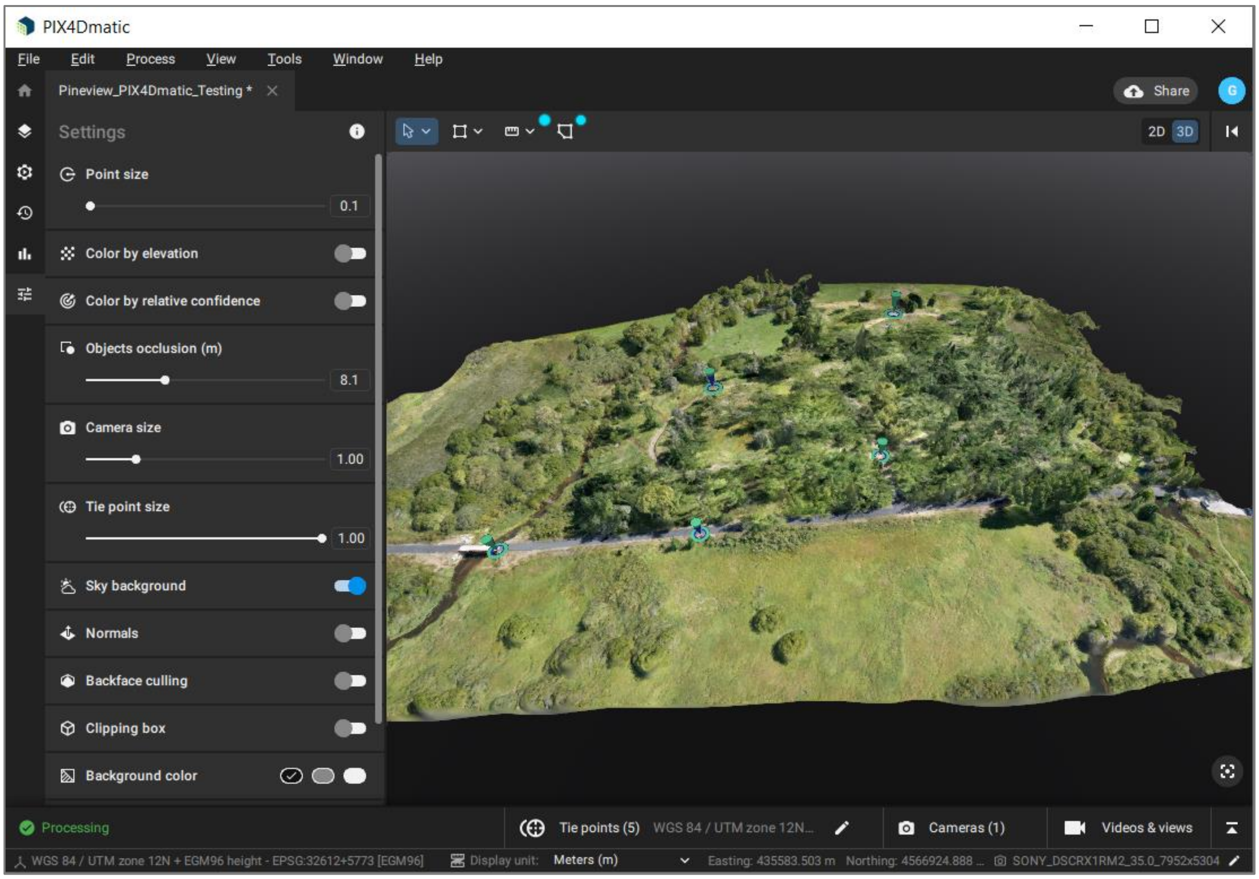
Processing UAS Imagery in PIX4Dmatic



Introduction

PIX4Dmatic is photogrammetry software designed to process unmanned aircraft system (UAS) imagery using Structure from Motion (SFM) to generate orthomosaics, 3D models, point clouds, and digital surface models. PIX4Dmatic is optimized for photogrammetric processing for large scale, corridor, and terrestrial projects. According to PIX4D, it is designed to handle and process more images and larger projects than its predecessor, PIX4DMapper.

This exercise will introduce you to the general workflow for processing UAS imagery in PIX4Dmatic. As you work through this exercise, please refer to the PIX4D Help Documentation for additional information about each of the steps. The help documentation can be found on the PIX4D website or by clicking the **Help** tab within the software interface.

The dataset used for this training was acquired on September 9, 2022, near Pineview Reservoir, Huntsville, UT. The mission was flown with Vision Aerial SwitchBlade, equipped with a 42 Megapixel Sony RX1r II camera. The imagery was acquired at a height of 90 m above ground level, with image overlap of 85% endlap (along the flight line) and 65% sidelap (overlap of adjacent flight lines).

Objectives

- Become familiar with the user interface and features found within PIX4Dmatic.
- Learn how to georeference imagery and create a dense point cloud, a digital surface model (DSM), and an orthomosaic with PIX4Dmatic.

Required Data:

- Download and unzip Pix4Dmapper_Pix4Dmatic_Ex1_data.zip, which contains 116 images collected over an old campground near Pineview Reservoir in northern Utah. This is the same data used for the Pix4Dmapper exercise. So, no need to download it again if it was previously downloaded for the Pix4Dmapper exercise.

Prerequisites

- Install and activate PIX4Dmatic (please see PIX4Dmatic Installation Guide for details).

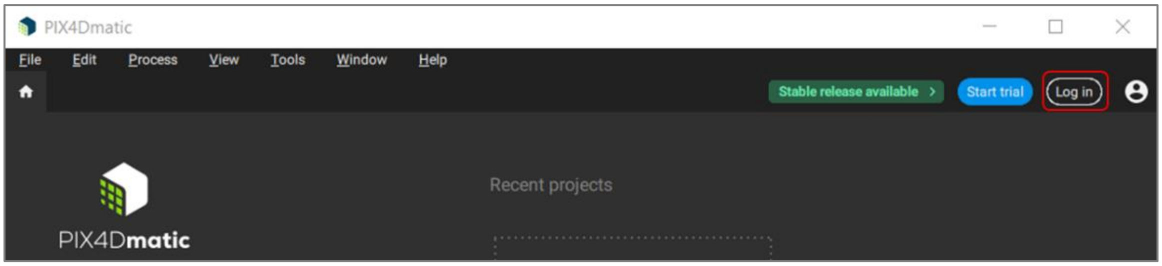
> ***Note:*** *If you experience cursor misalignment when working with PIX4Dmatic you will need to override the High DPI scaling settings applied to PIX4Dmatic by Microsoft Windows. To do this, open* ***Windows File Explorer*** *and navigate to the* ***Program Files*** *folder on the drive where PIX4Dmatic is installed (likely C:\Program Files\PIX4Dmatic\). Open the PIX4Dmatic executable file by right clicking* ***PIX4Dmatic.exe*** *and selecting* ***Properties****. In the* ***Properties*** *window, select the* ***Compatibility*** *tab. Select* ***Change high DPI settings****, and in the pop-up window, check the box next to* ***Override high DPI scaling behavior****. Click* ***OK*** *to close both pop-up windows. You may need to close and reopen PIX4Dmapper for the cursor to be recalibrated.*

