mode and fly away from the train track to stop the driver getting distracted. The site is also relatively flat and exposed, so make sure that the wind conditions do not exceed 15 m/s. If the wind exceeds 15 m/s bring the drone back into land.

Checking the Flight Parameters

So far in the DJI Pilot app you have outlined the mapping parameters for our topographic survey mission. Once the drone has been assembled at the take-off point, and the necessary safety checks have been completed, the drone is ready for flight.

Pre – Flight Check:

- Drones take-off point is in a clear open sky location. Not located close to any metallic objects that could cause magnetic interference
- IMU Warm Up – ensure the IMU has warmed up for 3-5 minutes before flight. The DJI Pilot App will release a notification saying the INS IMU has warmed up and is ready for flight
- Custom Network RTK – RTK needs to provide a fixed solution. The standard deviations should be at the cm level. If RTK does not work, change the mount point on the NTRIP login, and confirm that the drone is in a clear open sky location
- D-RTK2 Base Station – In mode 5 and connected to the D-RTK2 base station
- Engage maintain positioning accuracy mode. If RTK signal is lost during flight, the drone will hover until the RTK returns to a fixed status. The data will be

separated as 2 LAS files, however these can be merged into a single LAS file in the data processing
- Complete one final check – upload flight mission to begin the survey

Collecting the Data

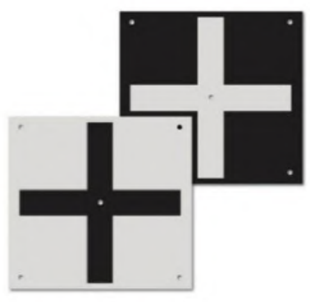
As the drone is collecting the data, you can view the drones flight with either the RGB camera, or the LiDAR scanner. The image below shows the drone collecting the LiDAR data. If you are not able to view the drone collecting the point cloud information, the drone is not capturing the LiDAR data. In this instance, bring the drone back in to land, and hard reset the drone turning it off and on. If you are uncertain whether you have correctly captured the data, try removing the SD card and inserting it into your PC to see whether the LiDAR files are present.

Establishing the Checkpoints

For LiDAR datasets, ground control points, also known as GCP's, can be used as a form of Quality assessment. Technically they operate as checkpoints as they are used to verify the accuracy of a survey. GCPs are used in the aerotriangulation process to help tie the survey data to OSGB36, and improve the accuracy of the model, whereas checkpoints are used to verify the accuracy of the reconstruction. This course does not cover the essentials of photogrammetry. The Zenmuse P1 (*course content released soon)* course covers the necessary knowledge needed to mark the ground points in DJI Terra.

The first step is to ensure that the GCP's are spaced evenly across the survey area. Considering that they are only checkpoints, and not used in the reconstruction process, there is no limit to the number of checkpoints required on site. Just confirm there are enough ground control points in place to suitably assess the average absolute height error for the entire area.

They need to be clearly visible across from above, so they can be spotted in the RGB point cloud when opened in Terrasolid, The GCPs used in this survey were the RSL512 Ground Control targets (*available for purchase through Heliguy).*



For areas of hard ground, spray paint can be used to establish the ground control. Alternatively if there are any noticeable features (corner of a manhole cover), these can also be marked with the GNSS receiver. However this is not recommended practice, particularly if the features are in a busy, pedestrianised area.

The points used in this course were marked with an Emlid GNSS receiver. There are other GNSS solutions available from manufacturers such as Leica or Trimble. For redundancy, 6 measurements were collected from each control point across the site. The receiver was recording data for 15 seconds at a time on each checkpoint. Static GNSS receivers can also be used to establish known points in the survey, and further improve the accuracy. Alternatively, points can established as a part of a control network by completing a traverse with a Total station. For this survey, the control points were collected in OSGB36/ British national grid, however the measurements could also be taken in ETRS89, and then converted to a specific reference frame in the post processing.

Emlid RS2 Base Station

Potential Sources of Error – Solutions to problems when capturing the data

It's important to be prepared for any errors that could go wrong when working out on site.

If the drone is low on charge part way through the mission, the batteries can be hot swapped, meaning that the batteries can be changed with the drone still turned on (*video available in M300 handover course)*. It's important that the drone is turned on when changing the batteries so it resumes the flight mission from where the survey was stopped. When it comes to post-processing the data it will be stored as 2 separate LAS files, however the raw data can be imported into the same folder and processed in DJI Terra to have it processed as a single LAS file. It's important the batteries are removed and replaced one at a time to keep the drone powered on. The dual battery configuration is one of the enhanced safety features on the M300 that means one battery will successfully power the drone, even if the other one fails.

It's important to switch your M300 to manual flight mode by flicking the switch in the middle to atti mode, and then back to GPS if the weather conditions take a turn for the worse when out on site. Safely return the drone to the home point, and wait for the conditions to ease. The M300 should not be operated in wind speeds higher than 15 m/s. If it starts to rain when the survey mission is engaged, the drone should be returned to the home point. The L1 can still technically fly in rainy conditions, but the final dataset can be affected by the wet weather.

For weather conditions that are foggy or misty, the drone can still be flown, however the flying height will need to be reduced so VLOS is not lost on the drone. For instance, if the drone was meant to be flown at a 100m altitude, reduce the size of the survey area, and change the flying height to 50m. If the drone is not visible during flight, return to the home point to wait for the conditions to ease.

The L1 can also be used for night time flights. If flying the drone at night ensure that the beacon lights on the drone are visible. The outputs from the drone will only be presented in terms of reflectivity, height and return, so RGB colouring does not need to be enabled.

Lastly this section covers what to do if RTK connection drops on the drone. Data quality can be sustained, even if the RTK connection drops on the drone. Enable "maintain positioning accuracy mode" on the smart controller so you do not lose RTK connection when flying. On older versions of firmware, the drone would have paused the flight, and hovered at a safe altitude until the RTK returned to a fixed status. Now the drone will fly with decreasing positional accuracy for an extra 10 minutes, before losing RTK connection.

2.5 - PROCESSING IN DJI TERRA

Latest Firmware Update (26/01/2022) :

As of 26/01/2022 DJI Terra recently brought out a new firmware update for DJI Terra. V3.3.0 has released a series of updates to the systems processing power and interface. Further information on this content can be accessed using the link below:

https://terra-1-g.djicdn.com/851d20f7b9f64838a34cd02351370894/DJI%20Terra/Release%20Note/DJI%20Terra%20Release%20Note%20V3.0.0.pdf

All of the DJI Terra post processing material that follows is still applicable to the latest version of DJI Terra. Course material for new firmware will be updated in due course.

Section 2.5 introduces the first data processing module of the course using DJI Terra software. By the end of this session you should:

- Understand how to generate a raw 3D Point Cloud in DJI Terra
- Understand how to generate a 2D orthophoto from your raw photos
- Become familiar with the raw files captured by the L1 sensor
- Understand what file outputs have been generated from your point cloud processing
- Be able to navigate between the different views in DJI Terra and understand what they mean
- Be able to perform basic measurements and calculations in DJI Terra
- Become familiar with the outputs in the quality report
- Understand the possible causes of error with the L1 sensor

DJI Terra Introduction

DJI Terra was developed as an easy-to-use mapping software to helps users map, visualize and capture drone data. It has applications in a variety of industries including construction, agriculture and energy. DJI Terra offers 4 post processing workflows- 2d map, 2d multispectral map, 3d reconstruction, and Lidar point cloud processing. In this course, the LiDAR point cloud processing will be used for processing the raw LiDAR data, and the 2D map is used to show how a 2D orthophoto can be created.

This first section looks at installing DJI Terra onto your PC. There are 4 main packages available when you purchase DJI Terra. These are Cluster, Pro, Agriculture and Electricity. For surveying and mapping applications DJI Terra Pro is the recommended version. This version incorporates an optimise point cloud accuracy function which is useful for processing datasets that require the survey grade accuracy. This course used a DJI Terra Pro licence to process the survey data.

DJI TERRA

In your Zenmuse L1 box, you will receive a complimentary 6 month Terra Pro licence with the purchase. A detailed list of the parameters and differences between each software package can be found on the DJI website from this link here:
DJI Terra
The key differences between the different systems are shown in the bullet points below:

- DJI Terra Agriculture – Online – Basic Terra version - No 3d reconstruction or 2D Urban mapping
- DJI Terra Pro – Online + Offline – Mapping solution
- DJI Terra Electricity – Online - Mapping solution + Electricity application and detailed inspection

- DJI Terra Cluster – Offline - Multiple computers conduct computations simultaneously

After your 6 month free trial, the DJI Terra Pro licence can be purchased as an annual licence from Heliguy for £990.00. To purchase this item as a perpetual licence it would cost £3430.00 for one device. It is very important to remember that once the code has been activated on the PC, the licence cannot be un-binded. Ensure the licence is activated on the same PC that you wish to carry out the processing on.

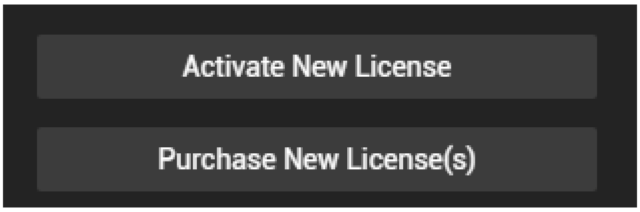
For L1 data processing you need to ensure your computer is equipped with the NVIDIA graphics card and at least 4 GB of VRAM. The CPU must incorporate at the very least an intel core I5 processor and have sufficient storage. For every 1GB of raw point cloud data files ,your PC will require 4GB of memory. Refer to the diagram below for a detailed overview of the RAM required.

Graphic Card	RAM	Max size of raw point cloud
GeForce GTX 1050Ti with 4GB of VRAM	16GB	4GB
	32GB	8GB
	64GB	16GB
	128GB	32GB

Installing Terra onto the PC

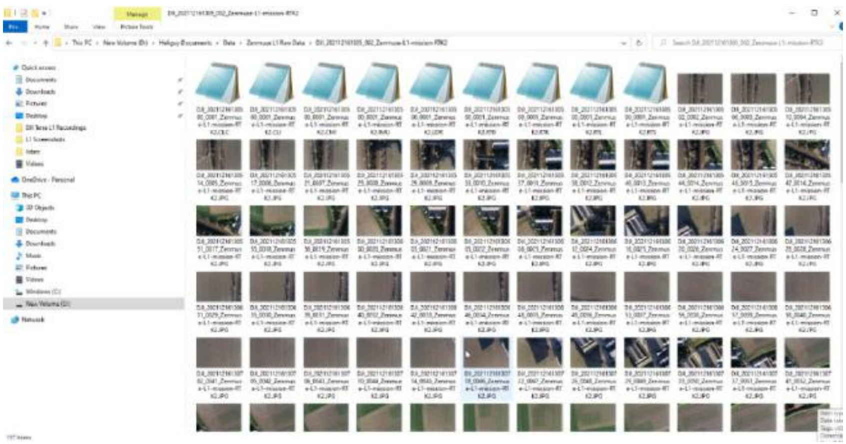
To activate the DJI Terra online licence, download the latest version of DJI Terra from the DJI website. The list providing all of the Terra versions can be found under downloads from the link. Upon loading the DJI Terra application you should be prompted to fill in your DJI account details.

