Kinematic Positioning and Navigation – Winter 2018: Homework #5

Structure from Motion (SfM)

Overview: In this homework assignment, you will process imagery acquired with a senseFly albris (formerly called "eXom") unmanned aircraft system (UAS) in structure from motion (SfM) photogrammetry software to obtain GIS-ready data products, including an orthomosaic in GeoTiff format and a point cloud in ASPRS's LAS format. The imagery was acquired with the senseFly albris UAS (shown below) over a tower on April 26, 2016. The processing will be performed in Pix4D drone mapping software. We will first perform rough georeferencing, relying solely on stand-alone, L1 code-ranging GNSS acquired on the albris. Then, we will add GCPs surveyed with RTK GNSS and see if this improves the results.

Part I: Pix4D Project Setup and Processing

Before you can complete this exercise, you will need to set up a Pix4D trial account, download and install the software, and download the UAS imagery.

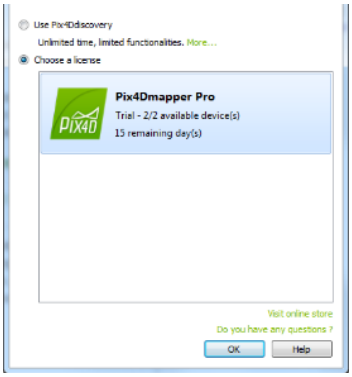
1. Go to: https://cloud.pix4d.com/signup/
    a. Fill out the online form to create a new account.
    a. You will receive two email messages from Pix4D, the first asking you to confirm your email address and the second saying that your account has been created. Once you get the 2nd email from Pix4D, you can just log into Pix4D with the email address and password you created.

b. Download and install the Pix4D Mapper software.

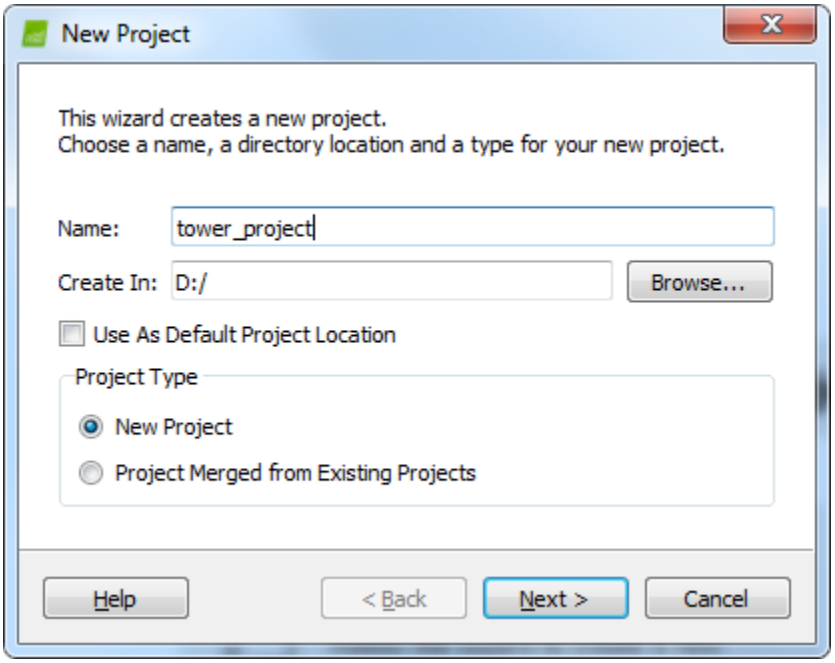
2. Copy the JPEG images from the following FTP site to this imagery folder: ftp://ftp.engr.oregonstate.edu/pub/civil/Parrish/UAS_SfM_workshop/

   Also copy the file called GCPs_tower.txt from the FTP site to your local folder.

3. Start Pix4D and log in using your new account. When prompted, select "Choose a license" and the Pix4Dmapper Pro, then click ok.