Table of Contents

Part 1: Getting Started

A. Creating a new project

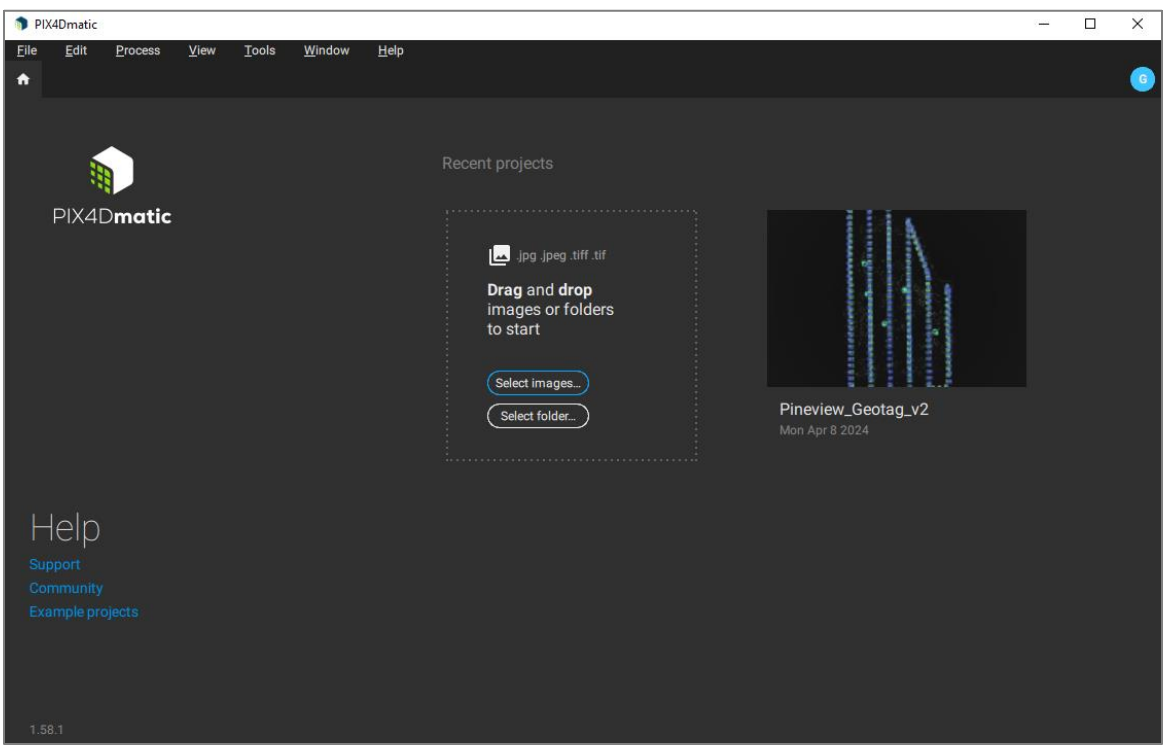
1. In your Windows **Start Menu**, search for **PIX4Dmatic** and click on the application icon to launch.
2. Before creating your first project, log into your PIX4D user account. Click the **Log in** button in the upper right corner of the window.



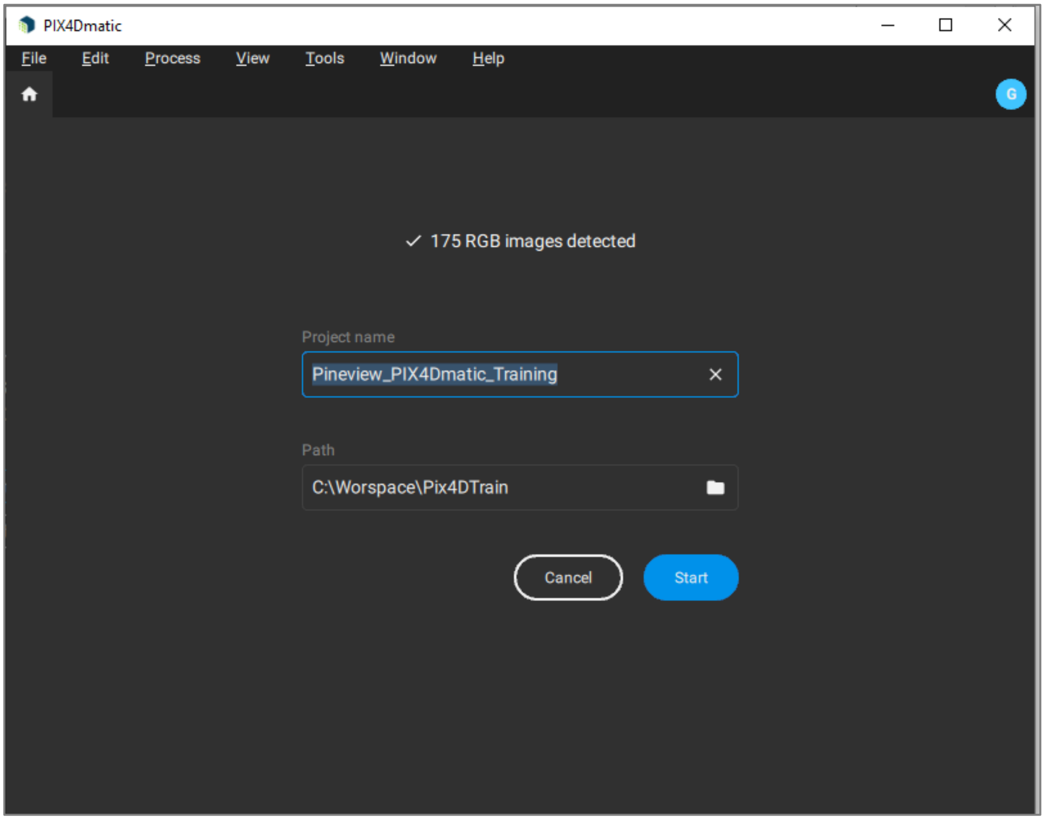
3. Enter the Forest Service PIX4D email: **sm.fs.gtac_uas@usda.gov**, and password: **gtac123**. Then click **Log in**.

NOTE: *If you are connected to VPN upon logging in, PIX4Dmatic may notify you that there are no licenses currently available. If this occurs, log out of PIX4Dmatic, disconnect from VPN, and log back into PIX4Dmatic.*

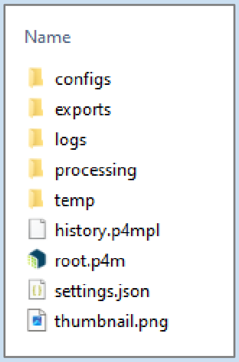
4. You can create a new project by dragging and dropping images or image folders, or by selecting the **Select Images** or **Select Folders** menu items, on the home screen. For this exercise, click on **Select Images.**



5. Browse to the unzipped training data folder **/Mapper_Matic_ex1_data/100MSDCF**, where the imagery is stored. Select all 116 images and click **Open**.
6. Name the project ***Pineview_PIX4Dmatic_train***, select an appropriate path, and click **Start** to create the project and begin importing images. Adding images can take several minutes depending on computer resources. Progress % will be displayed in the lower left corner of the window.



Note: *Structured subfolders will be generated within the project directory that you have named. Processing logs are written to the* ***logs*** *directory. Quality Reports, point clouds, meshes, digital surface models, and orthomosaics will be written to the* ***exports*** *directory.*