To activate the Terra Pro licence onto the PC, go to the profile icon at the top right of the screen, and click on Activated Licences - Activate New Licence. This will send you to a web browser where you are required to fill in the activation code provided as a 6 month free trial in the L1 box. Once successfully activated it will show the ID, expiry time and binding status of the activated licence. Click device binding and then press bind to bind the licence to the current computer used. Once completed it should say “bound” next to the licence of the corresponding ID under activated licenses.



Processing the 2D Orthophotos

The SD card on the L1 will automatically store the photos captured from the L1 in the same folder as the LiDAR output. In DJI Terra go to new mission, and then select “2D map” under where it says reconstruction mission. Under “add folder”, add the folder that contains the raw jpeg images, and positional data from the drone. The LiDAR and calibration files will also be in this folder. *Latest version of DJI Terra means users need to select visible light – 2d model to process a 2d orthomosaic.*



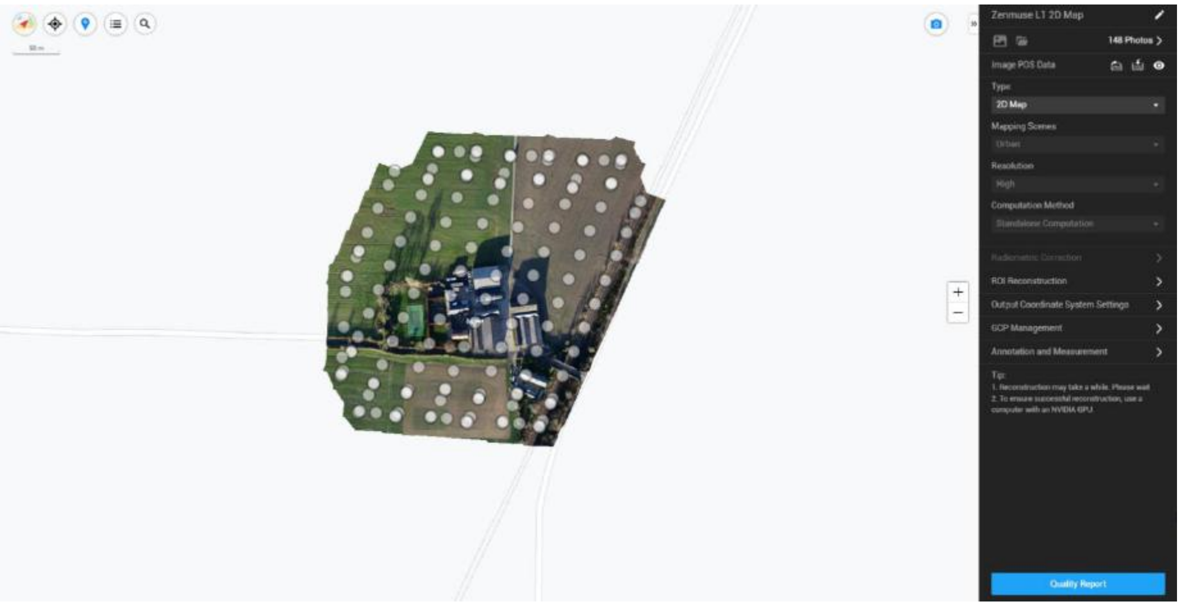
The mapping scene should be set to urban, especially if there is an even distribution of rural and urban features in the survey area. Most applications use an urban mapping scene. DJI Terra also provides fruit tree mapping scenes, and rural mapping scenes, however these scenarios are most best suited for agricultural applications. Users can plan operations for field or fruit trees when using one of these scenarios.

The resolution can be left on high to produce the highest quality orthophoto:

- High Resolution = Original resolution of captured photos
- Medium Resolution = 1/2 of the original resolution
- Low Resolution = 1/3 of the original resolution

For the output coordinate system select WGS-84 as a known coordinate system. It should have the authorization code EPSG4326. This will match the RTK position marked at the photo-centres of each individual photo. 2D orthophotos can also be processed relative to OSGB36, however this involves exporting the positional data and changing the EXIF data in a third party software. The Zenmuse P1 course soon to be launched on the Heliguy online portal will provide a step-by-step on how to process georeferenced orthophotos + 3D models with DJI Terra.

Start the reconstruction. When the reconstruction has finished it should produce a 2D orthophoto of the survey area. An orthomosaic is an aerial image of an area corrected for perspective, camera tilt, lens distortion and topographic relief. The corrected image has no distortion whatsoever and the scale is uniform across the orthophoto. This makes it possible to derive true distances as they would appear on the surface.



To assess the accuracy of the orthomosaic, prior to processing you would need to go to GCP management to generate an aerotriangulation report. For this course we are not going to assess the accuracy of the image output, however the Heliguy Zenmuse P1 course will cover all the content needed to process and fully understand the photogrammetric output.

Data Management

Section 2.7.3 looks at the raw L1 data that is stored on the micro SD card of the L1. All folders can be transferred from the micro SD card to a raw data folder on your PC. On closer inspection of the files, all of the photogrammetry and LiDAR data is stored in a single folder. If you had to hot swap your batteries halfway through the flight, the data will be split across 2 separate folders. Each of the individual photos in this file have a known corrected GNSS position at the photocentre of each image, and are saved as a jpeg file, so processing is fairly automatic.

As for the remaining files in the folder, there is a mix of information. In this folder you have stored a CLC, CLI, CMI, IMU, LIDAR, RTB, RTK, RTL and RTS file. The point cloud will fail to process the data if one of these folders is missing from the document.

- CLI - LiDAR camera calibration data
- CLC - LiDAR IMU calibration data
- CMI – Visual calibration data
- IMU – Inertial navigation data
- LiDAR – LiDAR point cloud raw data
- MNF – Visual data, however this has currently been omitted from the document with no impact
- RTB – RTK base station data
- RTK – Main antenna data for the RTK
- RTL – Rod arm data
- RTS – RTK sub antenna data

The calibration files can be opened and checked in a separate notepad document. The results from the remaining files cannot be read in the notepad, and the results can only be assessed once in DJI Terra.

LiDAR Point Cloud Processing – Overview of the parameters

This section goes over the recommended parameters for processing the LiDAR dataset. To start the process go to LiDAR point cloud processing and click new mission.

Once the project has been created and named, the raw data can be loaded into DJI Terra. Locate the folder where the L1 data is stored, and click add folder. For large survey areas that could not be covered by a single flight, the different folders can be merged into a single directory to generate one large LAS file. Alternatively, the separate point cloud documents in DJI Terra can be merged into a single LAS file using the Terrasolid software. The point cloud can be processed from this point here, however it's always worth looking over the parameters, and tailoring them towards your project.

Point cloud density refers to the number of coordinates collected per unit area. DJI Terra provides 3 levels of density- High, Medium and Low.

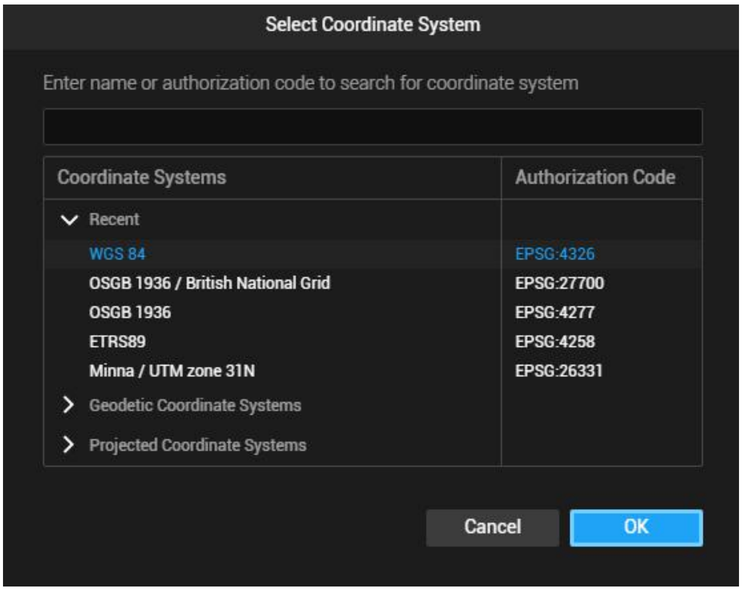
- High point cloud density – 100% data used
- Medium point cloud density – 25% data used
- Low point cloud density – 6.25% data used

A low reconstruction would generate an LAS file much quicker than a high reconstruction. If your computer is short on storage it may fail to generate a high density point cloud, whereas it may succeed on the low density.

In the output coordinate you specify the coordinate system for your project. This can be either an arbitrary coordinate system, or a known coordinate system. Arbitrary coordinate systems locate the point cloud in blank object space. This guarantees high relative accuracy, however the points are not georeferenced to a point on the earth's surface. When it comes to generating the 2D orthophoto, if the imported images do not include any GPS information, the output coordinate system will automatically be set to the arbitrary coordinate system.

As the data imported contains GPS information, DJI Terra should automatically set the output coordinate system to a known system. It provides a choice of either a geodetic or a projected coordinate system. Data can also be imported as a .prj file into DJI Terra. Usually, this would be downloaded from the website https://spatialreference.org.

Geodetic coordinate systems represent where the data is located on the earth's surface, whereas projected coordinate systems represent how to draw the 3D surface onto a flat 2D plane. The end goal of this project is to localise the data to OSGB36 British National Grid as a projected coordinate system. Initially the data needs to be processed in WGS-84, EPSG code EPSG:4326. This system is selected from the list of geodetic coordinate systems. The altitude settings can be left on default.



The point cloud effective distance can be left at the default 250m. This refers to the cloud points with a distance greater than the set value from the LiDAR emission centre, which is filtered out during post-processing. Setting this value too low will remove most points from the dataset. Secondly, the optimise point cloud accuracy tool can be used to optimise the adjustment of the point cloud data scanned at different times, which improves the overall accuracy of the dataset. For Surveying and Mapping applications it is recommended to enable the optimise point cloud accuracy tool, but for powerline reconstruction this function should be disabled. It is worth noting that processing time will be longer when this function is enabled.