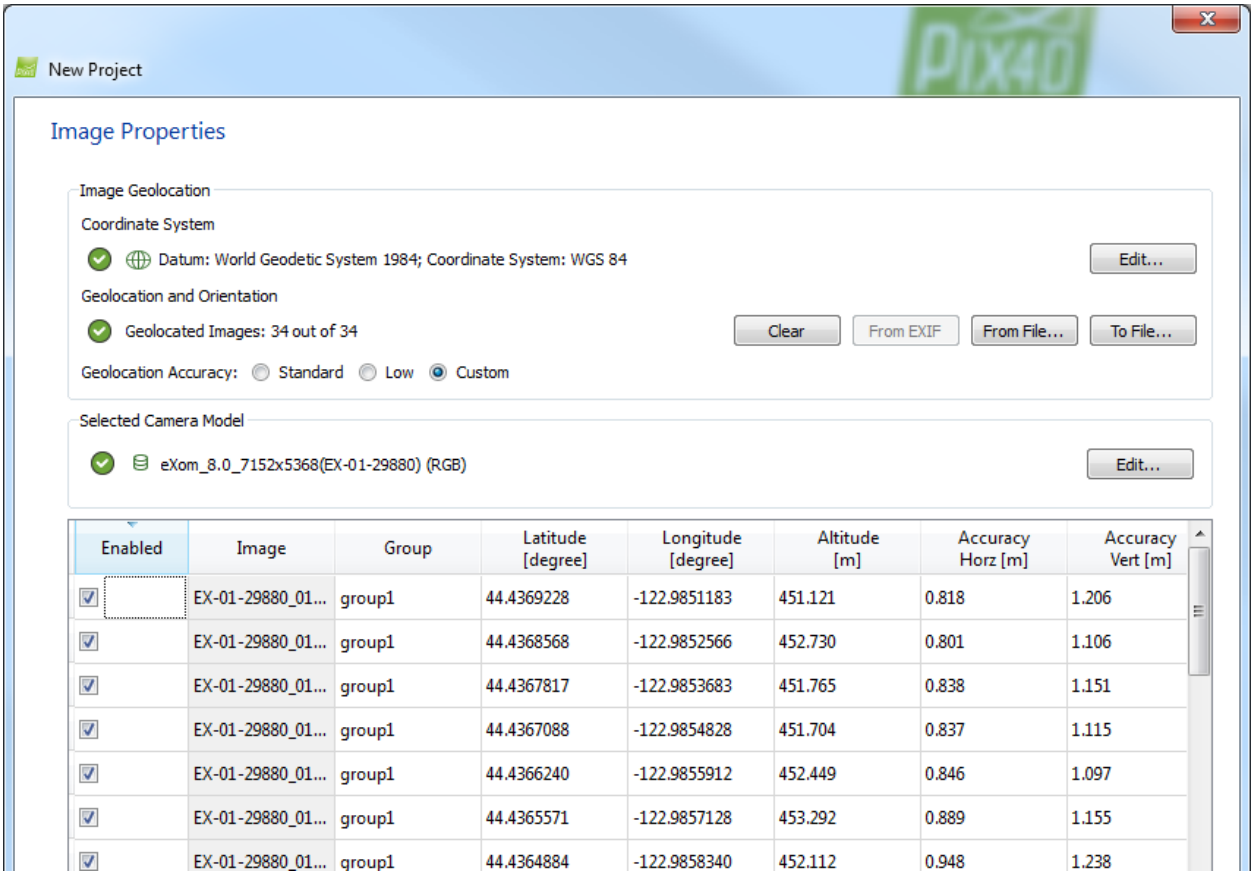
4. Click Project, New Project
   a. Browse to your local drive and name the project: tower_project. Then click Next.



5. At the Select Images window, click Add Images and then select all the images in the imagery folder that you created on your local drive earlier.

a. Click Next

6. At the Image Properties window, keep the datum and coordinate system set to WGS 84, as the positioning is based on the stand-alone pseudorange GNSS recorded in real-time on the UAS. You should see the following for Image Properties:



Enabled	Image	Group	Latitude [degree]	Longitude [degree]	Altitude [m]	Accuracy Horz [m]	Accuracy Vert [m]
☑	EX-01-29880_01...	group1	44.4369228	-122.9851183	451.121	0.818	1.206
☑	EX-01-29880_01...	group1	44.4368568	-122.9852566	452.730	0.801	1.106
☑	EX-01-29880_01...	group1	44.4367817	-122.9853683	451.765	0.838	1.151
☑	EX-01-29880_01...	group1	44.4367088	-122.9854828	451.704	0.837	1.115
☑	EX-01-29880_01...	group1	44.4366240	-122.9855912	452.449	0.846	1.097
☑	EX-01-29880_01...	group1	44.4365571	-122.9857128	453.292	0.889	1.155
☑	EX-01-29880_01...	group1	44.4364884	-122.9858340	452.112	0.948	1.238

7. Camera Model should be auto-populated (e.g., albris_8.0_7152x5368). Click Edit to look at the camera model info.

Q1: What is the image sensor format (rows by columns) in mm and in pixels?