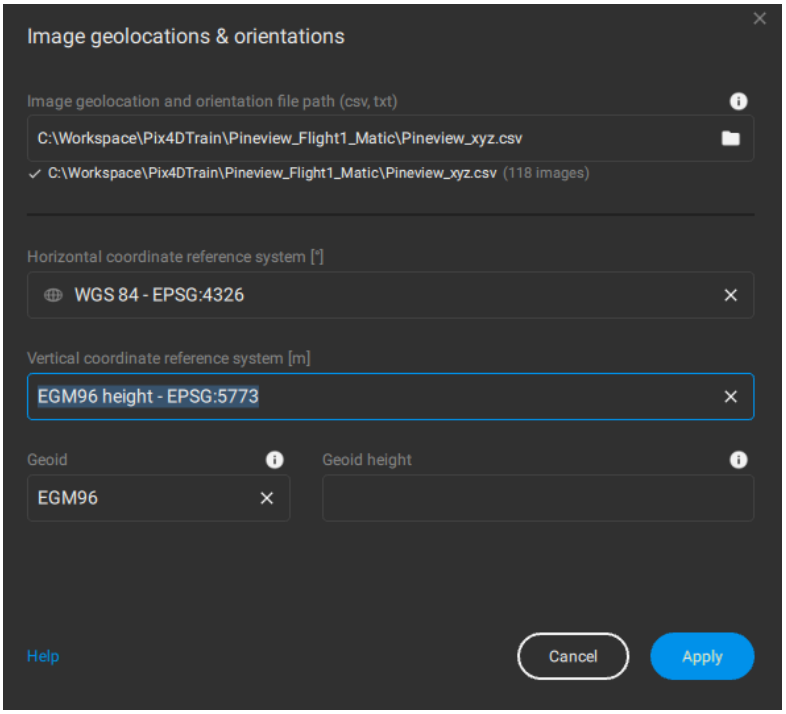


Projects will be created in C:/Users/user/Documents/PIX4Dmatic/ by default if you did not assign a path in step 4 above. In the PIX4DMatic window, navigate to ***File/Open project folder*** *or* ***File/Open project export folder*** *to open these directories in Windows Explorer.*

B. Image Geolocation and Coordinate Reference System

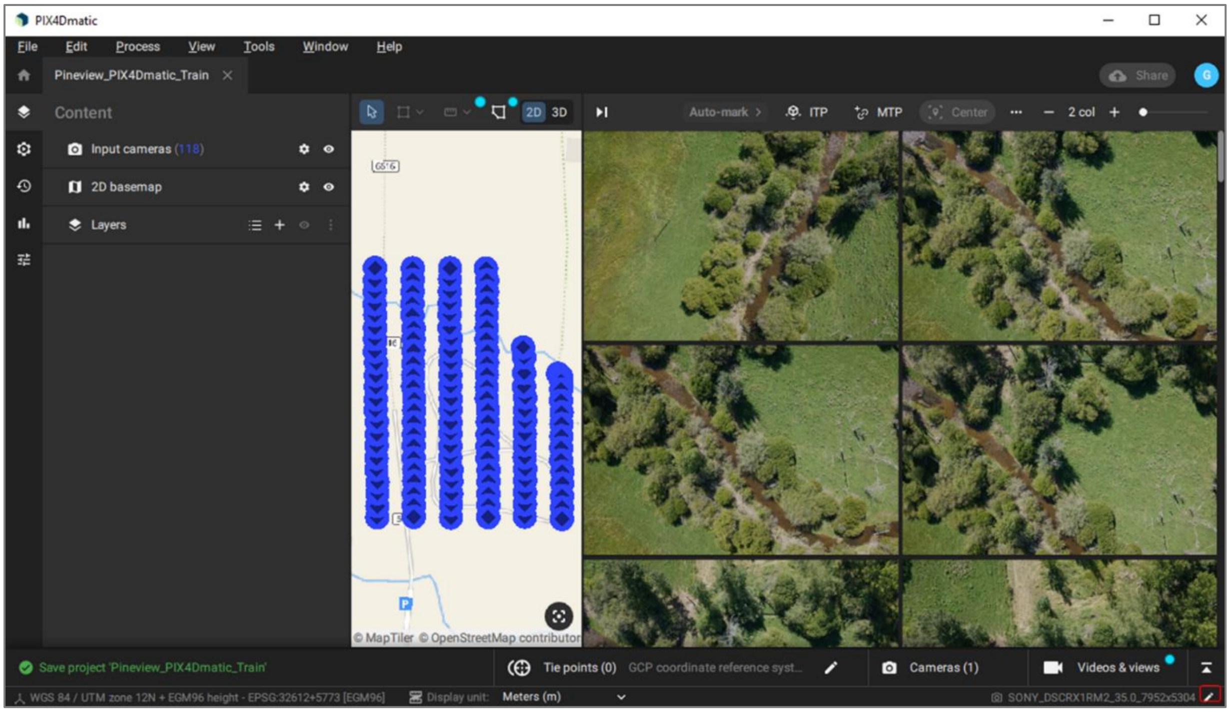
PIX4Dmatic will automatically read the geolocation and Coordinate Reference System (CRS) for input images that have compatible tags in their EXIF files (headers). If the images do not have position information in their EXIFs, the image geolocations must be imported manually from a .csv file and the CRS must be assigned.

1. The images used in this exercise do not have geolocations in their EXIFs. To import image geolocations, select **File/Import/Image geolocations and orientations…** and select **PIX4D.csv** from **/Mapper_Matic_ex1_data/LOG1** training data folder.
2. Next, assign the CRS for the images. Set the **Horizontal coordinate reference system** as **WGS84 – EPSG:4326**, and the **Vertical coordinate reference system** as **EGM96 height – EPSG:5773**, and then click on **Apply**.



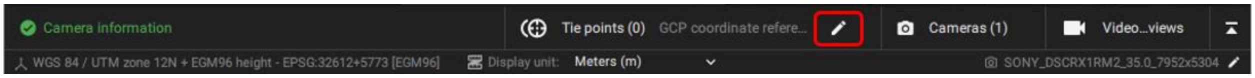
Note: *It is important to note that image names in the geolocation import file are case sensitive and must match the image names exactly. Geolocation import file format specifications can be found on the PIX4D Help Documentation website.*

3. The image locations and basemaps will be displayed in the data viewer panel in the center of the PIX4Dmatic window. Processed outputs will be added to the viewer as they are created throughout the processing workflow. Layer visibility can be turned on and off in the **Content** tab. We will look more closely at the data viewer and Content tab in a later section of this exercise.



C. Project Coordinate Reference System

1. The project CRS is the coordinate system that will be used for the output image products, and by default will be WGS 84 / UTM, with the appropriate UTM zone assigned automatically based on the input image geolocations. The project CRS can be set manually by assigning a CRS to ground control points (GCPs), also referred to as Tie points. Tie points / GCPs are optional, and in projects that do not use them, the project/GCP CRS can still be manually assigned by clicking on the **pencil icon** in the **Tie points** tab on the bottom of the window.



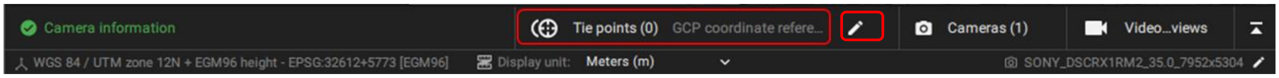
2. We will assign GCPs in the next step in this exercise, so click **Cancel** in the Select GCP coordinate reference system window for now.
3. Save your PIX4Dmatic project before moving on by selecting **File/Save**.