The reconstruction output can be selected to the format you require. There are multiple format options available. The format used for display of 3D point clouds in DJI Terra is PNTS, and is selected by default. LAS is the industry-standard binary format for laser scan data. This can be paused if the reconstruction is draining too much memory from your computer, and resumed at a later time. Point cloud files can also be exported as:

- PLY
- PCD
- S3MB

Click start processing to start the point cloud reconstruction. The processing can be paused and resumed at a later time if the processing is draining too much CPU memory from your computer.

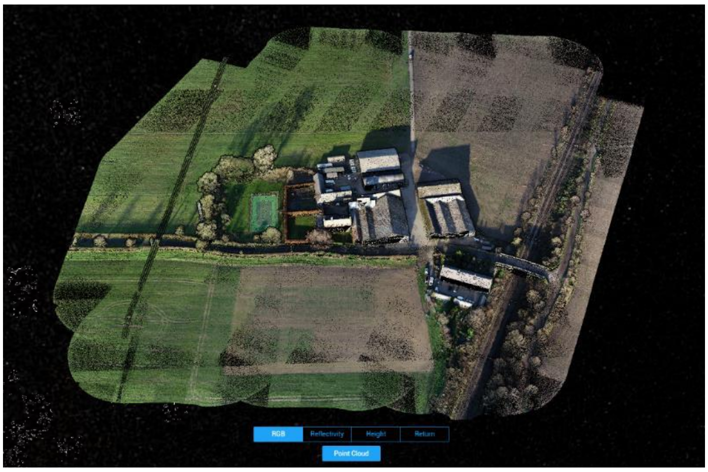
File Outputs

This section looks at the result files generated from DJI Terra. Once the data has been processed, the file will be named with a number, and not the project's title. This can be found in the same drive as your DJI Terra application, and should be under DJI Terra data. The files generated are the same ones that will be used later in this course in the Terrasolid module.

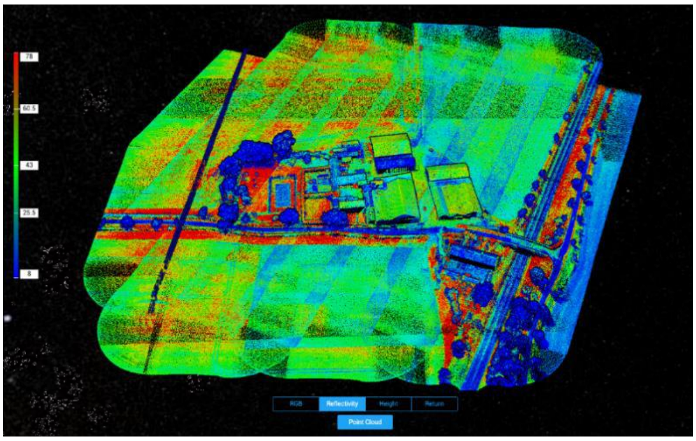
- LAS – industry standard format for LiDAR point cloud data. Data stored in a binary format. Records information such as RGB colour, reflectivity and echo that each 3D point belongs to.
- SBET.OUT - Post processed trajectory file. Encoded within this binary format is information regarding the GPS time, geodetic coordinates, altitude, xyz velocity, xyz acceleration, xyz angular rate as well as roll, pitch and platform heading.
- SMRMSG.OUT - post processed precision file containing the RMSE (root mean square error) for the drones position, velocity as well as roll, pitch and yaw.

Viewing the Point Cloud

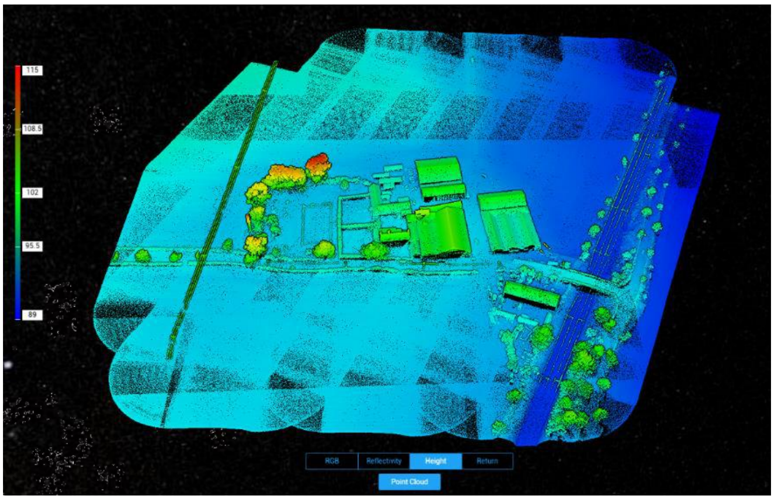
Once the reconstruction has finished, the point cloud automatically shows in the display. It can be viewed by either RGB, Reflectivity, Height or Return. RGB colour shows the point cloud in its true colour form, and enabling this feature before flight allows the drone to collect the photogrammetry data too.



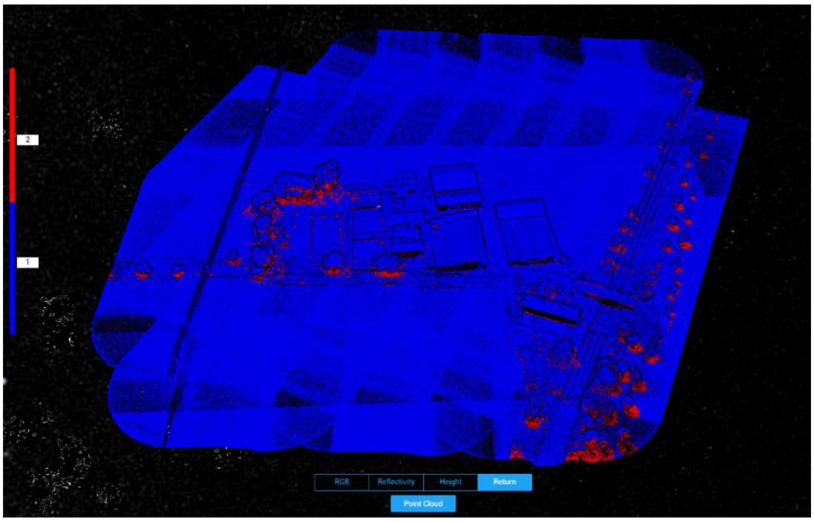
Reflectivity shows how the light emitted by the scanner interacts with the earth's surface. As outlined previously in the course workbook, there is both diffuse and spectral reflectivity. Lidar does not always lead to consistent results when viewed in terms of reflectivity, as the returned signal can be influenced by many factors such as the glossiness of the surface, the distance to the object, angle between the surface normal and the incident laser ray, and the moisture content on the surface. But this does not take it away from the fact that this view has important applications in feature detection, land cover classification and identification of wetland areas.



The point cloud can also be viewed by height. This shows how the elevation changes across the site, highlighting the high and low points of the dataset.



Finally, the point cloud can also be viewed by return, which displays the number of backscattered rays recorded by the L1 sensor. The screenshot below shows the sensor on dual return. If triple echo mode was selected, this would provide a green band also, highlighting the points that provided 3 returns. The areas highlighting dual return are mainly located around the sides of buildings, and in the areas of vegetation.



There are also some basic zoom and navigation tools to use in DJI Terra:

- 2D Overhead View
- 3D view
- FPV view – Using the control key can zoom into the point cloud, and move between 2D and 3D views

Navigate and perform basic measurements in DJI Terra

There are a variety of tools included in DJI Terra that can be used to pan, and take measurements from the point cloud. Using the left click of the mouse you can pan around the point cloud, and zoom in to areas of interest from an FPV view. Click and hold the left side of the mouse whilst pressing the control key to change the angle of the point cloud. Using this tool allows you to zoom right into the dataset. For those involved in forensics or accident investigation, this is a useful tool as the data can be quickly captured on site, and then processed and viewed back in the office.

DJI Terra also provides a variety of measurement tools. Under where it says annotation and measurement, there are four main tools for collecting measurements in DJI Terra. These are:

- Coordinate
- Distance
- Area

- Volume

The Coordinate tool can be used to verify the precise location of a point, with the point presented in terms of latitude, longitude and altitude in the WGS84 coordinate system. If you are not using Terrasolid in the next module, this could be used to check the accuracy of control, providing that a coordinate transformation has been computed for either the Terra-measurements or the control points.

The Distance tool can be used to measure the distance between two points. One left click places the first marker down, and the second click places the second marker to derive the distance. To save the measurement right click the mouse and press save. All saved measurements are stored on the right side of the screen. If you were wanting to measure each face of the building, 4 separate measurements could be taken, or if you wanted to calculate the total perimeter, the line tool could be drawn around the entire building before saving the measurement. The data can also be exported as an excel spreadsheet by going to manage, all, and then export.

The area tool calculates the total surface area from a section of the point cloud; the results can be presented either as the projected area of the fitted area. The projection area refers to the 2d measurement of a 3d object by projecting the shape to an arbitrary plane, whereas a fitted area refers to the actual measurement relative to the WGS84 coordinate system. The outputs can be exported the same as the distance or coordinate measurements.

Finally DJI Terra provides a volume tool, and is especially useful for stockpile calculations and deriving the cut/fill volumes. Once the points have been selected around the area of interest, the volume is presented in terms of cut and fill. This is calculated relative to either a base plane from the lowest point, or a base plane relative to the mean elevation of the points. Cut volumes refer to land that is above the base plane, whereas the fill volumes refer to land that is below the base plane. For earthwork applications, a cut volume would inform engineers that land needs to be excavated, whereas a fill volume would tell the engineers that land needs to be filled in or raised.

Quality Report

The processing output produces a Quality Report that provides a breakdown of the processing time for each component. The Quality Report does not assess the accuracy of the point cloud. To assess the accuracy of the dataset, the point cloud will be exported to Terrasolid in the next module.

The Input information overview shows the time spent loading the pose data and point cloud data into DJI Terra.

Also listed are the various file formats and the resolution of the processed point cloud.

Finally, the performance review outlines the processing time for each component. In the screenshot below, the largest amount of time was allocated to the LPP time, which refers to the time spent optimizing the accuracy of the point cloud.

DJI Terra Lidar Quality Report

Input Information Overview

Item	Value
Pose Data Collection Time	10.696 min
Point Cloud Collection Time	7.503 min
Lidar Block Count	1

Pose Status

Status	Total Time Duration
Good	10.696 min
Bad	0.000 min

Process Parameters

Process Parameters	Value
Resolution	High

Production

Production List
PNTS File
LAS File

Performance Overview

Item	Value
Pose Process Time	0.606 min
Georeference Time	0.652 min
LPP Time	4.857 min
Lidar Colorize Time	2.091 min
Save Result Time	3.590 min
Total Process Time	13.725 min

Error Messages

This section looks at some of the most common problems when using DJI Terra data, and how to fix the errors.

