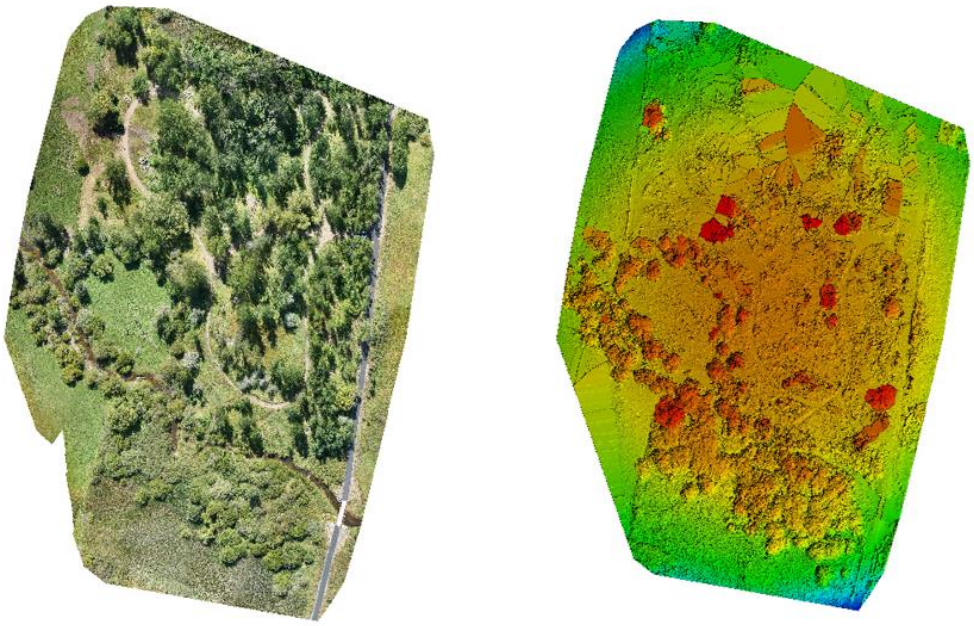
Processing UAS Imagery in PIX4Dmapper



Introduction

PIX4Dmapper (PIX4D) is a photogrammetry software suite compatible with unmanned aircraft system (UAS) imagery that enables you to define areas of interest, select processing options, add ground control points (GCPs), and create and edit point clouds, digital surface models (DSMs), meshes, and orthomosaics. Default templates provide automatic processing for new projects and can be customized for more control over data and output product quality.

This exercise will introduce you to the general workflow for processing UAS imagery in PIX4D. Please see Exercise 2 for a more in-depth look at some of the settings and tools found in PIX4D. 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.

Objectives

- Become familiar with the user interface and features found within PIX4D.
- Learn how to georeference imagery and create a dense point cloud, a 3D textured mesh, a digital surface model (DSM) and an orthomosaic with PIX4D.

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 Pix4Dmatic exercise. So, no need to download it again if it was previously downloaded for the Pix4Dmatic exercise.

Prerequisites

- Install and activate Pix4Dmapper (please see Pix4Dmapper Installation Guide for details).

Note: If you experience cursor misalignment throughout this exercise, open your **File Explorer** and navigate to your **Program Files** folder on the Drive you installed Pix4Dmapper. Right click on the pix4dmapper.exe file and in the **Properties** window, select the **Compatibility** tab. Enable **Disable display scaling on high DPI settings** and click **OK**. You may need to close and reopen Pix4Dmapper for the cursor to be recalibrated.

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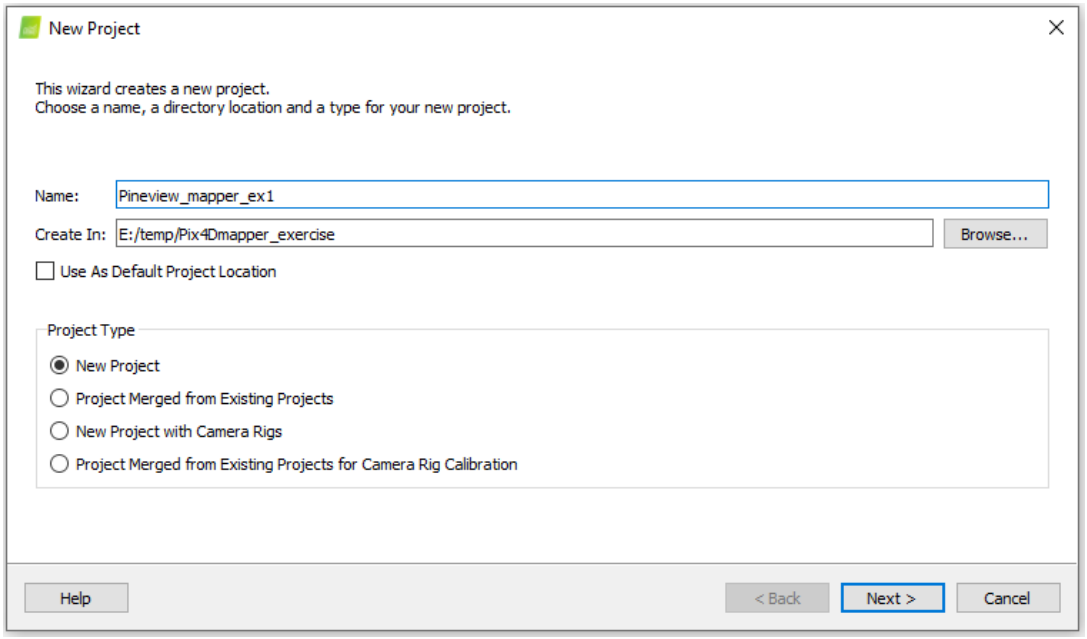
Part 1: Getting Started