Part 2: Adding Ground Control Points

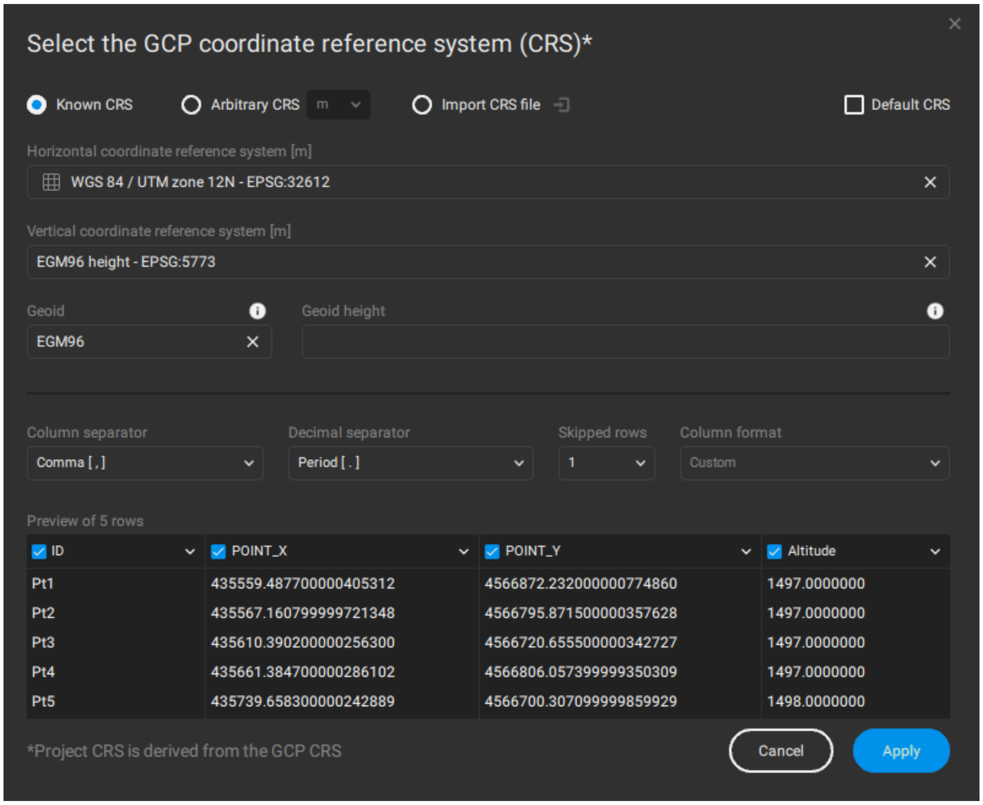
Ground control points are used to improve both the absolute positional accuracy and relative precision of photogrammetric projects. GCPs are locations with known positions and are typically measured with high accuracy GNSS receivers. GCPs can also be manually derived from existing orthomosaics in instances where acquisition of GCP's in the field is not feasible.

A. Import Ground Control Points

1. Ground control points (GCPs) are an optional step in processing imagery in PIX4Dmatic, but they improve the absolute and relative accuracy of photogrammetry project, so in this exercise we will import and mark GCPs. PIX4D refers to both GCPs and Checkpoints (CPs) as *Tie points*. To import GCPs, select the **Tie points** tab at the bottom of the window.



2. Click **Select from disk** and browse to the unzipped training data folder (…/Mapper_Matic_ex1_data) and select **Pineview_GCPs.txt**, then click **Open**.
3. In the Select GCP coordinate reference system window, assign the **Horizontal coordinate reference system** as ***WGS 84 / UTM zone 12N – EPSG:32612***, and assign the **Vertical coordinate reference system** as ***EGM96 height – EPSG:5773***, with **Geoid** set as ***EGM96***. Once you have set the CRS, click **Apply**.



Note: *If the GCP coordinate system is geographic, then the project CRS will default to UTM, and the project CRS cannot be manually set to another CRS.*

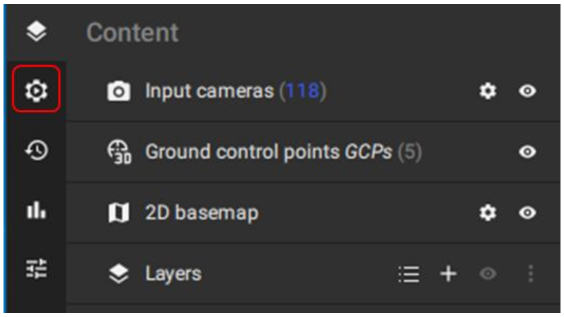
4. Save your PIX4Dmatic project before moving on by selecting **File/Save**.

B. Mark Ground Control Points

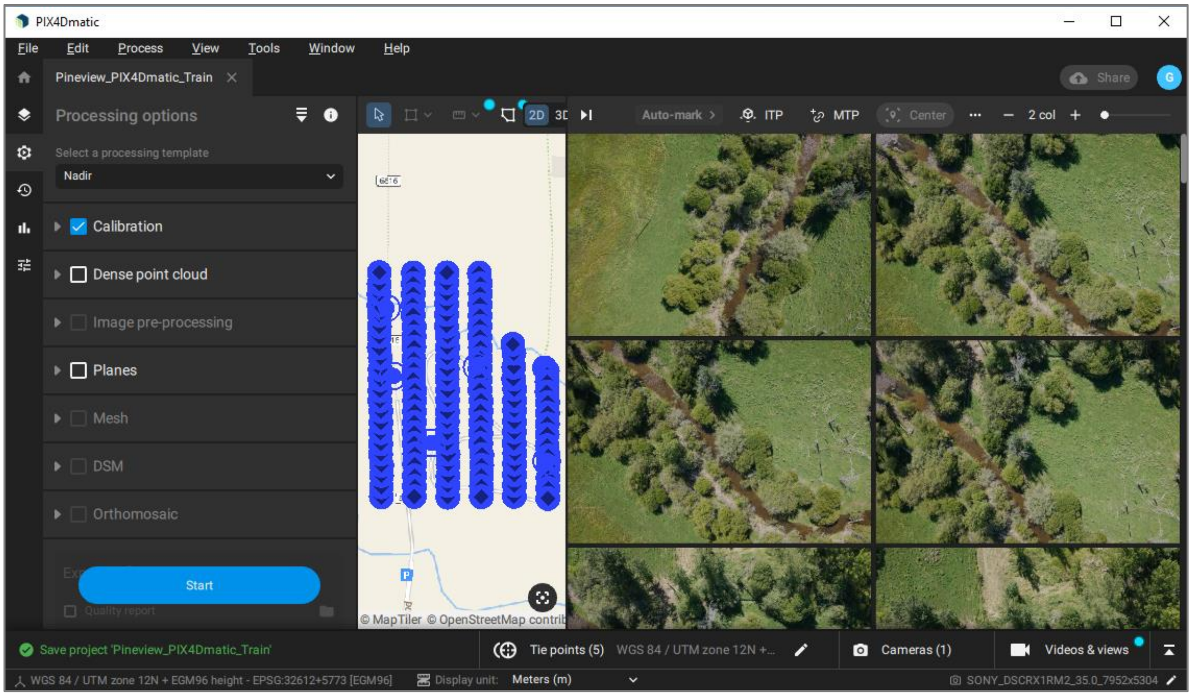
GCPs can be marked on the input imagery at different stages in the processing workflow. Marking the GCPs prior to running the image Calibration step requires more effort because the GCPs will be positioned in relation to the initial image geolocations. Running the Calibration processing step first will reposition the input imagery with greater precision because the exterior and interior camera parameters will be utilized. This will result in closer initial alignment between the GCPs and the input imagery and will improve efficiency when manually marking the GCPs in the imagery.