Error message - Reconstruction failed:

If the reconstruction fails to start, or fails after a certain point, this is usually to do with the amount of storage available on the PC. If there are many active projects open in the DJI Terra directory, this usually point towards a storage problem on the desktop. If Terra successfully processes low point density point clouds, but not high density datasets, this confirms there is a storage problem. Navigate to the DJI Terra directory and locate the folders where all your projects are saved. They should be listed by numbers increasing from 1. Delete all the projects that are no longer required. This will only send them to the recycle bin, so ensure these folders are permanently deleted from the recycle bin to allow the Lidar reconstruction to complete successfully.

Error message - The Lidar point cloud POS data is abnormal:

This error message indicates the RTK connection was disconnected during flight or there was no RTK base station data available. Alternatively this error can show if there is an RTK connection, but the drone remains stationary and is stuck in a static hovering position. If you receive this error you should try the PPK workflow. Failing this the data can be recollected.

Error message - the raw data of the Lidar point cloud is abnormal:

The collection time of the LDR file (laser point cloud file) does not correspond to the collection time of other files. This is most likely caused from the files being copied incorrectly. Ensure that the correct files are in the correct directory, and the collection times align. If you used the PPK workflow, ensure the times covered from the base station data match the times you completed your survey. If this fails you will have to recollect your data.

Error message - the raw data is missing or the file path is wrong:

This error will indicate that the RTK base station data is missing or the RTK network turned off during flight. Alternatively, if the file suffix is wrong, or the RTK files are saved in the wrong format, this could cause this error message. If you receive this message, you should try downloading third party GNSS data from the ordnance survey website, and use the PPK workflow. If this still fails to work, the data will need to be recollected.

Error message - LiDAR point cloud accuracy optimization failed:

For this error, the easiest solution is to disable the optimise point cloud accuracy function. If the optimise point cloud accuracy function needs to be enabled, the drone data should be recollected. In preparation for the next drone flight, check the flight parameter settings. Check that the altitude is not too high, the speed of the drone is not too fast and that there is some degree of overlap between the flight lines.

Error message - LiDAR point cloud POS calculation failed:

This indicates that the contents of some files are incorrect or missing in the directory. It could also highlight that the timestamps in the IMU and RTK files do not overlap. The best solution for this error message is to recollect the data. If the PPK workflow was used, ensure that the existing RTB file has been removed from the directory, and replaced with the OBS file.

Error message - Quality of the point cloud model is poor or the result has severe data loss:

Receiving this notification can point towards a variety of things. Firstly, if the survey mission had begun before the IMU had completely warmed up, this could introduce a weak accuracy into the results. Secondly, a poor positional accuracy indicates an error with the RTK. This could be down to the NTRIP connection, providing a float solution rather than a fixed one, or it could be that the D-RTK2 was accidentally moved during the survey as it was collecting the RINEX data. The best solution for this error message is to recollect the data. For the PPK workflow from a third party source, ensure that the GNSS baseline is 10km or less.

2.6 - PROCESSING IN TERRASOLID

Session 2.6 introduces the key information needed to classify and clean your point cloud in Terrasolid. By the end of this session you should:

- Understand how to export the raw Lidar data from DJI Terra into Terrasolid
- Understand how to convert the point cloud data to the OSGB36/ British National Grid coordinate system.
- Be able to use the Terrasolid processing wizard to classify and clean the L1 dataset
- Use TerraModeler to create a Digital Terrain Model and check the classification of the ground layer
- Understand how to verify the accuracy using the Ground control points

Installation of the Terrasolid UAV Bundle

The first step requires installation of the Terrasolid UAV bundle onto your PC. Ensure that the PC is the same PC that was used to previously install the DJI Terra software. Terrasolid will automatically recognise the activated licence on this account and as such data classification can begin straight away. However before processing, the correct package needs to be downloaded, and assigned to the same drive as DJI Terra.

Terrasolid provides 2 UAV bundles on the Terrasolid website. For those who have an existing Bentley account, the Bentley Terrasolid package can be downloaded from the Terrasolid website. Ensure that the Bentley platform is already installed on the PC prior to installing the software.

Download Terrasolid UAV bundle with Spatix platform

Bentley

Terrasolid UAV Bundle evaluation download for Bentley platform users

For users who don't have a Bentley licence, the Spatix platform can be downloaded free of charge. This licence is free until December 31st 2022. Spatix is a small 3D CAD system developed by GISware Integro, and provides the same functionality for those users who do not have an existing Microstation account. To access the complete range of Terrasolid tools a Microstation licence will be required, however users will be able to accurately process and classify the Zenmuse L1 data using the Spatix version. Spatix software was used to process the data for this course.

Starting the Terrasolid Drone Project

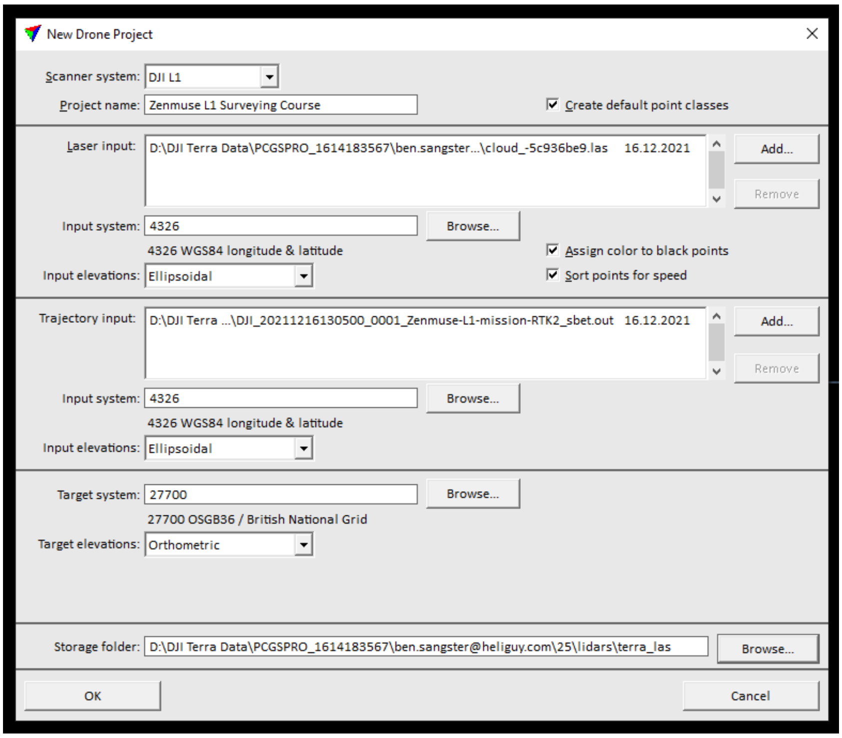
Section 2.8.2 sources the raw processed LAS file from DJI Terra and uploads it into a Terrasolid. In this section a coordinate transformation is used to convert from WGS84 to OSGB36/ British National Grid.

If the Terrascan window has not loaded automatically, it can be loaded by going to Views – Application- Terrascan – View Window.

The Wizard on the Terrascan window is the main interface used for classifying and cleaning the L1 data. Click start new drone project to begin the Terrasolid processing. Firstly, the scanner system needs to be specified as the DJI Zenmuse L1, and the drone project needs to be named. In the laser input box goes the LAS file that was processed using DJI Terra. The software should automatically recognise the coordinate system, but if not this needs to specified as 4326 WGS84 latitude and longitude. The input elevations need to be selected as ellipsoidal. In trajectory input put in the sbet.out file that contains trajectory information for the drone.

The target system specifies the projection system for the survey. In the target system select OSGB36/ British National Grid as the desired system, and the target system should automatically set itself to orthometric height. Most surveyors and engineers in the UK work with orthometric height relative to Ordnance Datum Newlyn (ODN). The elevation corrections are drawn from an OSTN15 text file located in your Terra directory, so the LAS file generated is fully georeferenced to OSGB36/ Ordnance Datum Newlyn. Further reference frames and geoid models are available for those users that working to OSGB36.

Click OK and the software automatically reads the point cloud in, transforms the coordinates, assigns colour to black points and imports the trajectory information. More than one LAS file can be loaded into a single project by rerunning the “Start new drone project” tool to load more LAS files. Providing the trajectory file is correct, the point clouds should align automatically.

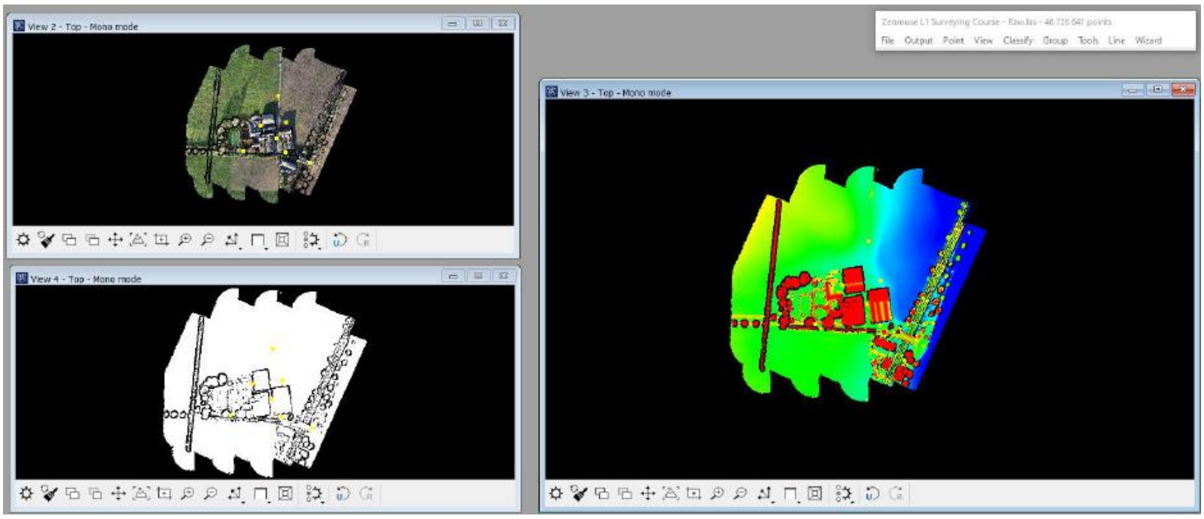


LAS files loaded into Spatix should be saved as a raw point cloud file so new drone projects don't have to be created at the start of each Terrasolid document. Click on file - save points as – LAS file version 1.4. To import this file into the display go to read points - read points as.

Navigating Terrasolid

This section aims to help you gain an understanding of the Terrasolid software, and provide an overview of the basic tools that can be used to classify and display your point cloud data.