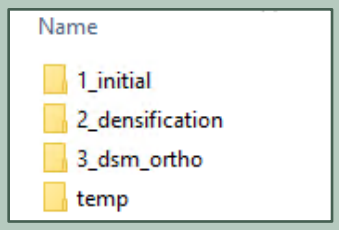
In this first part of the exercise, you will navigate the project creation wizard, which consists of five windows, to configure important settings and options for your PIX4D project. This section will acquaint you with folder directories where the project outputs will be stored, where you can manage the camera model's parameters, select coordinate systems, and select your processing options template.

A. Create a Project

1. Launch PIX4D by searching Pix4Dmapper in the Start menu bar and click **New Project**.
2. Name the project Pineview and set your file directory. Make sure the radio button for New Project is selected and click **Next**.



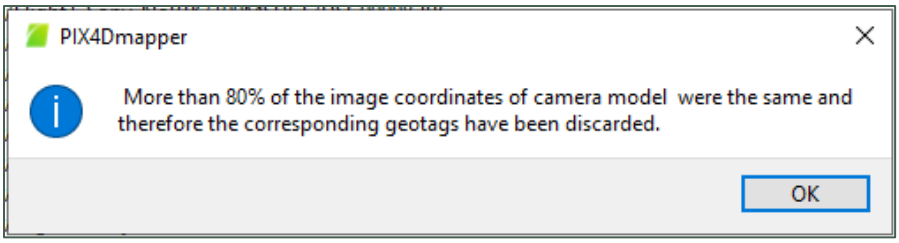
Note: Structured subfolders will be generated within your project folder along with your LOG file, which you can use to review your settings and accuracy once your project is finished. You can locate your generated reports in **1_initial**, your point clouds in **2_densification**, and your digital surface model and orthomosaic in **3_dsm_ortho**.



If you leave the file directory as the default pathway, your project folder will be created at **This PC**, **Documents**, **Pix4D**. If you want to save the project folder elsewhere, you can specify a desired directory upon creating a new project. After you finish processing, you can go to this folder to access the products and to import them into other GIS software, such as ArcGIS Pro, for further investigation and use.

B. Add the Imagery

1. In the Select Images window, click on **Add Images** and browse to the unzipped folder for Pineview_Flight1_Sony subfolder 100MSDCF in which the imagery is stored. Select all 116 images and click **Open** and **Next**.
2. The images used for this exercise were not geotagged, so you'll get the following message. In step 5 below, we will use a log file with coordinates to import the image locations. In response to the warning message that pops up, click **OK**.



3. In the Image Properties window, leave the following parameters as their default values:
   i. Datum: WGS 1984; Coordinate System: WGS 84 (EGM 96 Geoid)
   ii. Geolocation Accuracy: Standard
   iii. Selected Camera Model: DSC-RX 1RM2_35.0_7952x5304 (RGB)
4. In the same window, under Geolocation and Orientation, you will see an exclamation point next to Geolocated Images: 0 out of 116. Click on **From File…**
5. In the Select Geolocation File Window, click on **Browse...** and navigate to the Pineview_Flight1_Sony subfolder LOG1. Select the Excel file named PIX4D and click **Open**. Your File Format will display the correct order for Latitude, Longitude and Altitude, so click **OK**. Your Image Table will now display these values for each image.

Selected Camera Model

DSC-RX1RM2_35.0_7952x5304 (RGB) Edit…

Enabled	Image	Group	Latitude [degree]	Longitude [degree]	Altitude [m]	Accuracy Horz [m]	Ac V
☑	DSC00003.JPG	group1	41.25003430	-111.76697530	1590.070	5.000	10.000
☑	DSC00004.JPG	group1	41.24996180	-111.76697530	1590.260	5.000	10.000
☑	DSC00005.JPG	group1	41.24985880	-111.76697530	1590.460	5.000	10.000
☑	DSC00006.JPG	group1	41.24975200	-111.76696780	1590.350	5.000	10.000
☑	DSC00007.JPG	group1	41.24964520	-111.76696780	1590.270	5.000	10.000
☑	DSC00008.JPG	group1	41.24953470	-111.76696780	1590.170	5.000	10.000
☑	DSC00009.JPG	group1	41.24942780	-111.76696780	1590.030	5.000	10.000
☑	DSC00010.JPG	group1	41.24931330	-111.76696780	1590.060	5.000	10.000

6. Click **Next**.
7. In the Select Output Coordinate System window:

i. Ensure that the Unit is specified as meters (m).

ii. Leave the following parameters as their default values:

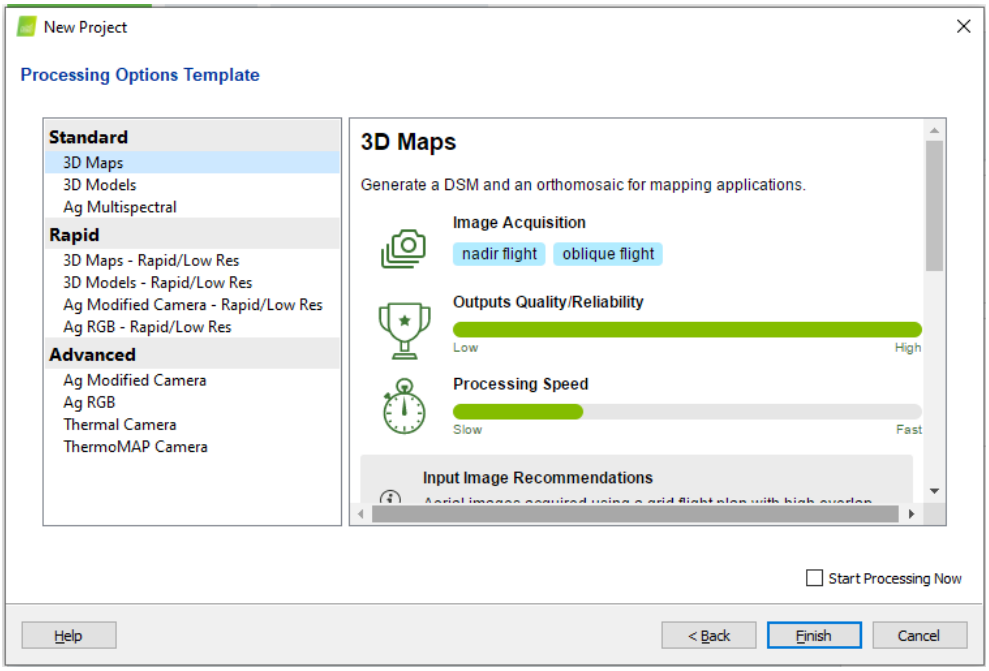
(a) Autodetected: WGS 84 / UTM zone 12N

(b) Advanced Coordinate Options: unchecked.

8. Click **Next**, allowing some time for PIX4Dmapper to process your input.

C. Select Template

1. Under Processing Options Template, navigate to the **Standard** section, then select **3D Maps**.



Note: Depending on what outputs your project requires and what imagery you are loading, you can opt for different templates. For producing Point Clouds, DSMs, and Orthomosaics from aerial imagery, you will select either Standard or Rapid **3D Maps**. Rapid will produce lower quality results quickly and can be used for data checks or for slower laptops. The 3D Maps options are also good for measuring volumes, digitizing houses and roads, and generating contour lines. For producing 3D meshes and models from oblique imagery, you can select either Standard or Rapid **3D Models**. This option is good for 3D models of buildings, statues, and other objects.

2. Uncheck **Start Processing Now** since we'll explore our processing options before we start aligning the images.
3. Click **Finish** to finalize the initial project setup. In the Map View, you should now see red points representing the location of your images.

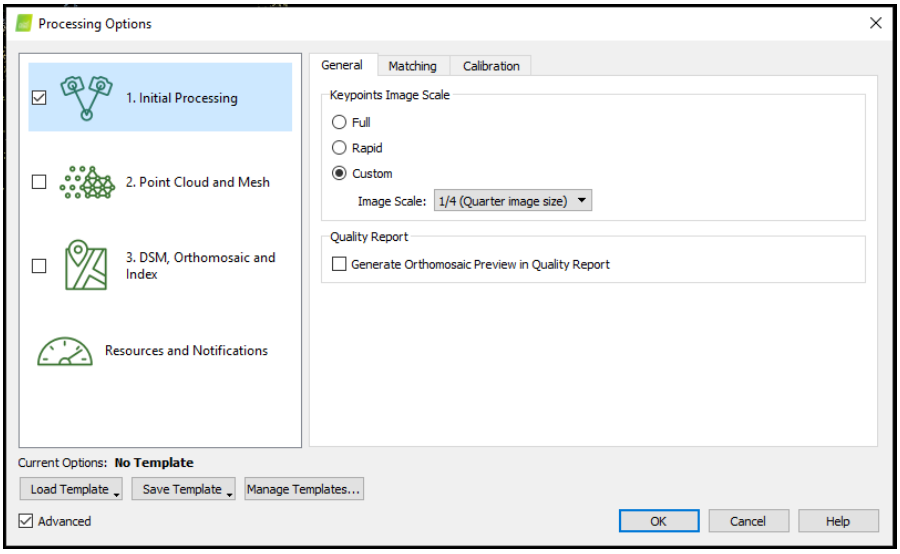
Part 2: Image Alignment and Calibration

After loading the images and setting up the project file, PIX4D gives you the option to run Initial Processing. In this step, Pix4Dmapper aligns the images to one another using Structure from Motion (SfM) algorithms. The first part of this is that it finds thousands of contrasting features in each image, which are saved as key points. It then compares key-point patterns between images to identify and

create automatic tie points. Once the tie points are identified, the software uses aerial triangulation to estimate the camera-calibration parameters and to refine the image coordinates and location of the images. This improves the accuracy of the 3D model and products.