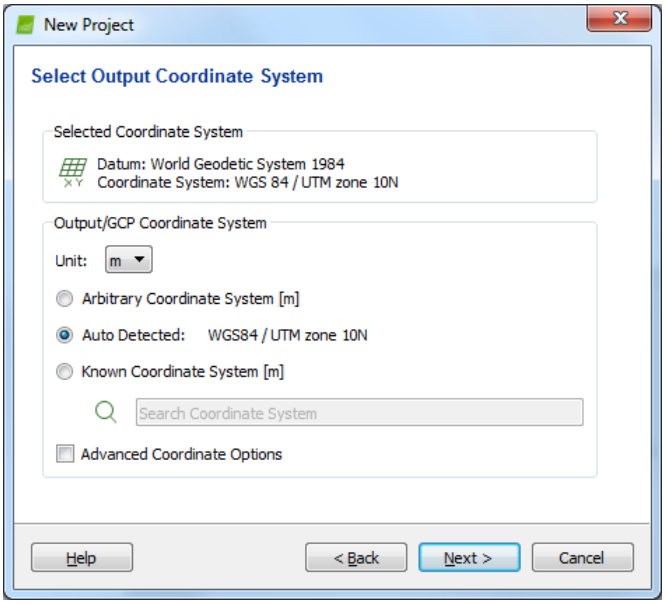
Q2: What is the camera focal length in mm?

Q3. What is the pixel size on the chip in µm?

8. Click OK, and Next when finished examining the camera model info. This will bring you to the "Select Output Coordinate System" Menu. Leave the default value as "auto-detected: WGS-84 /

UTM zone 10N" and the units as meters. This will set the map projection to Universal Transverse Mercator (UTM), Zone 10 N.

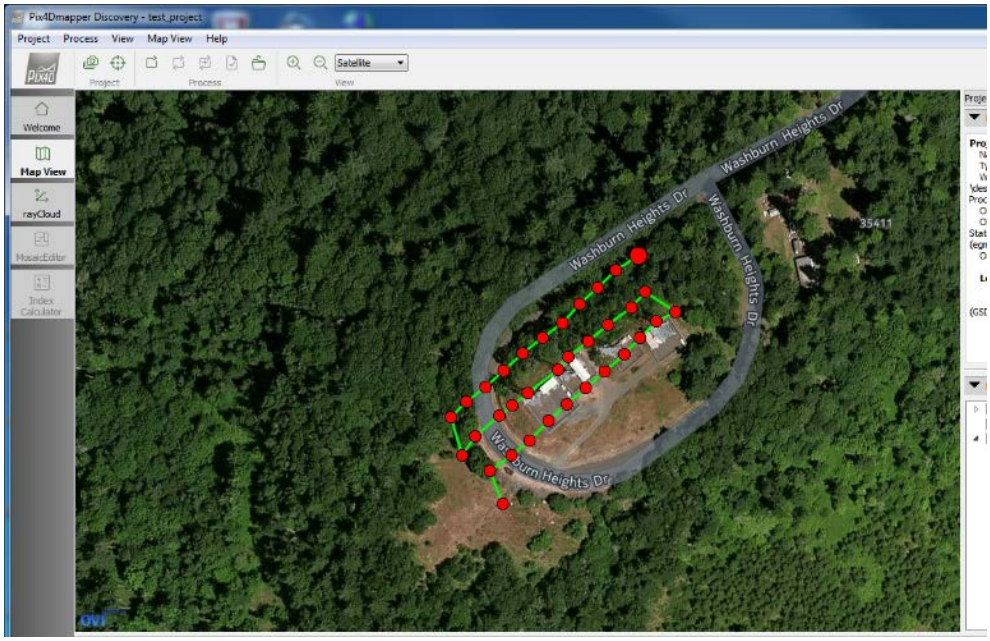
Q4: What are UTM coordinates, and what longitude range is spanned by zone 10N?



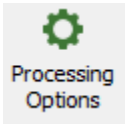
9. Click Next to bring you to the Processing Options Template. (Note: it is not necessary to use a Processing Options Template, but this will save you time in generating some of the standard outputs with default options.)

10. In the Processing Options Template, select 3D Maps. This will generate a number of outputs, including an orthomosaic and a point cloud, which are our desired outputs for this exercise.

11. Click Finish, and you should be back to the main Pix4D interface. Using the mouse scroll wheel, zoom in on your photo centers to see the flightlines:



12. Before you start processing, it is important to ensure the settings are what you want. Click Options and verify that the following options are selected (these should all be the defaults):



(Lower Left of Window)

    a. Initial Processing, General:
        i. Full Keypoints Image Scale
        ii. Check Generate Orthomosaic Preview in Quality Report
    b. Point Cloud and Mesh
        i. Image Scale = ½ (Half image size, Default)
        ii. Point Density = Optimal
        iii. Minimum Number of Matches = 3
        iv. Export: LAS
        v. Under 3D Textured Mesh, check the box for Generate 3D Textured Mesh, Medium Resolution
        vi. Click OK
    c. DSM, Orthomosaic, and Index
        i. Resolution: Automatic: 1 GSD
        ii. Use Noise Filtering
        iii. Use Surface Smoothing: Sharp
        iv. Raster DSM: GeoTIFF, Inverse Distance Weighting
        v. Merge Tiles
    d. Resources and Notifications
        i. Should not need to change anything; just click OK.