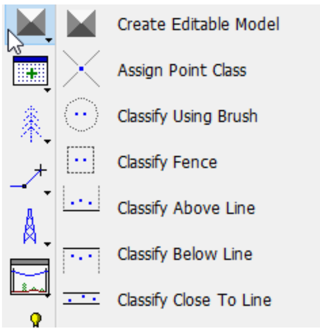
Terrascan is the application for managing and processing your point cloud. Under view, there is the display mode icon which can be used to change the display of the point cloud. This can be used to display the point cloud either by RGB colour, point class or elevation.



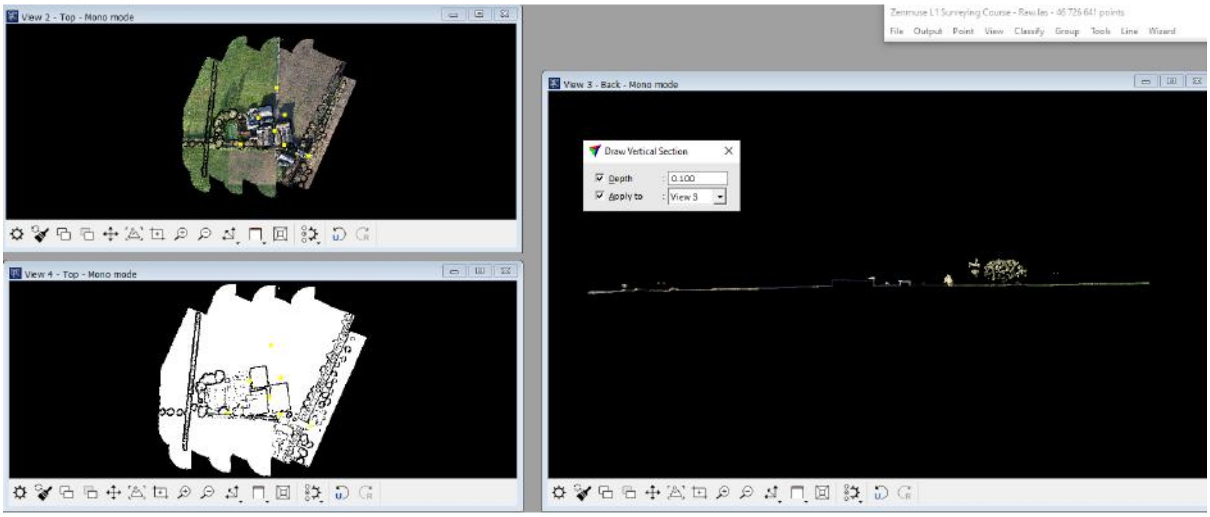
Certain classes can also be turned off and allocated to particular views. For example once the ground layer has been established, all other classes in the dataset can be turned off so all that is seen is the classified ground data. The processing wizard was used previously to create the new drone project, however it's also used for automating the data classification. The view statistics tool can be used to provide a breakdown of the classified points.

Terrasolid also provides means for manual classification. Points can be manually classified in a variety of ways:

- Assign Point Class
- Classify Using Brush
- Classify Fence
- Classify Above Line
- Classify Below Line
- Classify Close to Line



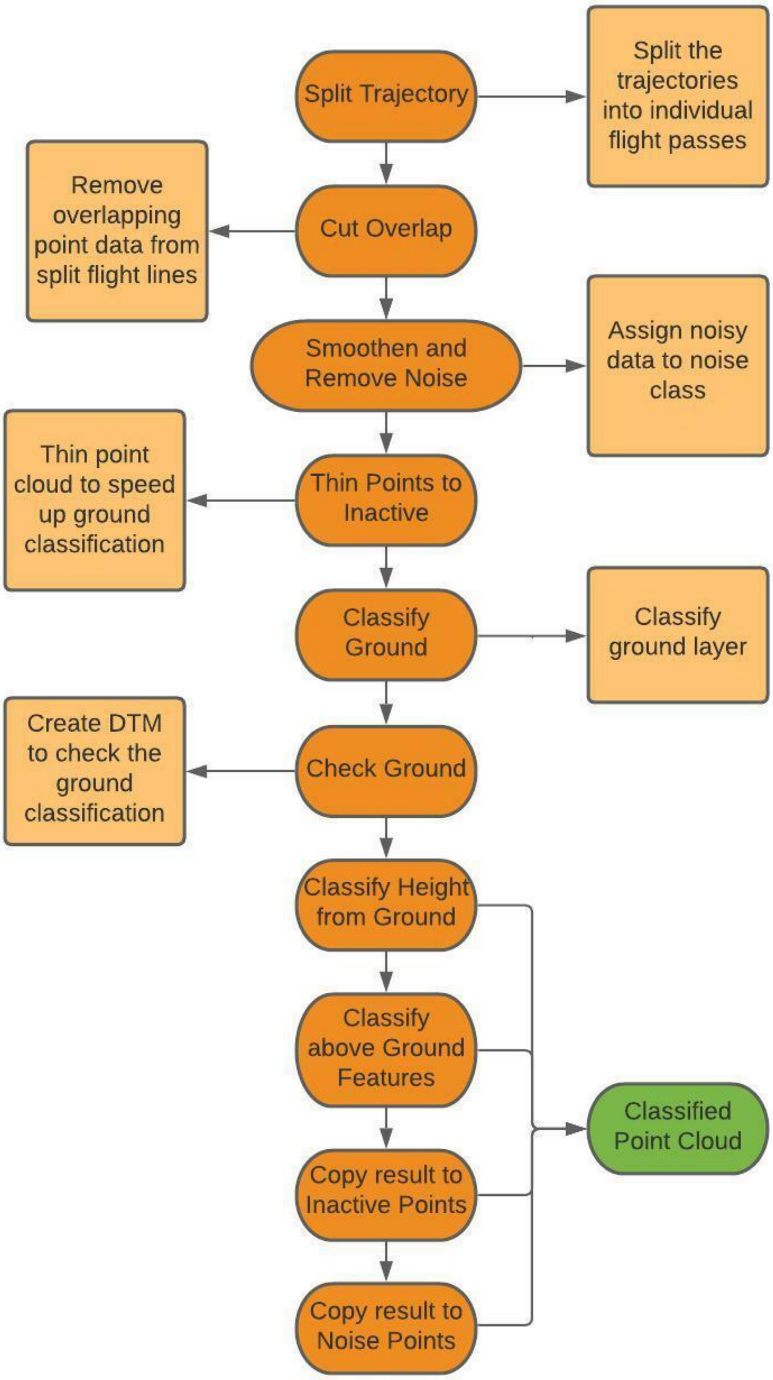
Probably the most important tool throughout this module is the Vertical Cross Section. To choose the correct tool, simply click and hold on one of the icons on the left, and move the mouse down to select the utensil required. The Vertical Cross section is useful for verifying the distance between the highest and lowest point of the point cloud, or viewing how well the L1 has penetrated the vegetation canopy.



To introduce new views into the display, click new view (mono), followed by window tile.There are many more tools that can be used with the Terrasolid UAV bundle. The outcome of this course only aims to provide the fully classified point cloud georeferenced to OSGB36. Further information on Terrasolid workflows can be found online, or from the Heliguy team.

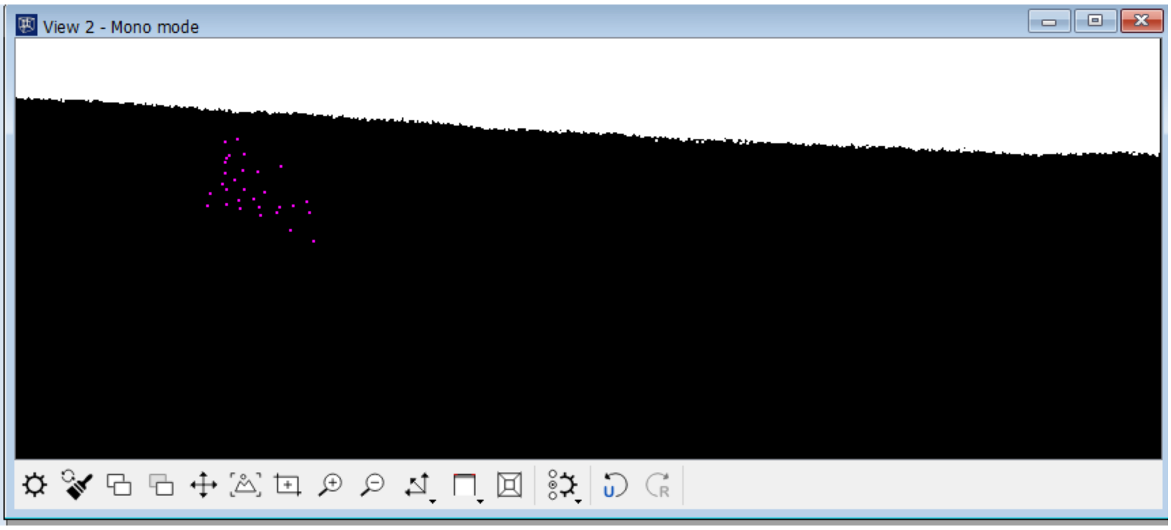
Geoprocessing Wizard

The Terrasolid wizard is used for classifying and cleaning the point data. At the end of this section you should have a fully classified point cloud, removed of noise, that can be exported as a DTM surface, or as an LAS file.