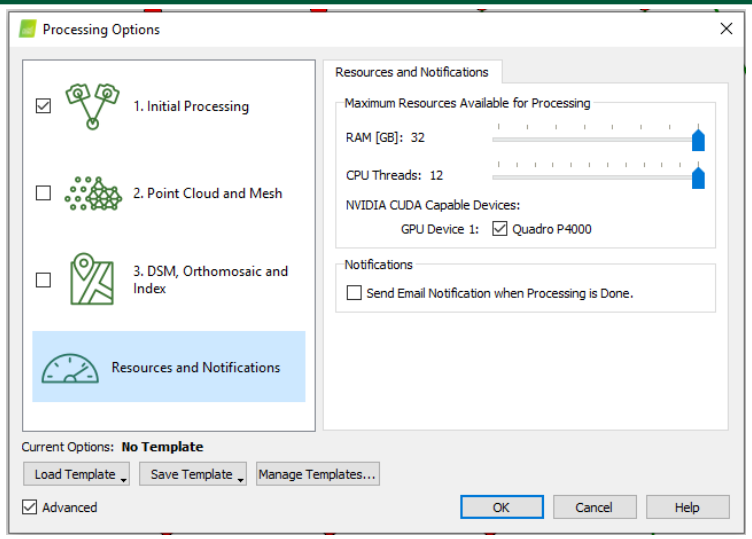
A. Image Alignment and Calibration

1. If you cannot see the Processing menu at the bottom left of the screen, navigate to and click on the **View** tab in the main menu and then click **Processing**.
2. In the Processing menu at the bottom left of the main window, all three steps (**1. Initial Procesing**, **2. Point Cloud and Mesh**, and **3. DSM, Orthomosaic, and Index)** are red, which indicates that these steps are not complete. Place a checkmark next to **Step 1** and leave **Steps 2** and **3** unchecked.
3. Click on the **Processing Options** button to the left of the processing steps. There are three tabs for the Initial Processing options: General, Matching, and Calibration. Under the **General** tab, click on **Custom** and change the dropdown to **1/4 (Quarter image size)**. Also, uncheck the **Generate Orthomosaic Preview** option.

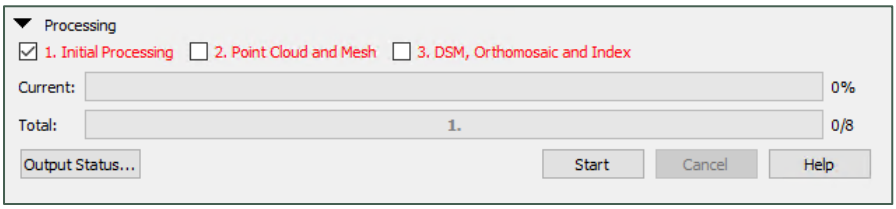


***NOTE**: Half image size works well for most projects and is a good balance for processing speed and accuracy. However, to reduce processing time for this exercise we recommend going with 1/4 image size. If your computer does not have a dedicated GPU or has less than 16GB of RAM, you may want to change this setting to 1/4 or 1/8 to reduce processing time for this exercise. Also, the **Generate Orthomosaic Preview** option adds processing time, so that's why we recommend turning it off for this exercise.*

4. Click on the **Matching** and **Calibration** tabs to review settings. However, for this exercise, we'll use the default values.
5. Click on the **Resources and Notifications** options and ensure that there is a checkmark next to your NVIDIA GPU, if you have one. Using a GPU will greatly reduce processing times.



6. Click **OK** to close the Processing Options window.
7. Once again, make sure there is a checkmark next to only **1. Initial Processing** and then click **Start**. Depending on your computer's components, this can take several minutes to run.



8. Review the generated Quality Report to ensure that all images aligned and that there is are no overlap issues within the dataset. The report will automatically export as a PDF to your project folder and update each time you run a new step.

Note: Your Quality Report contains insights into the calibration (alignment) of the images and the optimization of the camera(s). It contains useful graphics to help you spot problem areas where there might not be enough image overlap. The Bundle Block Adjustment section shows the optimized values to help remove distortions that are caused by imperfections with the camera and lens. The report also records information about which processing settings were used.

Red image points in the rayCloud and in the Quality Report indicate that the image(s) didn't align correctly due to insufficient tie points. In some cases, changing settings within the **Initial Processing** step and rerunning it can help improve results. The main settings to change while troubleshooting non-aligned images are the Image Scale (under the General tab) and increasing the number of keypoints (under the Calibration tab). Image alignment issues are usually caused by insufficient image overlap.

9. Monitor the processing status bar at the bottom of the PIX4Dmapper interface. After it completes, save your project (**Project**, **Save**).
10. Select the **rayCloud** tab on the left hand side of the software interface and navigate around the cameras and Tie Points cloud in the main window. Left click and hold to pan around and zoom into the point cloud as you move your mouse or finger on your trackpad, and hit shift in addition to rotate the point cloud.