13. Under Processing, click all 3 boxes to run: 1) Initial processing, 2) Point cloud and mesh, and 3) DSM, Orthomosaic and Index.

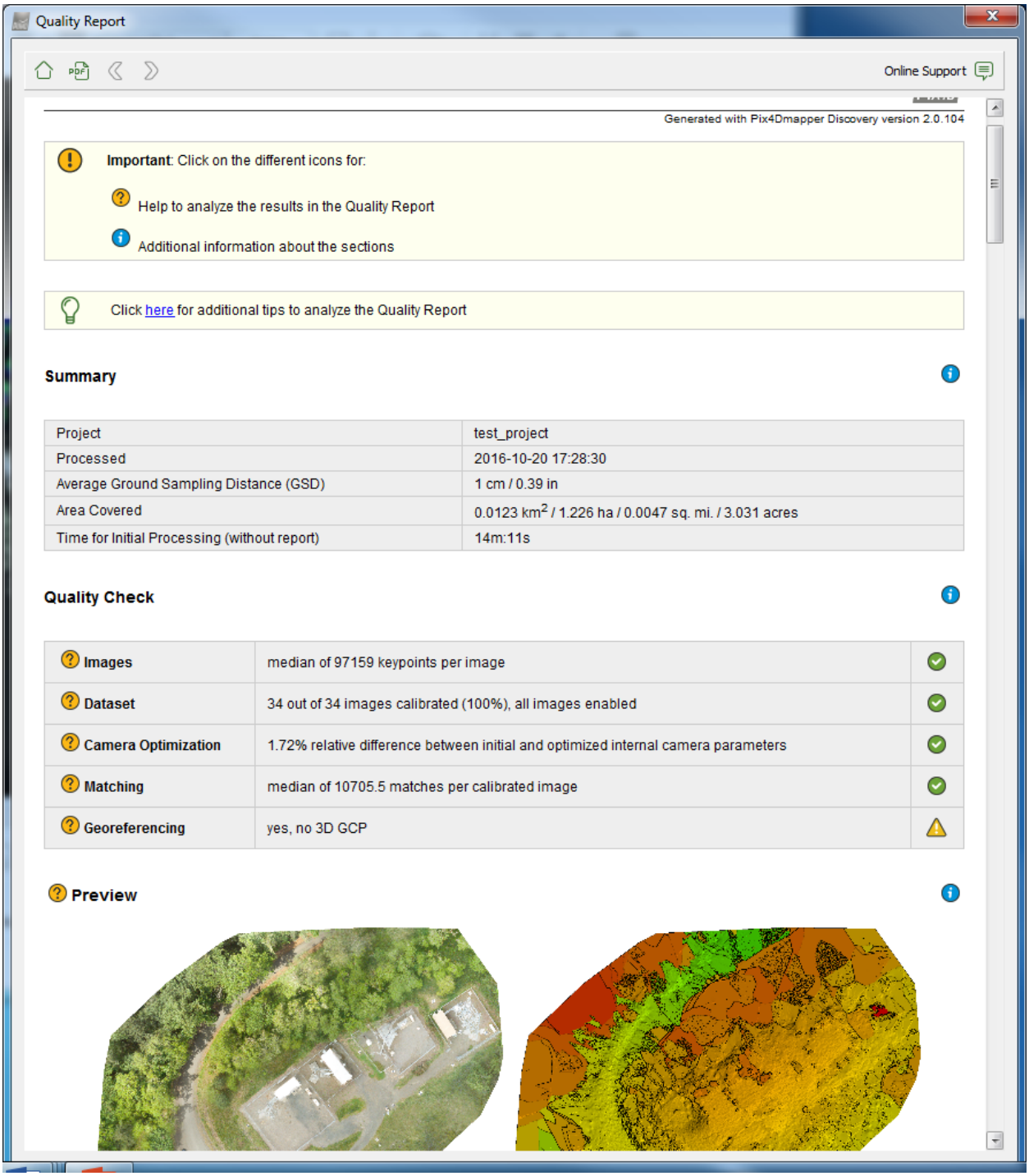
a. Click start
b. Circles representing photo centers will first turn green (as keypoints are computed) and then blue (as matches are computed) as the processing progresses.

14. FYI: the processing may take up to an hour to complete, depending on your computer RAM, graphics card, etc.

Part II: Analyzing Results of Pix4D processing

1. When the processing is complete, review the Quality report. (Note: if it doesn't automatically pop up for some reason, you can view it by opening 

in \Pix4D_demo_exercise\tower_project\1_initial\report\html\ in a web browser.)