Split Trajectory
Split the trajectories into individual flight passes
Cut Overlap
Remove overlapping point data from split flight lines
Smoothen and Remove Noise
Assign noisy data to noise class
Thin Points to Inactive
Thin point cloud to speed up ground classification
Classify Ground
Classify ground layer
Check Ground
Create DTM to check the ground classification
Classify Height from Ground
Classify above Ground Features
Copy result to Inactive Points
Copy result to Noise Points
Classified Point Cloud

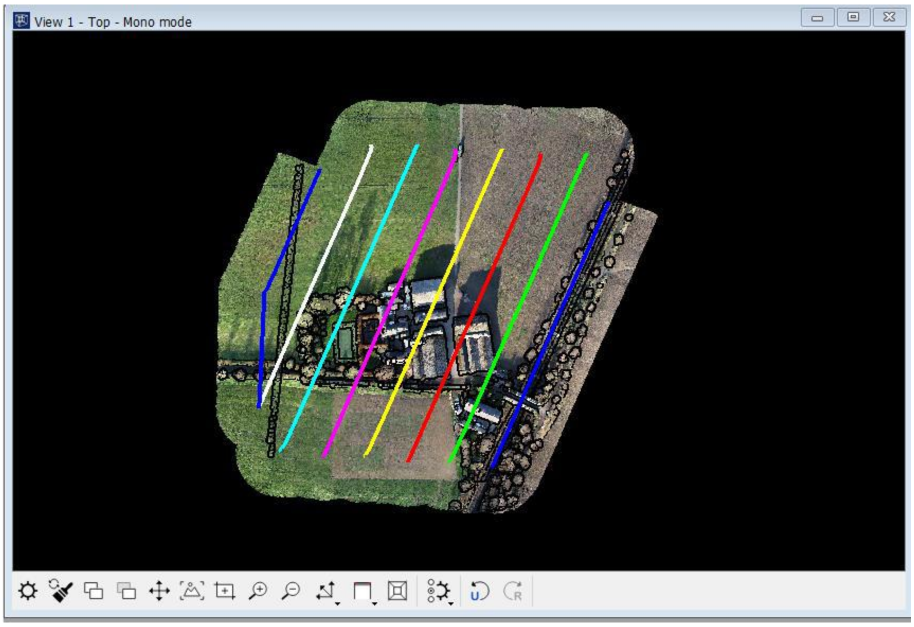
Check the Quality of the Dataset

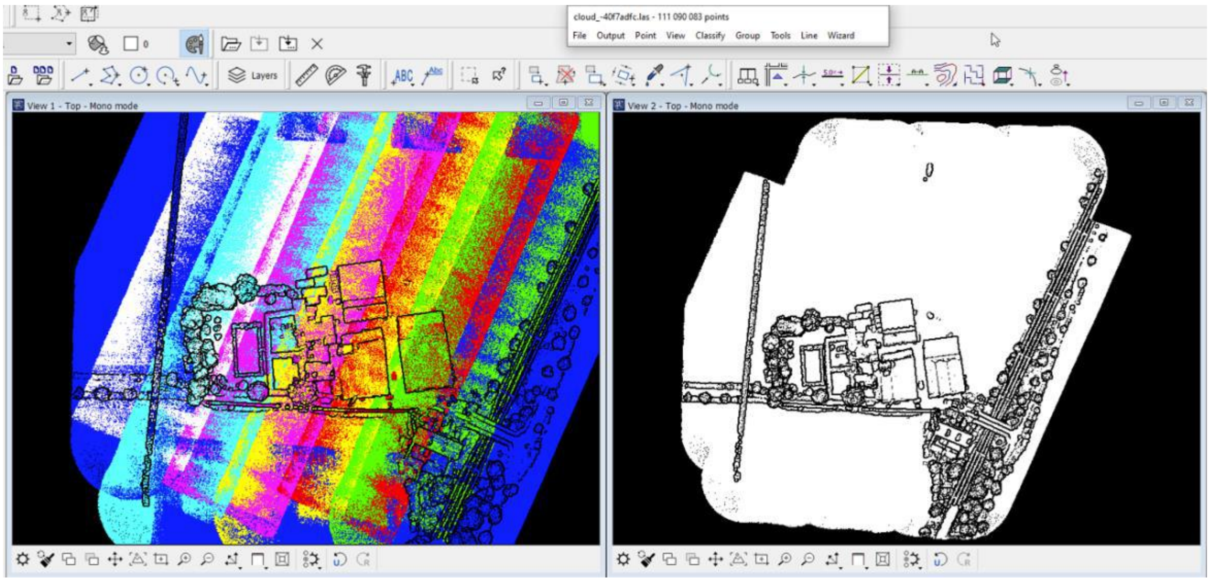
Before we utilise the wizard to classify the dataset, it is good practice to manually remove noise from the point cloud using the vertical cross section tool. Draw a vertical cross section around the entire dataset, and assign it to view 2. If there are any anomalies in the dataset, they will be significantly above or below the vast majority of the points. The dataset shows a few low points that do not align with the elevations in the rest of the dataset. These can be manually classified as low points. Go to classify below line and classify these as low points. To completely omit these points from the LAS file go to Point – Delete – By Point Class. Select low point to remove the points you just classified.



Split Trajectories

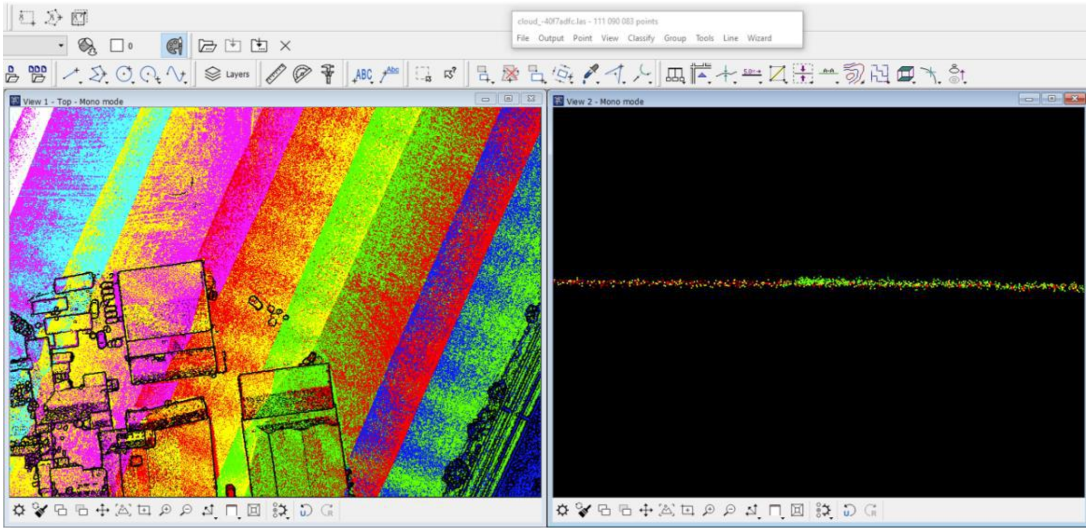
The first part of the processing procedure involves splitting the trajectories into the individual passes over the survey area. In the processing wizard, turn off all of the other processing steps apart from the split trajectories function. The settings can be left as default. Press OK, and the processing should complete relatively quickly, as the software is pulling the trajectories information from the sbet.out file imported at the start of the drone project. Next go to Manage Trajectories – Tools - Draw into design. Before doing this, increase the strength of the line to 4, to make the flight lines more visible. Close the design file, and display the flight lines by going to View - Display Mode, and changing the view to line. As you can see, a colour has been assigned to each flight pass. At this stage there is a lot of overlap between the flight passes. The vertical cross section tool can also be used to verify there are no mismatches between the flight lines. Some passes may exhibit more point to point noise than others.

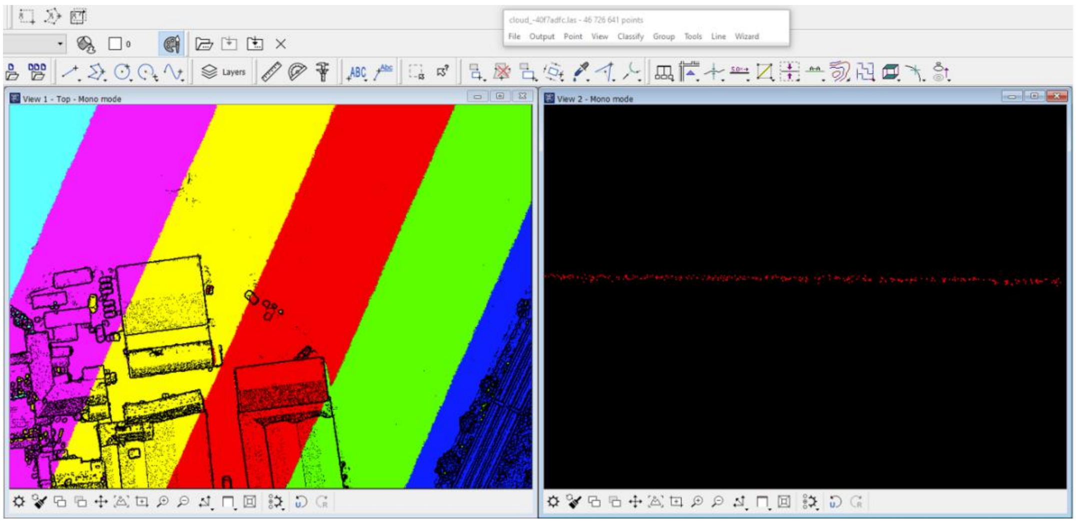




Cut Overlap

The next step of the processing wizard uses the cut overlap tool. This keeps only one flight pass at each location, removes the edges of the scan corridor, and removes some of the noise from the dataset. As can be seen in the vertical cross section view, the software only keeps the better matching data making the point cloud look a whole lot cleaner. If there are any minor height mismatches in the data, using the cut overlap tool can help correct the elevation differences between flight lines. The dataset is now a whole lot more accurate and cleaner than before. To understand how many points have been removed from the dataset, the total number of points can be seen at the top of the Terrascan window.

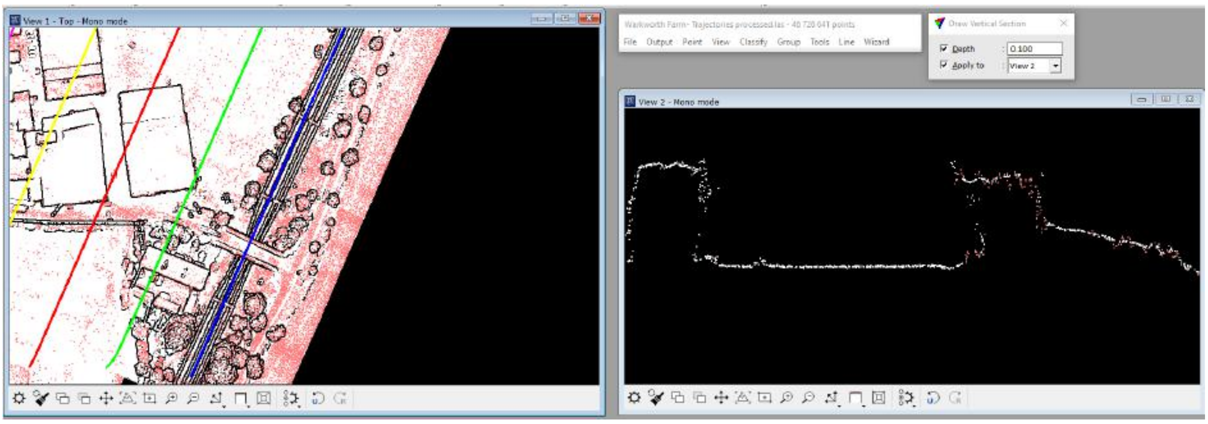




Smoothen and Remove Noise

Step 3 smoothens and removes noise from the dataset. The parameters can be left as default for this step. If you go on settings, you can see that the non-vegetation only feature has been enabled. The software ignores all the points that are green in RGB colour, and classifies only the hard detail features. Any points that are green are classed as vegetation, and not used when classifying the noise data. If this feature was disabled, the software could wrongfully classify stray points as noise, whereas in actual fact they're part of the tree canopy. Click OK and the software will automatically determine which points can be classed as noise. These points can be completely omitted from the dataset by going to Point – Delete – Delete by Point Class – Noise.