Part 3: Adding GCPs

UAS images typically contain geotagged coordinates (embedded in the files) to georeference the outputs. These geotagged coordinates are usually accurate to within 2 meters or so, which provides sufficient accuracy for many projects and applications. However, if the images lack geotagged coordinates or if you wish to improve the accuracy of the products, the user can optionally use Ground Control Points (GCPs) to refine the model. Ground coordinates for GCPs generally come from another reference image or by collecting the information in the field with a GPS unit. The latter method, which is the method used for this exercise, generally produces the most accurate results but also requires the use of specialized GPS equipment and potentially the help of a survey crew that knows how to use the equipment. Refer to the zoomed-in images referenced in Appendix A to see the GCPs for this exercise.

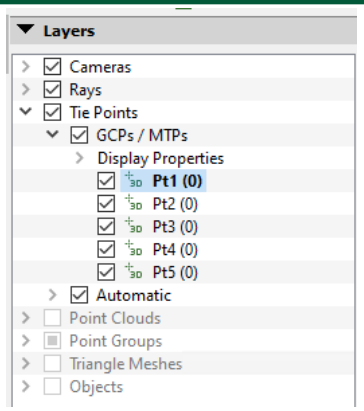
A minimum of three GCPs are needed to georeference the model. For best results, it is recommended to distribute five to ten GCPs throughout the model. GCPs can be added either before or after running the **Initial Processing** step. It is easiest and most efficient to add them after image alignment using the rayCloud, which is what we'll do for this exercise. The main advantage of the rayCloud is that it automatically estimates which images GCPs fall on since the images have already been aligned. This makes placing GCPs with the rayCloud much faster than using the Basic Editor tool. For this exercise, we will locate five GCPs that were marked in the UAS imagery with orange bucket lids.

A. Adding the first Ground Control Point

1. Under **Project** in the main window, click **GCP/MTP Manager**.
2. Click **Import GCPs**.
3. For **Coordinates Order**, select **X, Y, Z** then **Browse** and locate the file Pineview_GCPs.txt with the GCP coordinates in the course downloads folder. Click **Open** and **OK**. The table will be populated with the GCP coordinates.
4. Click **rayCloud Editor**. The GCP Manager window will close and you should now have the properties of the first GCP displayed on the right of your screen.

Note: GCPs can be manually created using reference imagery and a digital elevation model (DEM). However, keep in mind that your products will only be as accurate as the reference data. In this exercise, GCP coordinates are provided, but tools like ArcGIS Pro or Google Earth can be used for displaying reference data and for obtaining the needed GCP coordinates. To create your own GCPs, you'll need to locate unchanged features (rocks, road intersections, trails) that are clearly visible in both the UAS imagery and the reference imagery. You would then make note of the longitude, latitude, and elevation (x, y, z) values of those features, as found in the reference data viewer (ArcMap or Google Earth). This information can then be added into the GCP/MTP Table located in the GCP/Manager window.

5. Under the **View** tab in the main menu, ensure **rayCloud** and **Show Sidebar** are turned on.
6. In the **Layers** list on the left-hand side, click the drop-down arrow next to **Tie Points** if it is not already expanded, and do the same again for **GCPs/MTPs**. You should now see all 5 GCPs listed.

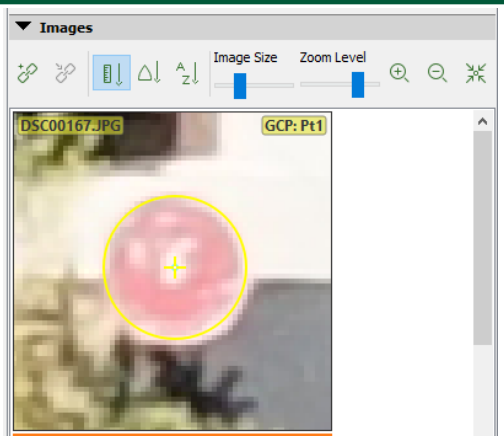


7. Click on the first GCP listed. This will activate the first GCP in the **Properties** sidebar on the righthand side of the screen, which is where you'll locate and mark the GCPs in the individual images.

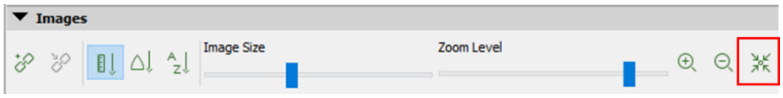
NOTE: *If you don't see any images in the sidebar, you may need to click on* ***Images*** *at the very bottom of the Properties sidebar. Also, if you want more space for viewing the images, you can collapse* ***Selection*** *and resize the Properties sidebar as needed. The* ***Images*** *pane displays all images that Pix4Dmapper estimated to include GCP 1. The blue circle with a dot in the middle is the estimated location. It is common for the estimate to be off by a few meters to begin with. As you start to mark the GCPs, the estimate will be refined.*

8. In the **Images** pane, you can drag the **Image Size** slidebar to better see the images. You can also use the Zoom Level slidebar or Plus/Minus magnifying glasses to change the zoom on all images.
9. The first GCP is located at the center of the bucket lid at the edge of a pedestrian bridge. View the following image to see where to place the first GCP.