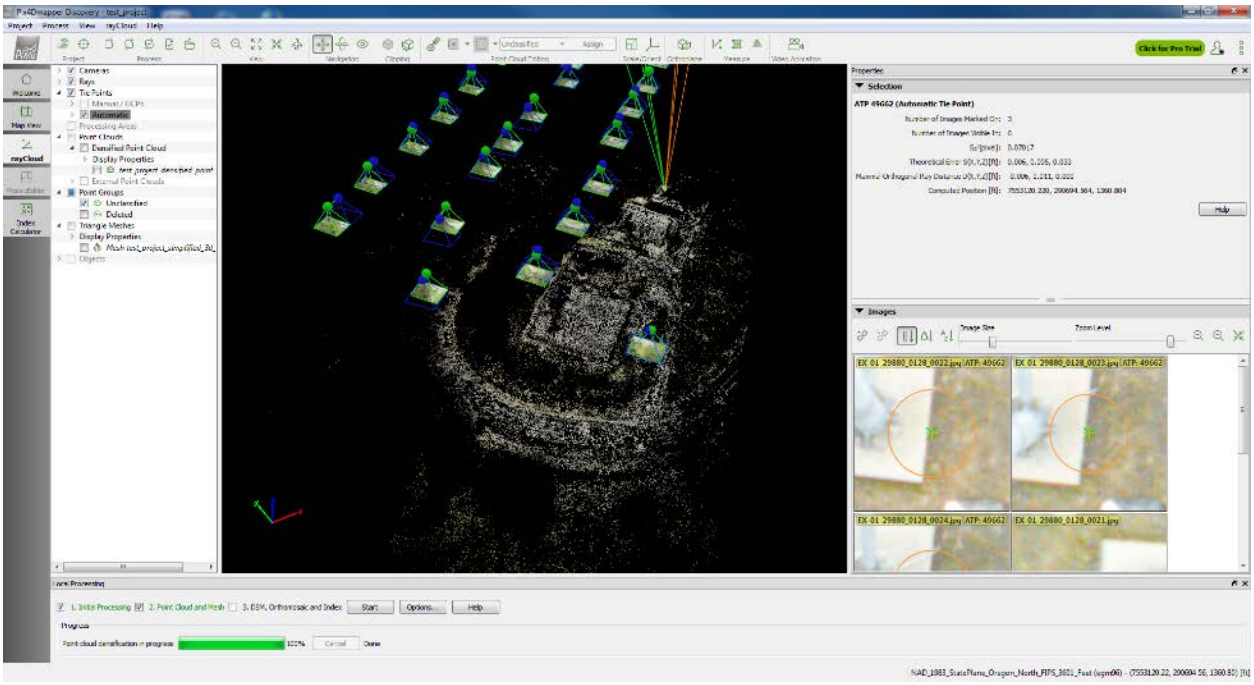


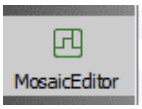
Q5: What is the meaning of the warning symbol next to Georeferencing (in the "Quality Check" section of the report)?

Q6: Under Absolute camera position and orientation uncertainties, what are the mean and standard deviation for X [m], Y [m], Z [m], Omega [degree], Phi [degree], Kappa [degree]?

2. When all processing steps are completed, with the rayCloud tab selected 

explore the point cloud that was generated
    a. You can use the mouse to zoom in and out, and tilt and rotate the point cloud to view it from different perspectives.
    b. By clicking points in the Ray Cloud, you can see all the photos in which a certain point appears



3. Click the MosaicEditor tab 

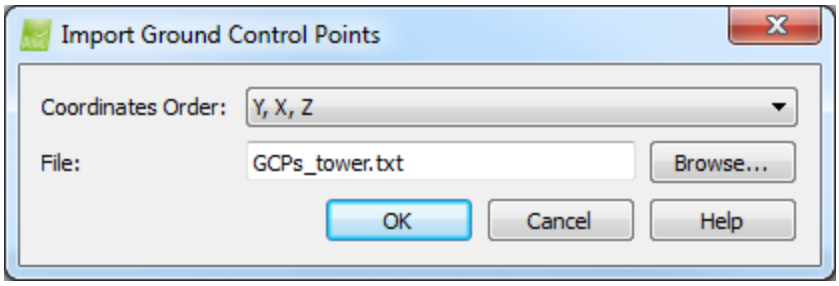
to start the process of generating an orthomosaic. This should take just a few minutes to run, and you will be able to see the ortho when done. Use the zoom tools to zoom in on different areas of the ortho.