Note: *Images of each GCP can be found in Appendix A at the end of this document.*

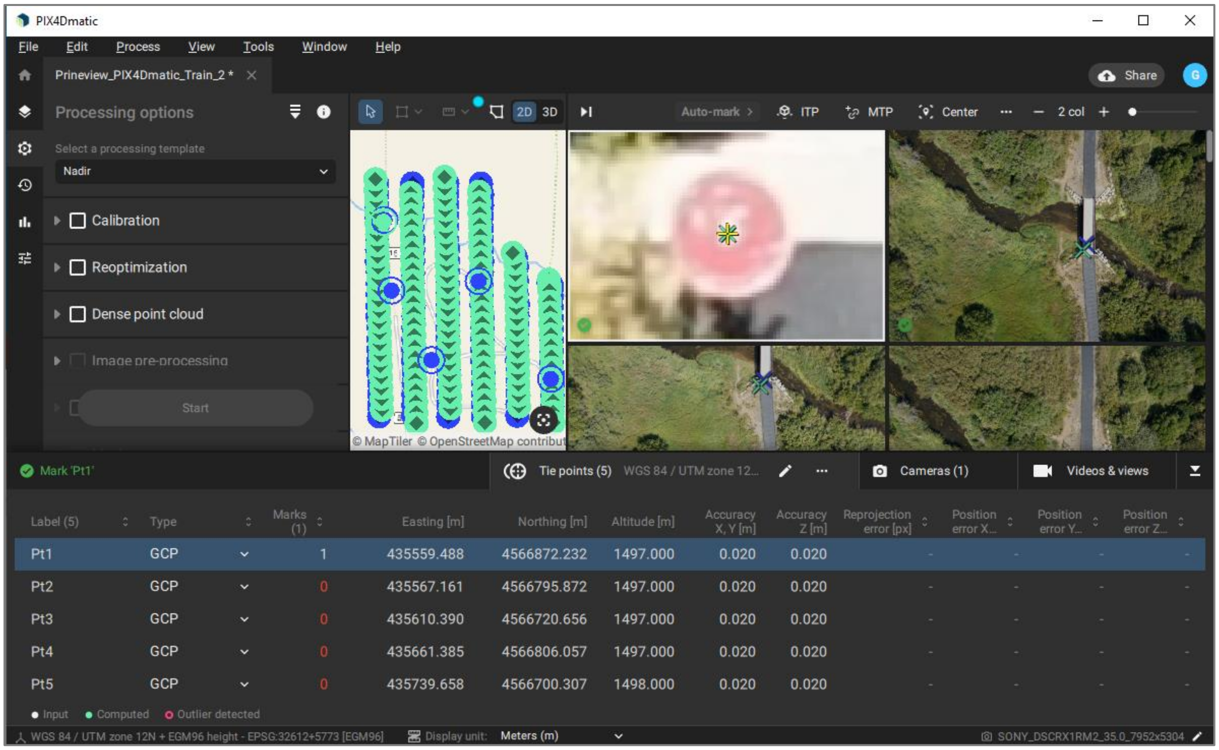
1. To run the initial image Calibration step, select the **Processing Options** tab on the left edge of the window. We will take a closer look at the various calibration options in Part 3 of this exercise, but for now, we will keep the default settings.



2. In the Processing Options window, check **Calibration**, and click **Start** to begin the calibration process. Calibration can take several minutes, depending on computer resources.

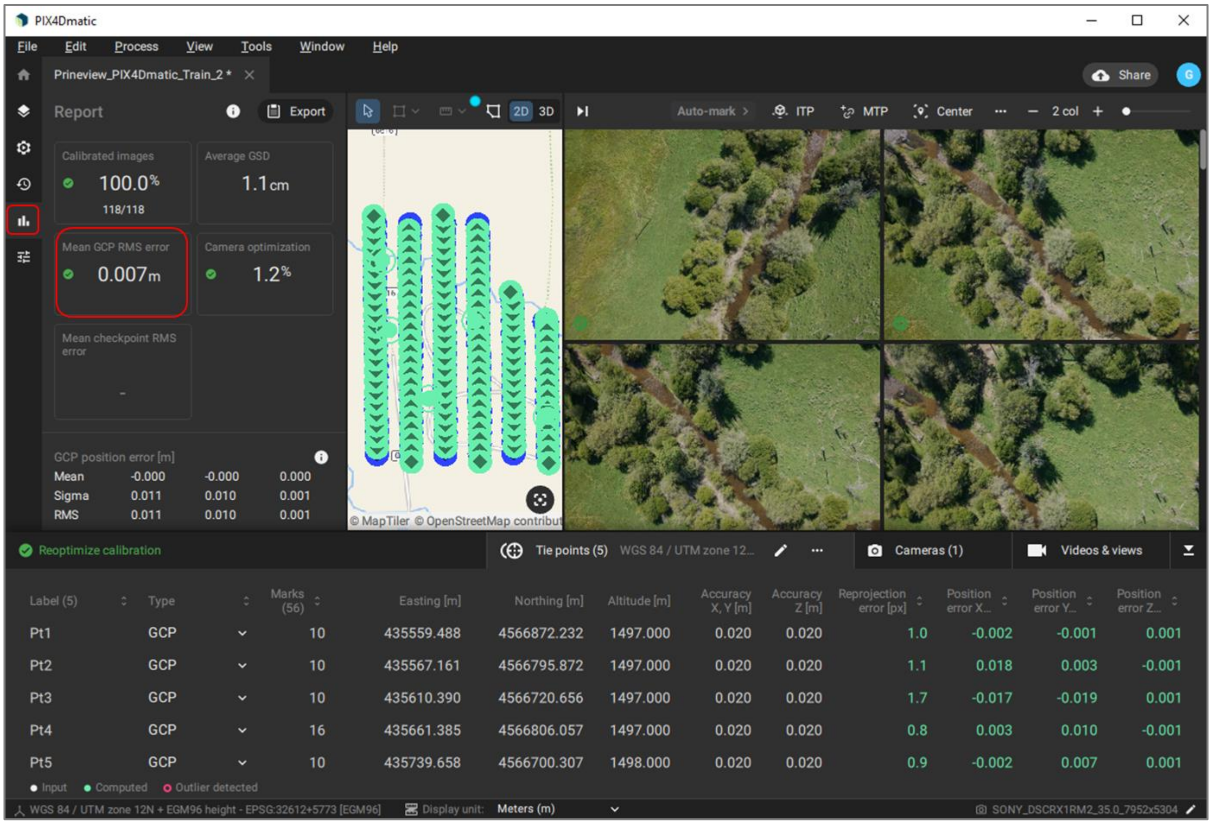


3. Once the Calibration process has run, you can begin tying images to the GCPs. Open the Tie points table by selecting the **Tie points** tab on the bottom of the window.
4. Left click on the first GCP in the table to highlight **GCP Pt1** (refer to Appendix A for placement of GCPs). The pane on the right will automatically update to show the images that may contain the selected GCP. Pull the image pane to the left to increase the size of the images. You will notice that PIX4D has placed blue Xs to mark the predicted location of the GCP.
5. Zoom in on the first image by hovering your mouse over the approximate GCP location and use CTRL and the scroll wheel to zoom in**. CTRL+Scroll** will zoom in centered on the location of your cursor.
6. Once you are zoomed in on the GCP in the image**, left click** to mark the precise center of the GCP in the image with a yellow +. If you mis-place a point, right click in the image and select **Remove mark**. Once you mark an image, PIX4D will automatically reproject the predicted GCP locations in each image with a green X. This may aid you in marking the subsequent images.



7. Repeat this process in the other images for GCP Pt1. In flights with a lot of overlap and sidelap, each GCP will be visible in many images. There is not a definitive number of images to tie to each GCP, but more is better. Additionally, marking images from adjacent flight lines should be done whenever possible because this in particular will improve the model solution.
8. Once all the images have been tied to Pt1, repeat the process for each of the remaining GCPs.
9. Save your PIX4Dmatic project (**File/Save)**.
10. After tying the images to each of the GCPs, and whenever any modifications are made to GCPs, the project must be Reoptimized to update the internal and external camera parameters. In the **Processing options** panel check **Reoptimization**. Expand the **Reoptimization** options, and toggle on the **Rematch** option to compute more matches between images and improve calibration results. Click on **Start**.
11. Once the Reoptimization has completed, inspect the project quality report to assess GCP accuracy. Select the **Report** tab on the left side of the window. The Mean GCP RMS error assesses the mean positional error in each direction (X, Y, Z) for all the GCPs (see following note).