10. To mark your first GCP, zoom out on the first image by placing your cursor over it and using your scroll wheel. Once you see the bucket lid near the corner of the bridge, use your scroll wheel to zoom in until you can clearly see the bucket lid. You can also pan around the image by holding down your mouse's left button and dragging the image.
11. Left click on the center of the bucket lid to place the GCP. A yellow circle with a green X in the middle will appear.

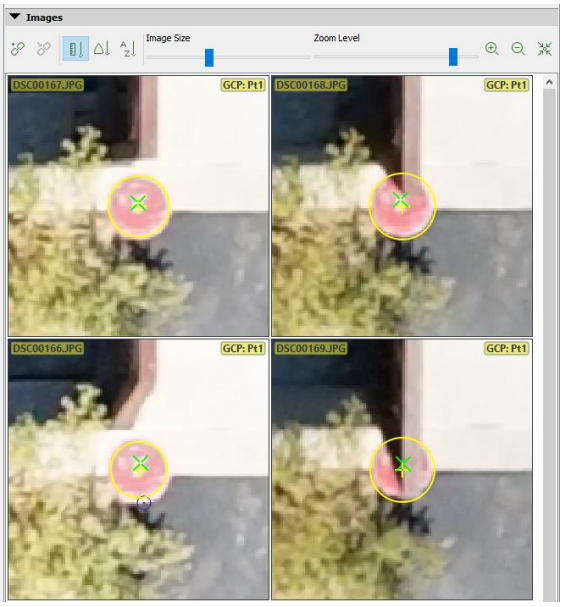


12. If you need to refine the placement of the GCP, either left click on a new spot in the image or drag the yellow circle to the correct location using your mouse's left button.
13. Repeat the last few steps to continue marking GCP 1 on the next couple images. This will help Pix4Dmapper refine the estimate for GCP 1.
14. Click on the **Focus on Selection** button at the top of the **Images** pane. This will recenter the estimated location on each image to make it much easier to mark GCP 1.



15. Continue marking GCP 1 on the remaining images.
16. Expand the **Selection** section (in the Properties sidebar) and hit **Apply**. This will save your edits for GCP 1.

NOTE: *Pix4Dmapper automatically filters the images that potentially include GCP 1. However, a few of the images may be just on the edge of where the GCP was located. If you can't find the bucket lid in an image or you can't clearly see it, go ahead and ignore it and move onto the next image.*

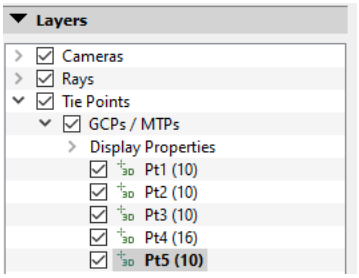


B. Adding the remaining GCPs

1. Click on the next GCP (Pt 2) in the **Layers** list on the left of your screen. The Images pane should update to show the image that potentially include GCP 2.
2. Repeat the steps covered in the previous section to mark GCP 2. Refer to Appendix A for the placement of GCP 2.

NOTE: *The images that you are placing the GCPs on may not always be oriented in the same direction as the images shown in Appendix A. This is because the images in Appendix A are oriented with north being up and the UAS images are oriented depending on the direction and orientation of the UAS during image collection. It is common for the UAS to rotate 180° at the end of each flight line. This may make it trickier to place some GCPs but is something frequently encountered in UAS data processing.*

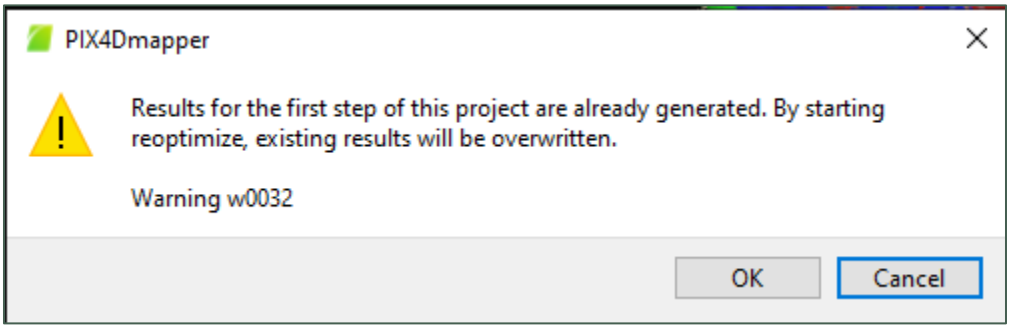
3. Repeat steps from the previous section until all 5 GCPs have been marked in the images. Remember to click the **Apply** button under the **Selection** pane after marking a GCP's images.
4. Under your GCPs in the Layers list, you should now see the number of images that each GCP was place on, similar to the following image.



5. Close the **Properties** sidebar by clicking the "**X**" to the right of **Properties**.

C. Reoptimizing

1. Under **Process** in the main menu, click **Reoptimize** and then save your project. Click **OK** if a warning message appears.