To verify the points that have been classified as noise, change the display mode to Class in the view window. Draw a vertical cross section around the areas of noise to clearly view what areas have been classified.



Thin Points to Inactive and Classify Ground

Classifying the ground layer is an essential step for later creating the DTM. Thinning the dataset is an optional step that assigns thin points to an inactive class. It speeds up the ground classification and tells the software to use only a subset of active points in the ground classification. It can be disabled, however this will just increase the processing time. The settings can be left as default for assigning the thin points.

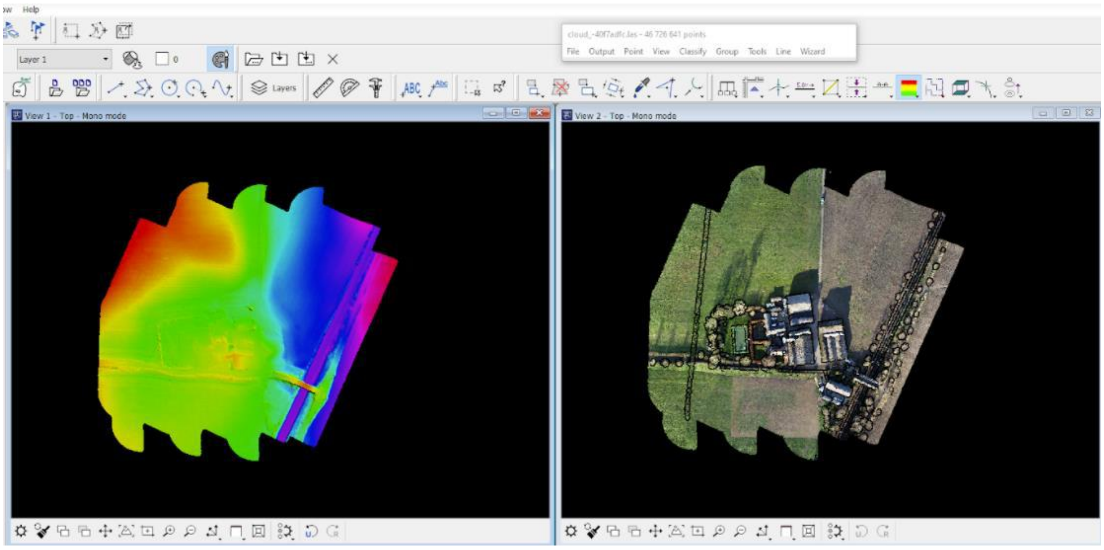
For classifying the ground, this should be changed to a 40m spacing. Press OK to start the ground classification. Once this has processed, go to view statistics to see how many points have been sent to the inactive class.

Check Ground – Creating the DTM for manual classification

The Check Ground step uses Terramodeler to create a triangulated surface model, and evaluate how well the software has classified the ground layer. If any areas of the site look peculiar, these can be amended by using the manual classification tools. The first step is to create the surface model:

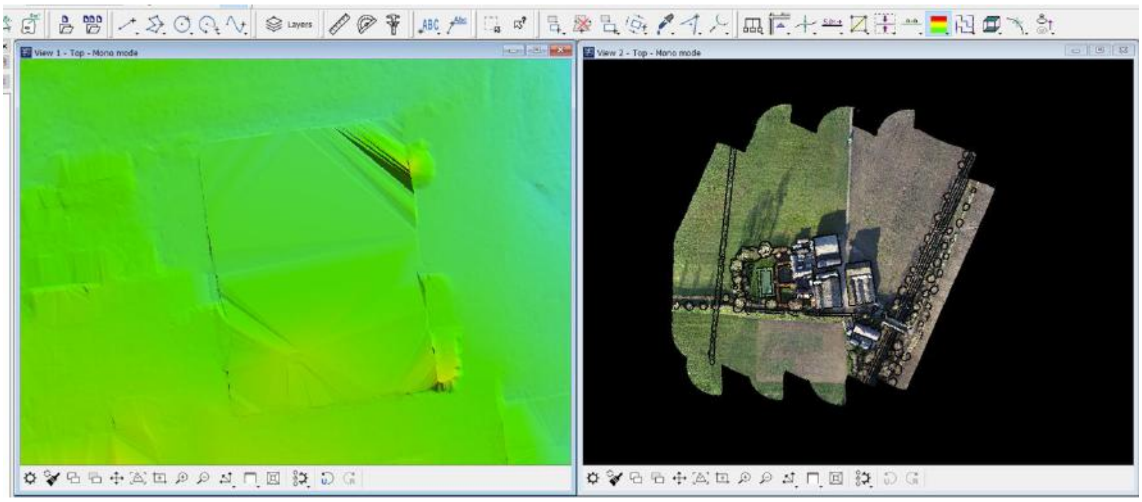
To create the surface model click the icon that says Create Editable model. Make sure the model is only using the ground class. From here go to Applications - Terra Modeler - Display Shaded Surface. The settings can be left as default, and assigned to a view window to display the model. If the surface model does not show right away, you may need to change the display mode in the view. Go to view by class, and deselect all of the active classes to display the DTM. If the model still doesn't show, return to the display window, and click Fit to see if the DTM fits to view.

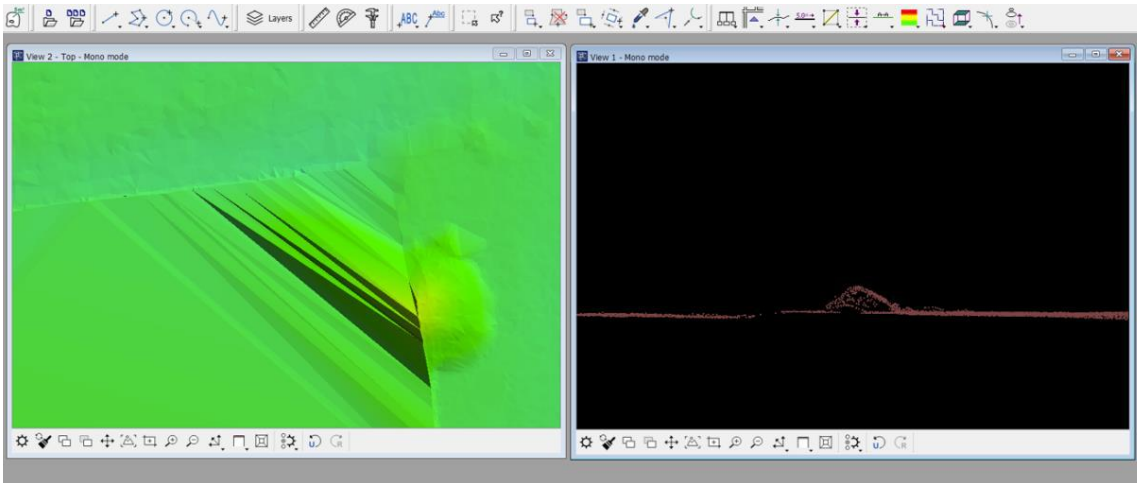
The DTM is used to check the ground layer, and establish whether the ground classification has completed accurately. You are now doing the "Check Ground" step in the Geoprocessing Wizard.

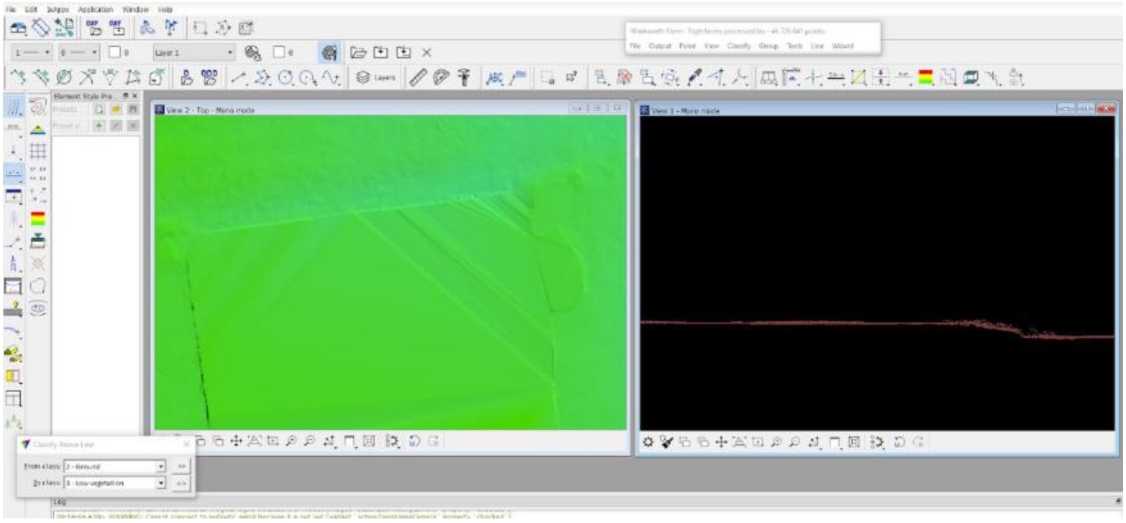


Firstly, open an RGB point cloud in a separate view so you can see what you are looking at on the shaded surface. It's also recommended to synchronise the view windows 1 and 2 so you are viewing the same location. Scan over the DTM to see if there are any areas that look a little peculiar, and re-classify these areas using the manual classification tools. Draw a vertical cross section around these features with a depth of 0.100m, and assign the cross section to a new view. Go to the display mode, and change the view to Class, deselecting all of the classes apart from the ground.

The screenshots below are used as an example to show you what you should be looking for. The TIN surface model does not quite match in the top right hand corner of the image, and clearly indicates the classification has incorrectly included some of the building in the ground classification. Using the above line classification tool, this area will be converted from the ground class, to the roof structure class. The DTM now shows that this has amended the surface model, and the ground classification is much more accurate. It is entirely up to you how long you want to check the ground using the DTM. However, as long as there are no significant gaps in the data, and the DTM looks relatively smooth, this data can be exported to other mapping software using a standardised file type.







To export this to another software such as ArcGIS Pro or QGIS, the TIN will need to be exported as an XYZ file. Go to Applications – Terramodeler – File – Export As – XYZ file to further utilise the surface model.

Classification of the Point Cloud

The final section of this module processes the last 4 steps of the wizard at the same time. These steps are:

- Classify height from ground
- Classify above ground features
- Copy result to inactive points
- Copy result to noise points

Classify height from ground classifies points which are within a given range compared to a reference surface. This tool classifies points into different vegetation classes in preparation for building classification, powerline processing or tree detection.