NOTE*: Mean RMS values less than or equal to 1.5 times the average ground sample distance (GSD) is considered good. Additionally, positional errors for individual GCPs can be viewed in the Tie point table (also shown below). When RMS errors are high, check the Tie point table. Often there is a single misaligned GCP that can be identified and re-marked on the images. Or, if the project has enough GCPs, the culprit GCP can be removed from the project. Modifications to any of the GCPs requires Reoptimization of the project.*



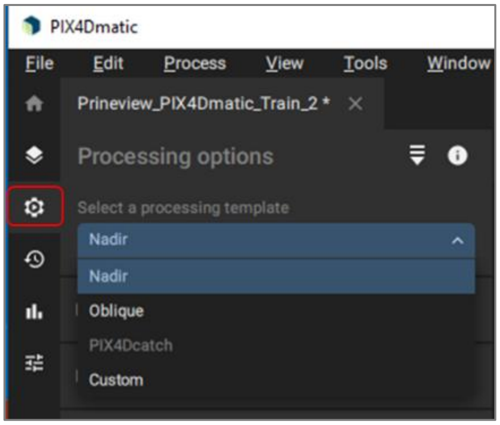
Part 3: Image Processing Options

Now that the initial project setup is complete, the images have been tied to the GCPs, the project has been reoptimized, and we have verified GCP accuracy, we will explore the image processing options in PIX4Dmatic to create a dense point cloud, digital surface model, and orthomosaic.

***NOTE**: Image processing steps can be selected and run all at once, or one at a time, sequentially. Running processing steps individually can be helpful for testing settings and trouble-shooting issues within each step before moving on to the next. This can be particularly helpful with the steps that require significant processing resources and time, such as dense point cloud and DSM generation. For this exercise, we will initiate all the processing steps at once.*

A. Processing Template

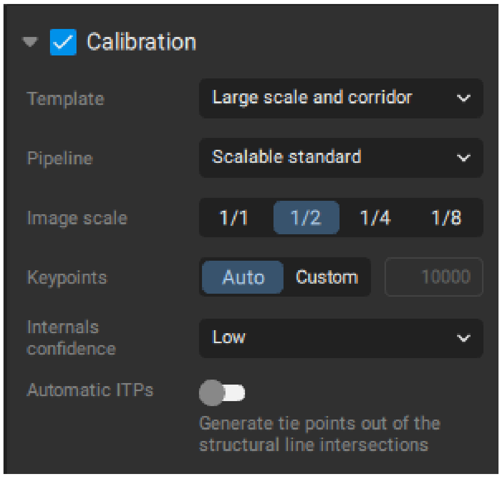
1. Each processing template assigns PIX4Dmatic's default processing settings and is a good starting place for the image processing workflow. For this project we are working with nadir imagery. Select the **Processing options** tab on the left side of the window, and in the **Select a processing template** pull-down menu, select the **Nadir** option. You will notice that as we adjust the default settings in future steps, the template will automatically change to Custom.



B. Calibration

The first step in the image processing workflow is Calibration. PIX4D will apply default settings based on your input imagery and the processing template chosen above. The Calibration process creates automatic tie points, identifies keypoints within in each image and matches keypoints between images, calibrates internal and external camera parameters, and uses GCP geolocations to locate the project.

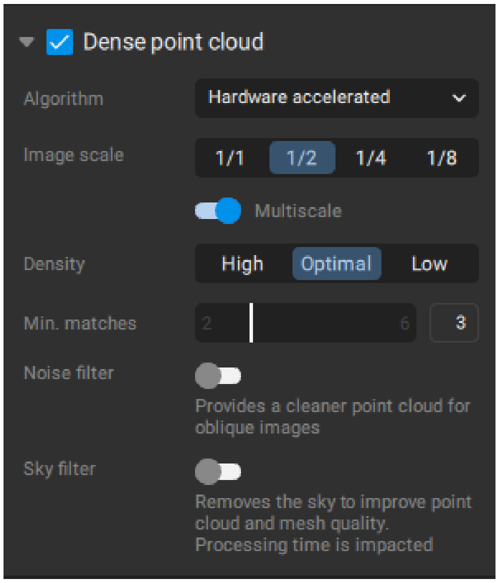
1. Expand the **Calibration** processing options by clicking the toggle button. The first step in the Calibration process is to select the most appropriate **Template**. **Large scale and corridor** is the default template, and is the best match for this exercise dataset, which is nadir imagery of mixed open and forested terrain.
2. **Pipeline** optimizes the internal and external camera calibration parameters. Scalable standard is the default option and is the fastest processing setting. Standard can result in higher quality image products but utilizes more processing resources and results in longer processing time. For this exercise we will use the **Scalable standard** setting.
3. **Image Scale** refers to the scale of the images used for extracting and matching keypoints, which are discreet features identified in each image that are matched between overlapping images. Processing time increases as image scale increases. It is recommended to reduce image scale for very high-resolution images, blurry images, and for flat and homogeneous or repetitive and complex are areas (i.e., trees, forests, and fields). Reducing image scale will also speed up processing. For this exercise we will use **1/2 Image scale**.
4. **Keypoints** mark discernable features within each image that are then matched with the same features identified on overlapping images. We will keep the default **Auto** setting that allows PIX4Dmatic to optimize the number of keypoints identified per image up to 10,000 points. For projects with alignment issues, the number of keypoints can be increased to improve image alignment.
5. Keep the default settings of **Internals confidence** as **Low**, and **Automatic ITPs** turned **Off**.



C. Dense Point Cloud

The Dense point cloud process creates three-dimensional points that represent the surface derived from the input imagery. The dense point cloud is the foundation on which the other image products are based.

1. **Algorithm** defines which densification process is used to create the dense point cloud. If your computer has a compatible GPU (graphics processing unit) installed the algorithm method will default to **Hardware accelerated**, which can reduce processing time. **Standard** will use the standard processing algorithm. Apply whichever setting is appropriate for your computer.
2. **Image scale** defines the scale of the image for 3D point computation. Point generation decreases as image scale decreases. Reducing the image scale can also significantly decrease processing time. Apply **1/2 image size** for this exercise. In vegetated areas reducing the image scale may result in more 3D points in some situations.
3. Turn on **Multiscale**. This will utilize the image scales that are lower than the image scales set in the previous step during dense point cloud processing. This is helpful in generating 3D points in vegetated areas and filling holes in areas of low texture. For areas with thin or narrow 3D features multiscale should be disabled.
4. **Density** will default to **Optimal**, which creates a 3D point for every 8th pixel of the 1/1 image scale. Setting the density to High will create a point every 2nd pixel and result in a higher density point cloud, but may not significantly improve results, and will increase processing time. Reducing density to Low will significantly reduce processing time and will yield a 3D point every 32nd pixel.
5. The minimum number of matches refers to the minimum number of images in which a 3D point is identified. The default is 3. For images with low overlap the number of matches may be lowered but will result in more noise. Lowering the number of matches may also improve point cloud density for tree canopies. Increasing the number of matches will improve point cloud quality but can result in fewer 3D points generated. For this exercise, we will set **Min matches** to **3**.
6. Leave **Noise filter** and **Sky filter** turned off. Noise filter is primarily used with oblique imagery to remove points that are far from images. The Sky filter removes points associated with the sky, which does not pertain to our dataset.



D. Image pre-processing

Image pre-processing is an optional processing step that can be skipped for this exercise.

E. Planes

Planes is a process that is specific to applications in the built environment, including inside and outside structures and urban settings. Planes can be used as a pre-process for the mesh generation to improve low texture surfaces like walls and roofs. We will skip this process.