Note: *If the operation to rerun the first step fails, make sure you do not have the previously generated Quality Report open in Adobe.*

Running Reoptimize will rerun the optimization portion of ***1. Initial Processing****. This will update the model and image locations to better fit the GCPs, with the goal of improving the global accuracy of the products. However, keep in mind that adding GCPs is an optional step and isn't needed for all projects. If improved accuracy isn't needed, users can move directly to creating the dense point cloud and orthomosaic after the Initial Image Processing.*

2. You can review the GCP error estimates and the refined calibration in the updated Report that opens after reoptimization. You can also access the report at any time by clicking on **Process** in the main menu and selecting **Quality Report**.

Ground Control Points

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
Pt1 (3D)	0.020/ 0.020	0.004	0.001	-0.002	1.449	10 / 10
Pt2 (3D)	0.020/ 0.020	-0.010	-0.007	0.004	1.224	10 / 10
Pt3 (3D)	0.020/ 0.020	0.013	0.005	-0.003	1.244	10 / 10
Pt4 (3D)	0.020/ 0.020	-0.003	0.008	0.000	0.714	16 / 16
Pt5 (3D)	0.020/ 0.020	-0.004	-0.007	0.001	1.068	10 / 10
Mean [m]		0.000007	-0.000056	0.000064		
Sigma [m]		0.007854	0.006043	0.002324		
RMS Error [m]		0.007854	0.006043	0.002325		

Part 4: Creating a Dense Cloud and Orthomosaic

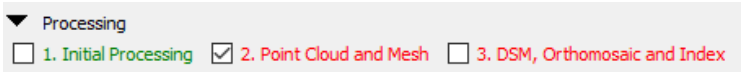
In this next section, we'll run **2. Point Cloud and Mesh** to create a dense point cloud by using the automatic tie points and GCPs a starting point. The total number of dense points that will be created, usually in the thousands to millions, depends on several factors, including but not limited to, image overlap, image content, and settings specified. The dense point cloud will provide a 3D representation of your study area and enable the generation of a DSM (and textured mesh, if desired). In **3. DSM, Orthomosaic and Index**, you will use the DSM as the input to generate the orthomosaic output.

A. Generating a Dense Point Cloud

1. Click on **Processing Options** in the bottom left-hand corner of the main window. Under the Point Cloud section, use the following settings (see following note):
   i. Image Scale: 1/4 (Quarter image size)
   ii. Point Density: Low
   iii. Minimum Number of Matches: 2
   iv. Classify Point Cloud: unchecked (unless if you want to give ground classification a try, but this will increase processing time)

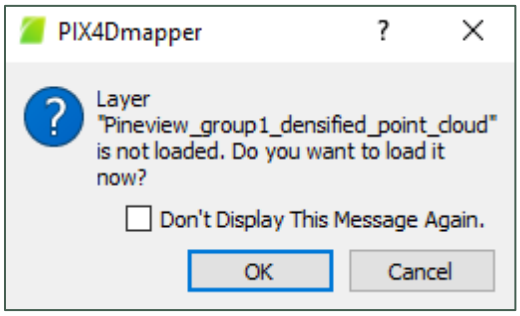
NOTE: *For this exercise dataset, we modified the default settings a bit to decrease processing times, but also to reduce voids in the point clouds and other products due to the dense vegetation. Half image scale works well for most projects. However, if you notice several gaps in the dense point cloud in vegetated areas, sometimes decreasing the image scale to 1/4 will produce better results. Decreasing the minimum number of matches to 2 may also help fill some of those gaps. The image scale greatly impacts processing times. Every step up in image scale (e.g., 1/4 to 1/2 scale) will nearly quadruple your processing time. If your computer doesn't have a dedicated GPU or at least 16GB of RAM, you could go with 1/4 for image scale to decrease processing time.*

2. Click on the **3D Textured Mesh** tab and uncheck **Generate 3D Textured Mesh** (unless if you want to produce a 3D model of the site, but this will increase processing time and isn't needed to create the orthomosaic).
3. Click **OK** to close Processing Options.
4. In the **Processing** menu at the bottom left of the screen, be sure to uncheck **1. Initial Processing** so as to not overwrite what you have already created and place checkmark next to only **2. Point Cloud and Mesh**. Then click **Start**.