<u>Part III: Improving Georeferencing with Ground Control Points (GCPs)</u>

1. The rough georeferencing performed using the geotags provided with the raw albris imagery resulted in an orthosaic with an offset of ~2.2 m (7.2 ft), with respect to the GCPs. To fix this, we will reprocess the imagery in Pix4D using the GCPs, which were surveyed with RTK GNSS.

2. On the Pix4D Menu bar, click Project > GCP/Manual Tie Point Manager

3. Click Import GCPs and browse to select the file GCPs_tower.txt. Make sure the Coordinates Order is set to Y,X,Z (Northing, Easting, Elev) as shown below:



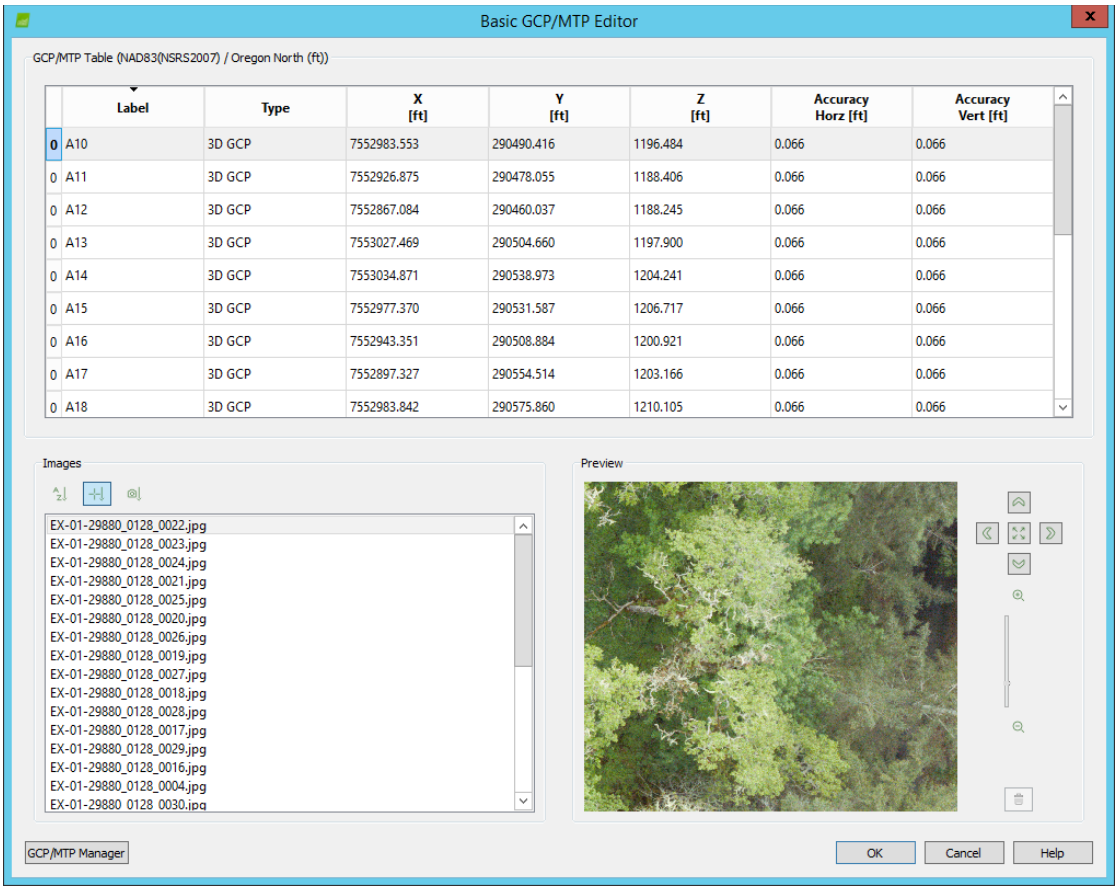
4. Click OK. (Don't worry if you get an error message saying that one or more GCPs are outside the project extents.)

5. Set the Units to ft.

6. Under Known Coordinate System [ft], click From EPSG… and EPSG:3646: NAD83(NSRS2007) / Oregon North (ft).
    a. Aside: this step is technically incorrect, as the correct datum is NAD 83(2011), but this is not available in the software.