Classify above ground features classifies those points above the ground into separate point classes. This ensures most of the points in the dataset are assigned to a point class. In the settings for above ground features, confirm that the vegetation index is selected so the software can deduce the areas covered with vegetation. These areas will be treated differently to the hard detail point classes.

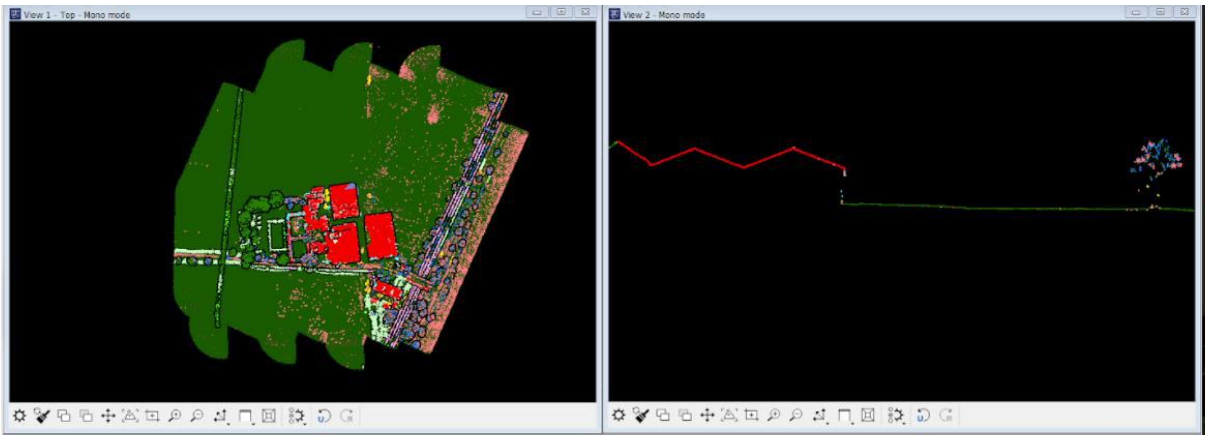
Copy result to inactive points restores the points which were omitted in the ground classification. The points which were assigned to an inactive class in the 'Thin Points to Inactive', are brought back into the point cloud and assigned to the correct point class.

Copy result to noise. Any noise in the dataset that has not been removed is provided a point class following the above ground classification.

Click OK to start the processing. Once the processing has finished, you need to check the classified above ground features to confirm that the points have been assigned to the correct point class. The TIN model is no longer required so this can be closed from the Terramodel surfaces window under Applications – Close Surface.

Firstly, check the ground layer, so in the existing view window display the ground as class. In a new view window draw a vertical cross section with a 0.100m depth. Using the image below as a example, this shows that all the points accurately represent the ground surface as no buildings or above ground features have been included in the classification.

Now you need to check the building classification, if there are any in your survey area. The image example of the vertical cross sections shows that the building roof has also been classified correctly. Finally, you should check the classification of the vegetation class, and soft detail features. The depth of the vertical cross section should be set to 1m so that the trees are more distinguishable. The image below also shows that the vegetation has been correctly identified by the software, as the points clearly form the shape of a tree.



If your survey area is dominated by a particular land feature, it is worth checking the point classification for that too. For instance, if your project took place in a car park, it would be worth checking the point classification of cars.

This concludes the use of the Geoprocessing wizard for cleaning and classifying your point cloud. As you can see the process is mostly automatic, and an effective way of classifying your point data. To complete this section, make sure the edits you have done are saved to a new LAS file before closing the document, and saved under the name “L1- classified”.

Validating the accuracy of the Point Cloud

Using the data you collected with the GNSS receiver in section 2.4, you are going to compare the accuracy of the point cloud to the true coordinates. Firstly ensure that the control points are stored in an XYZ format.

The example below used an EMLID Reach RS2, so the GCP positions were directly exported from the IPAD to the computer as a csv file. To view the survey data, I would recommend using Microsoft Excel, however a standard notepad document can also be used. The columns need to be arranged so they only show the Easting, Northing and Elevation values, in that order. It is very important that the order is not changed, and the rows are not edited in anyway. Each row represents a known position. All columns in the document that aren't Easting, Northing or Elevation can be removed. This is the standard XYZ file format, and even though this will be saved as a csv file, Terrasolid reads this data as positional data. Once the document has been saved, it is ready for upload to the spatix.

You will also need to save the file as a tab delimited text file. Open the text document once saved as a tab delimited file and reduce the spacing to 1 between the easting/ northing, and the northing/ elevation so it is readable in Terrasolid. Save the edited file.

L1 Surveying Course Checkpoints - tab.txt - Notepad

File Edit Format View Help

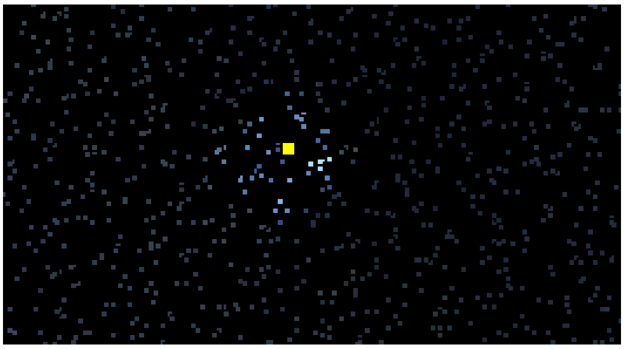
```
423582.814 607577.648 44.321
423601.237 607512.878 43.159
423578.697 607475.472 44.984
423600.445 607440.785 44.572
423496.381 607442.931 45.442
423539.056 607506.236 44.672
423660.203 607415.696 45.45
```

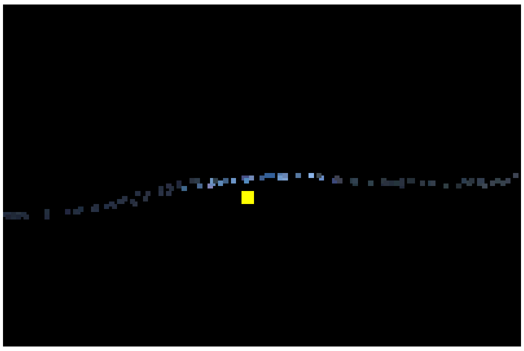
	A	B	C	D	E
1	423582.8	607577.6	44.321		
2	423601.2	607512.9	43.159		
3	423578.7	607475.5	44.984		
4	423600.4	607440.8	44.572		
5	423496.4	607442.9	45.442		
6	423539.1	607506.2	44.672		
7	423660.2	607415.7	45.45		
8					
9					
10					
11					
12					

Make sure the classified LAS file is closed, and there is no point cloud in the display. In the Terrascan window go to File, read points. Locate the text file you just saved, and open this into the main display. The control points should pop up straight away. You can change the appearance of the control points using one of the CAD features provided with Spatix. Change the colour of the markers to yellow, and the strength of the line to 5. Save this to a design file by going to Output – Write to Design File.

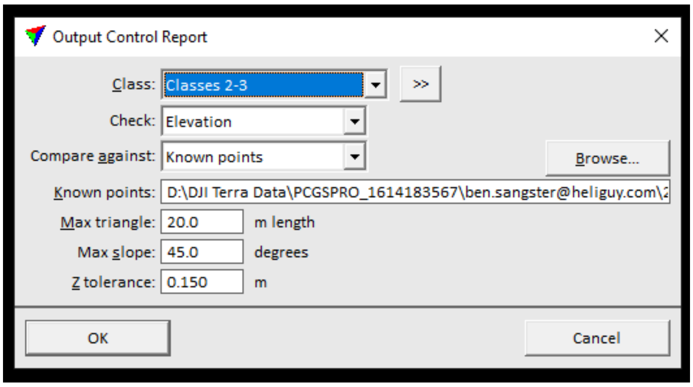
Confirm that the Colour by has been changed to Active Symbology. The points should automatically change colour when loaded into the software. The points can now be closed from the project by going to File – Close points.

Using the read points tool, bring the classified LAS file back into the document. You can now visually compare the planimetric accuracy of the point cloud to the true coordinates. Zooming into each of the checkpoints, confirm that they overlay the point cloud, as shown in the screenshot below. You can also visually compare the checkpoints relative to the point cloud in the vertical direction. Draw a vertical cross section around one of the control points to see how the elevations compare.

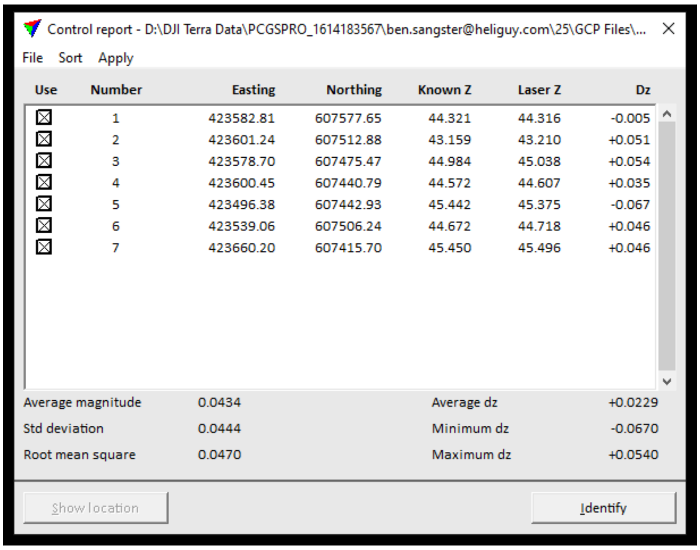




To quantitatively assess how well the coordinates compare in the vertical, you can use the output control report tool. In the Terrascan window go to Tools - Output control report. In the box that says class, ensure the ground control is compared to the ground class and the low vegetation class. The Check box should be changed to elevation as you are comparing the vertical coordinates. Load in the csv file you saved before in the box that says browse. Once all the settings look as they do in the screenshot below, click ok and the software should start calculating.



The errors calculated by Terrasolid are presented in terms of absolute error, so only the positive values of all the differences are used to establish the average error across the dataset. The image below shows that the average magnitude is 0.0434m, which confirms that the average absolute error is 43mm. The specs of the L1 sensor are accurate to 50mm so if your results are close to this value it confirms that your results are valid. If there is a systematic error across the dataset, you can automatically compute an elevation shift by going to Apply – Elevation shift.



Final Words

This completes section 2.8.5 of the course, and finalises your learning of the Zenmuse L1 Geospatial Workflow Course. The course content in the Zenmuse L1 workbook supplements the video material in the online portal, and is designed as a quick reference for any queries you may have. If you have any further questions on the content in this course please refer to the contact details illustrated at the start of the workbook.