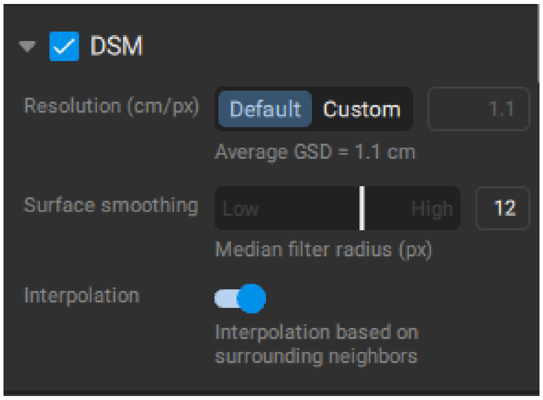
F. Mesh

The Mesh step is an optional process that generates a mesh from the Dense Point Cloud. Meshes are useful for creating detailed 3D models, but they add significant processing time and are not required to create DSMs and orthomosaics. Meshes can be viewed in **PIX4D**matic's 3D view and exported as a LAZ. *This step is optional and will add processing time.*

G. DSM

The DSM process creates a Digital Surface Model (DSM), which is a continuous value, 2D raster image of the elevations of the surface of the area of interest (AOI). The DSM is derived from the Dense Point Cloud defined in a previous step.

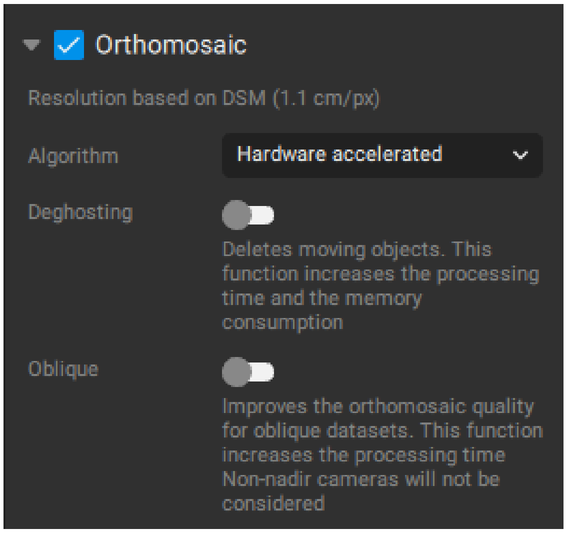
1. **Resolution** is the pixel size of the DSM raster and is automatically populated from the average ground sample distance (GSD) calculated for the project. The DSM resolution will define the orthomosaic resolution. For this dataset, the GSD should be **1.1 cm**. A custom resolution can be applied here if a target GSD is required.
2. **Surface smoothing** applies a filter to the DSM to smooth features and edges. The higher the value used, the more smoothing is applied to the DSM. The default value is 12, which applies a 12-pixel radius median filter to each pixel. Keep the **Surface smoothing** set to **12** for now.
3. The **Interpolation** process fills in holes where there is no dense point cloud data. Turning on Interpolation will approximate values across holes based on neighboring points and will result in a continuous surface. If Interpolation is turned off, any holes in the DSM will result in holes in the orthomosaic created in the next processing step. **Turn on Interpolation** for this exercise.



H. Orthomosaic

The Orthomosaic step corrects the geometric distortion in the individual images and then color balances and merges the images into a single, seamless, map-accurate mosaic image.

1. The orthomosaic **Resolution** is defined by the DSM created in the previous step.
2. **Algorithm** defines the algorithm used to create the orthomosaic. If your computer has a compatible GPU (graphics processing unit) installed, the algorithm method will default to **Hardware accelerated**, which can reduce processing time. **Standard** will use the standard processing algorithm. Apply whichever setting is appropriate for your computer. If errors occur during orthomosaic generation, or if output orthomosaics appear distorted, manually setting the algorithm to Standard may alleviate the issue.
3. **Deghosting** can remove objects that move during the time between acquisition of individual images. Deghosting will generally slow down orthomosaic processing and can also reduce orthomosaic detail in some situations. For this exercise, we will **turn off Deghosting**.
4. The **Oblique** function improves orthomosaic quality from oblique imagery. Leave **Oblique turned off** for this exercise.

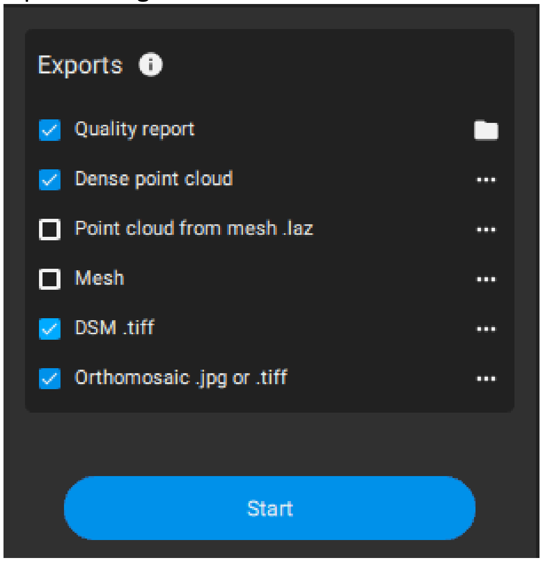


***NOTE**: For additional information on image processing options, refer to the [PIX4D Help Documentation website](#).*

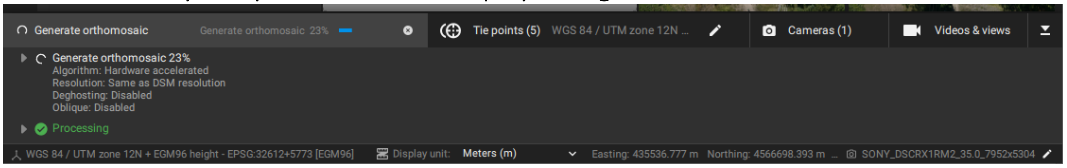
I. Exports

Export the main products by doing the following:

1. The **Quality report** is a PDF document with detailed assessments of project accuracy. The Quality report can be a helpful tool for assessing project results and troubleshooting issues when they arise during processing. **Export** the **Quality report** by selecting the check box.
2. The **Dense point cloud** will be exported as a LAZ file that can be imported by GIS applications for analysis. **Export** the **Dense point cloud.**
3. The **DSM** will be exported as a GeoTIFF file that can be imported by GIS applications for analysis. **Export** the **DSM.**
4. The **Orthomosaic** can be exported as a JPG or a TIFF file that can be imported by GIS applications for analysis. The default file type is JPG. Change the format to TIFF by selecting **...** on the Orthomosaic tab and changing the **Format** pulldown menu to **.tiff** and check the box next to **Orthomosaic**.
5. Once the export products have been selected, verify that the **Calibration**, **Dense point cloud**, **DSM**, and **Orthomosaic** processing steps are all checked on.
6. Click **Start** to begin processing.



7. Processing progress will be displayed in the Processing tab at the bottom of the window. Successfully completed tasks are displayed in green text.



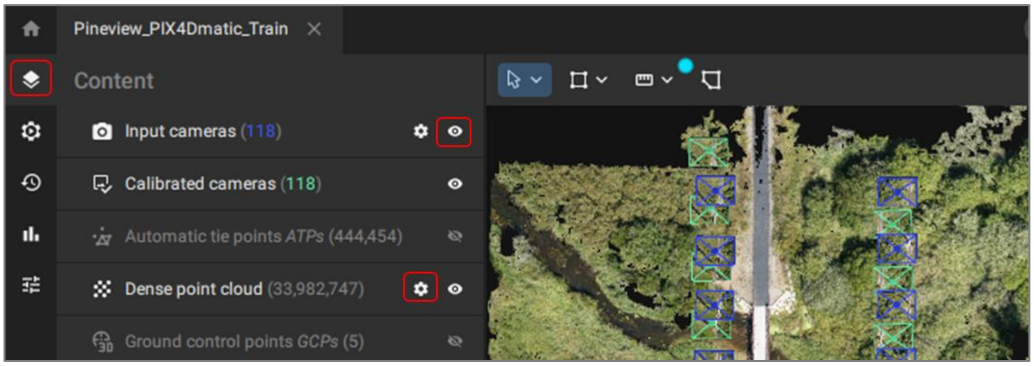
Part 4: Viewing Results

Data and image products that are created during the image processing workflow can be viewed within PIX4Dmatic in the map pane and/or exported to files that can be interrogated and analyzed in other software applications.