7. Click OK and then click on the Basic Editor option.

8. The list of GCPs is displayed:

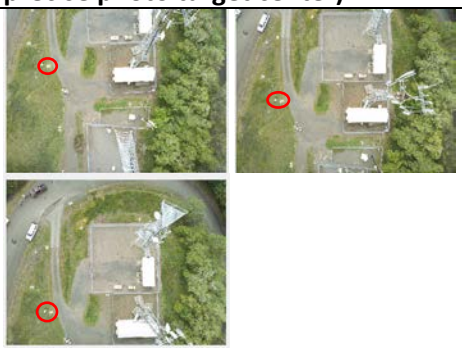
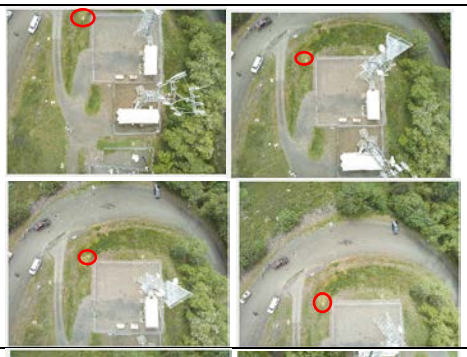
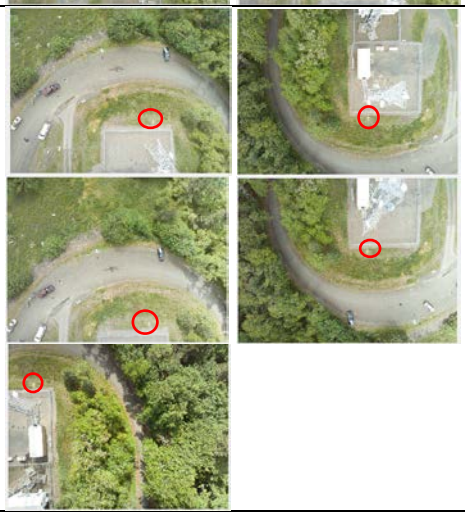


9. One at a time, click on the following GCPs in the table: A14, A16, and A17. Each time you click on a GCP, select each image in which it appears under 'Images' in the lower left portion of the screen. Each time you select an image, zoom in on the GCP in the photo preview and mark the GCP location with a yellow + sign by left-clicking on it.

Note: to navigate in the images and select the exact location of the GCP:

- Zoom in: Move the mouse scroll wheel forwards
- Pan: Using the mouse left clicking
- Click the correct location (center of the B&W cross pattern) with the left mouse button. A yellow + will appear denoting the GCP location

10. Mark the following GCPs on the images shown by zooming in on the photo panels and clicking on the centers of the targets, as shown here:

GCP	Photos in which it's located	Approx. location (note: need to zoom in to select precise photo target center)
A14	EX-01-29880_0128_0026.jpg EX-01-29880_0128_0027.jpg EX-01-29880_0128_0028.jpg	
A16	EX-01-29880_0128_0027.jpg EX-01-29880_0128_0028.jpg EX-01-29880_0128_0029.jpg EX-01-29880_0128_0030.jpg	
A17	EX-01-29880_0128_0030.jpg EX-01-29880_0128_0015.jpg EX-01-29880_0128_0031.jpg EX-01-29880_0128_0014.jpg EX-01-29880_0128_0006.jpg	

11. When you've marked all of the GCPs listed above, just hit OK

12. Click on Process, Reoptimize, and say yes to overwrite existing results. Wait for the "Optimizing with Geoinformation" to run.

13. Click Start to reprocess the imagery. This time you should see “Optimizing with Geoinformation” as one of the steps.

After reprocessing with the GCPs, view the new Quality Report

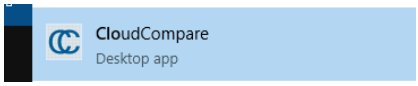
Q7: Do you still have the warning symbol under Georeferencing (in the Quality Check section of the report)?

Q8: What are the ‘Absolute camera position and orientation uncertainties’ now that you’ve incorporated the GCPs into the processing? Did the GCPs improve the results?

Q9: Do you feel the camera position and orientation uncertainties listed in the report both before and after using the GCPs are realistic? Why or why not?