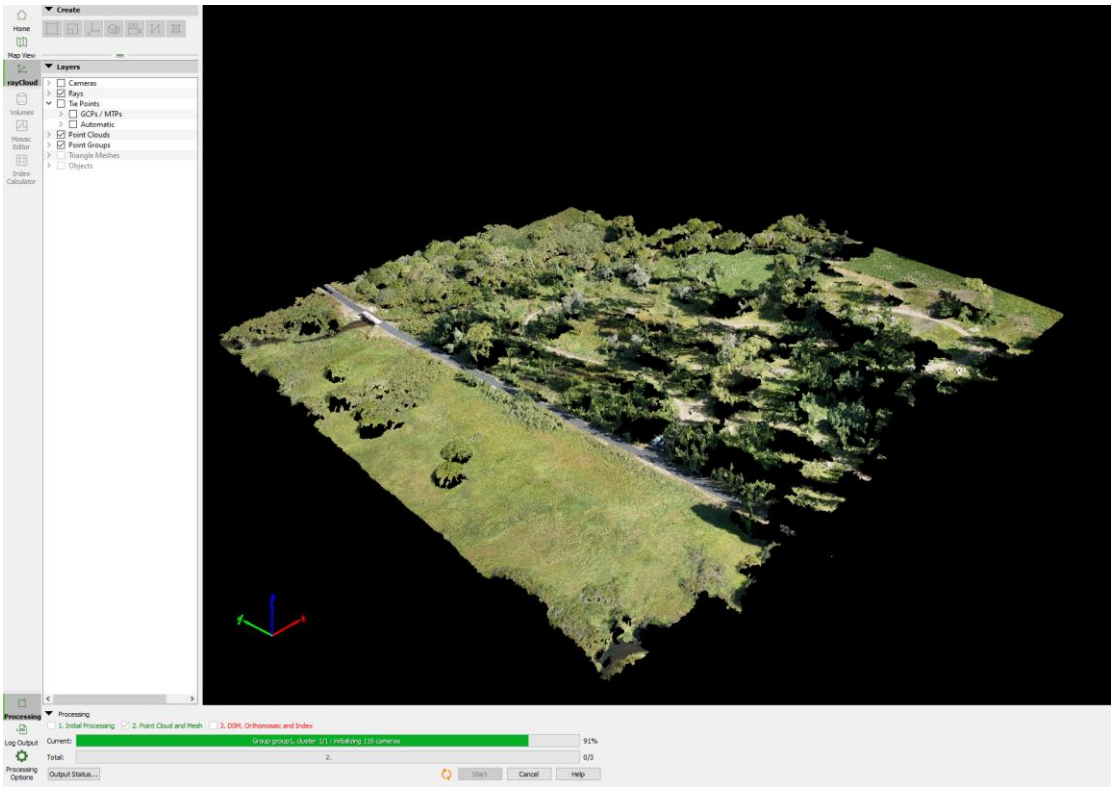


i. Expect for this to take anywhere from a few to several minutes to run, depending on your computer's components (RAM, GPU, processor, hard drive type).

5. Close your generated report, then navigate to **Layers** on the left-hand side of the screen and uncheck **Cameras** and **Tie Points.**
6. Under **Layers**, check **Point Clouds** and click **OK** in response to the warning message as shown below. Navigate around your dense point cloud.



Note: To tilt view your dense point and mesh, hold shift as you left click on your mouse or trackpad and move in the direction you would like to view the generated products from. Use the scroll wheel to zoom in and out. Left click to move horizontally. Click and hold the scroll wheel to orbit. To view all points within your dense point cloud, hit the **View All** button on the View toolbar.



7. Under **Project**, click **Save**.

B. Generating an Orthomosaic

1. Click the **Processing Options** button in the lower left of the screen.
2. Click on **3. DSM, Orthomosaic, and Index** and review the various options under the DSM and Orthomosaic, Additional Outputs, and Index Calculator tabs. Following are important settings for the DSM and Orthomosaic tab:
   i. For most projects, you'll want to leave the resolution at 1 x GSD to produce the highest resolution products possible based on your input imagery. However, for this exercise, go ahead and change the resolution to **Custom** and then enter **3 cm/pixel**. This will greatly reduce processing time for creating both the DSM and orthomosaic.
   ii. Place checkmarks next to GeoTIFF and Merge tiles for both the Raster DSM and Orthomosaic sections. This will ensure that DSM and orthomosaic TIFFs are generated. And having them merged is oftentimes easier to manage than separate tiles.
3. In the **Processing** menu, ensure that **1. Initial Processing** is still unchecked, uncheck **2. Point Cloud and Mesh** and check **3. DSM, Orthomosaic, and Index**.
4. Click **Start**. This may take several minutes to run, depending on your computer's components.
5. Note how the newly generated Quality Report resembles the previous one with additional information about your orthomosaic. Click **Close**.
6. On the left-hand side panel, click on **Mosaic Editor**.
7. In the main menu at the top of the software interface, click **Mosaic Editor**, then **View** followed by **Show DSM** to view your DSM and navigate around the output using the same methods to zoom, pan and tilt as described earlier in **Part 5**.
8. In the main toolbar, click on the **Display Mosaic** dropdown and select **Mosaic (group 1)** to view and explore the orthomosaic output. Zoom in and see if you can spot the bridge, picnic tables, firepit, and any pedestrians.
9. In the **Mosaic Editing** menu on the right-hand side, you have the option to edit and export a new orthomosaic (see following note). However, if no edits are necessary, you can go directly to your outputs in File Explorer by clicking on **Process** in the main menu and selecting **Open Results Folder**. The output files can be added to GIS software for additional analysis.
10. Under **Project**, click **Save**.

Note: Sometimes distortions may occur in an orthomosaic due to errors in the surface model and features not fully visible in overlapping images, especially if there is a lot of tall vegetation. You may wish to generate new products using different settings or edit your existing one. If there are relatively low number of distortions, you can use the Mosaic Editor to improve your outputs, see **Exercise 2: Additional Processing of UAS Imagery in PIX4Dmapper**, otherwise, consider rerunning Step 3 after making changes to the project's parameters by exploring the settings for each step under **Processing Options**.

Conclusion: Congratulations! You have completed this first Pix4Dmapper exercise for processing UAS Imagery! In this exercise, we learned how to use Pix4Dmapper to align images, add GCPs for georeferencing purposes and create a dense point cloud 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.