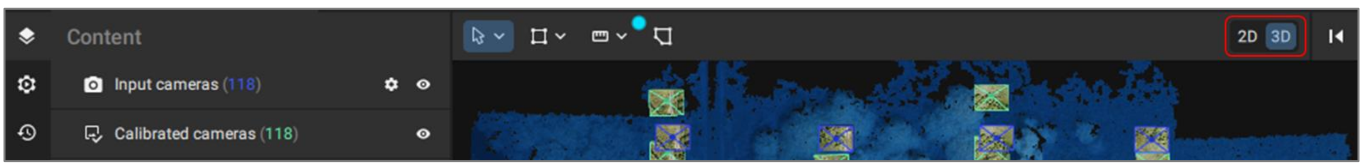
A. Contents, Settings, and Data Viewing

1. The data viewer in the center of the PIX4Dmatic window initially displays the input image locations and basemaps for the project area. Processing results will be added to the viewer as they are created throughout the processing workflow. Layer visibility can be turned on

and off in the **Content** tab by toggling the **eye icon** next to each layer's name, and some layers have additional display properties that can be modified via the **gear icon**.

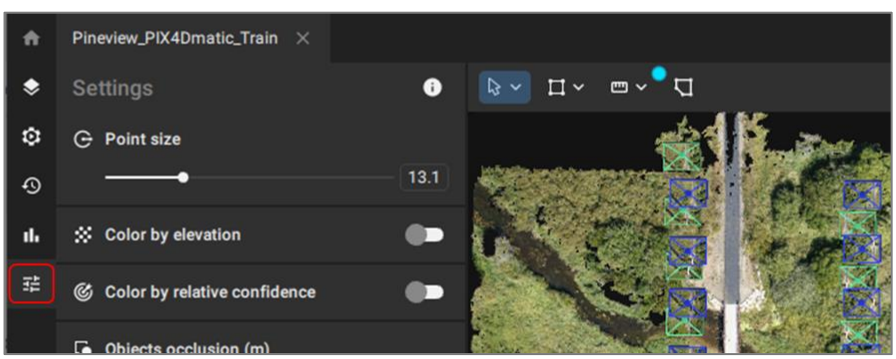


2. Project outputs can be viewed in 2D or 3D. Viewing mode (2D/3D) is controlled with the toggle buttons in the top right of the window, or by selecting **View/Switch to 2D (3D)**. Layer visibility varies with viewing mode:
   i. **Layers visible in 2D**: Cameras (Input and Calibrated), GCPs, DSM, Orthomosaic, and Basemaps
   ii. **Layers visible in 3D**: Cameras (Input and Calibrated), Automatic tie points, Dense point cloud, GCPs, and Mesh



> ***NOTE****: To navigate in the 3D view:*
> ***Left click*** *to pan*
> ***Right click*** *to rotate on x, y, z axis*
> ***Scroll wheel*** *to zoom in/out.*

3. The **Settings** tab contains most display settings for the layers in the viewer. A few of the settings you will likely use include:
   i. **Point size** - Changes the size of the points in the dense point cloud
   ii. **Color by elevation** - Displays dense point cloud points by color with color ramp choices
   iii. **Background color** - Select background color
   iv. **Basemap** - Changes the basemap in the 2D viewer



NOTE: *For additional information on Content, Settings and displaying data, refer to the [PIX4D Help Documentation website.](#)*

B. Exports

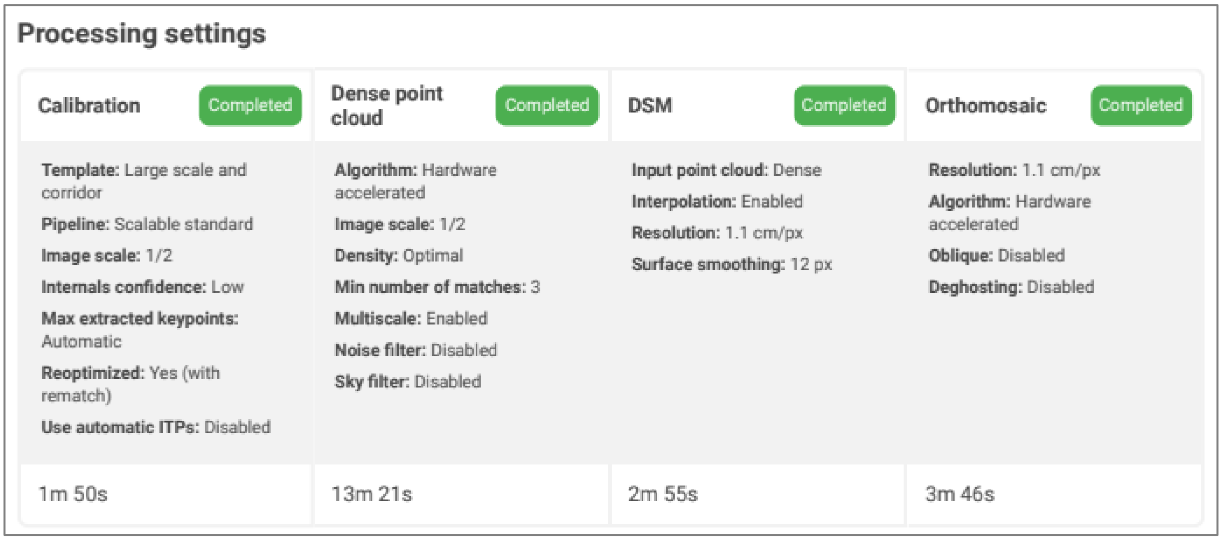
Exported image products are written to the **Exports** directory that was created by PIX4Dmatic when the project was created. To open the Exports directory, select **File/Open project export folder**. For this exercise, we exported the following data:

Pineview_PIX4Dmatic_train-dense_point_cloud.laz
Pineview_PIX4Dmatic_train-dsm.tiff
Pineview_PIX4Dmatic_train-orthomosaic.tiff

C. Quality Report

The **Quality Report** is also written to the Exports directory, and provides an analysis of the project accuracy, its output datasets, and a log of the processing settings used:

Pineview_PIX4Dmatic_train*-quality_report*.pdf



Processing settings

Calibration (Completed)	Dense point cloud (Completed)	DSM (Completed)	Orthomosaic (Completed)
Template: Large scale and corridor	**Algorithm:** Hardware accelerated	**Input point cloud:** Dense	**Resolution:** 1.1 cm/px
Pipeline: Scalable standard	**Image scale:** 1/2	**Interpolation:** Enabled	**Algorithm:** Hardware accelerated
Image scale: 1/2	**Density:** Optimal	**Resolution:** 1.1 cm/px	**Oblique:** Disabled
Internals confidence: Low	**Min number of matches:** 3	**Surface smoothing:** 12 px	**Deghosting:** Disabled
Max extracted keypoints: Automatic	**Multiscale:** Enabled		
Reoptimized: Yes (with rematch)	**Noise filter:** Disabled		
Use automatic ITPs: Disabled	**Sky filter:** Disabled		
1m 50s	13m 21s	2m 55s	3m 46s

Conclusion: Congratulations! You have completed this PIX4Dmatic exercise for processing UAS imagery! In this exercise, we learned how to use PIX4Dmatic to create a project, add GCPs, and create a dense point cloud, digital surface model, and orthomosaic. Additional resources, including a few tutorials and a very helpful user forum, can be found on the [PIX4D website](#).

Appendix A: GCPs

1. 

2. 

3. 

4. 

5.