Part IV (Optional): Viewing SfM-Generated Point Cloud in CloudCompare

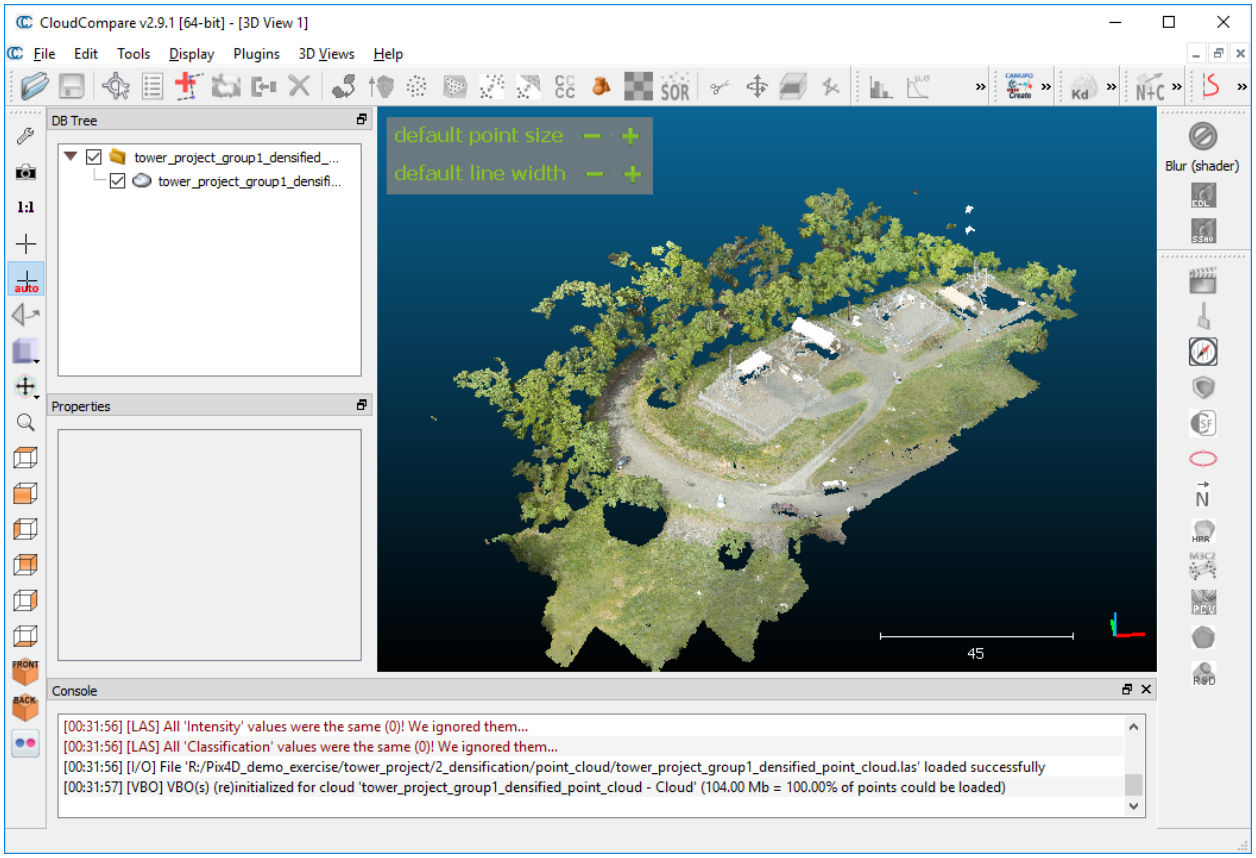
CloudCompare is an open-source 3D point cloud and mesh processing software package. If you want to download and install CloudCompare on your computer, you can use it to view the point cloud that you created using Pix4D.

1. Start the CloudCompare Desktop App: 

2. Find the file tower_project_group1_densified_point_cloud.las in your project folder and just drag it into CloudCompare.

3. Say yes to translate/rescale coordinates that are too big

4. Experiment with different ways to display and analyze your point cloud in CloudCompare:


CloudCompare v2.9.1 [64-bit] - [3D View 1]
File Edit Tools Display Plugins 3D Views Help
DB Tree
tower_project_group1_densified_...
tower_project_group1_densifi...
Properties
default point size
default line width
Blur (shader)
45
Console
[00:31:56] [LAS] All 'Intensity' values were the same (0)! We ignored them...
[00:31:56] [LAS] All 'Classification' values were the same (0)! We ignored them...
[00:31:56] [I/O] File 'R:/Pix4D_demo_exercise/tower_project/2_densification/point_cloud/tower_project_group1_densified_point_cloud.las' loaded successfully
[00:31:57] [VBO] VBO(s) (re)initialized for cloud 'tower_project_group1_densified_point_cloud - Cloud' (104.00 Mb = 100.00% of points could be loaded)

References for this Exercise and Recommended Further Reading:

Fonstad, M.A., J.T. Dietrich, B.C. Courville, J.L. Jensen, and P.E. Carbonneau, 2013. Topographic structure from motion: a new development in photogrammetric measurement. E*arth Surface Processes and Landforms*, 38(4), pp. 421-430.

Pix4D, 2017a. Processing Options Templates. Online: https://support.pix4d.com/hc/en-us/articles/115002471906-Processing-Options-Templates#gsc.tab=0

Pix4D, 2017b. Pix4D Quality Report Help. Online: https://support.pix4d.com/hc/en-us/articles/202558689#label104&gsc.tab=0

Pix4D, 2017c. How to include GCPs in the Project. Online: https://support.pix4d.com/hc/en-us/articles/202560239-How-to-include-GCPs-in-the-Project#gsc.tab=0

Pix4D, 2017d. How to mark GCPs in the rayCloud. Online: https://support.pix4d.com/hc/en-us/articles/202560769#gsc.tab=0