UAS Structure from Motion Image Processing with Pix4D

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Overview: The objective of this exercise is to process imagery acquired with a senseFly albris (formerly called the "eXom") unmanned aircraft system (UAS) in structure from motion (SfM) photogrammetry software to obtain georeferenced 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. Although ground control points (GCPs) were collected during this project using RTK GPS, we will initially perform rough georeferencing, based on the geotags provided with the imagery. (Note: this positioning is based on stand-alone, L1-only pseudorange GPS acquired on the albris.) A discussion of how to add GCPs is included at the end of these instructions.

Part I: Pix4D Project Setup and Processing

1. Log onto the Kearney 302 lab computer (if not already logged in):
    a. Username = coe_work
    b. Password = (provided by instructor)
    c. Note: it may take a while the first time you log onto the computer

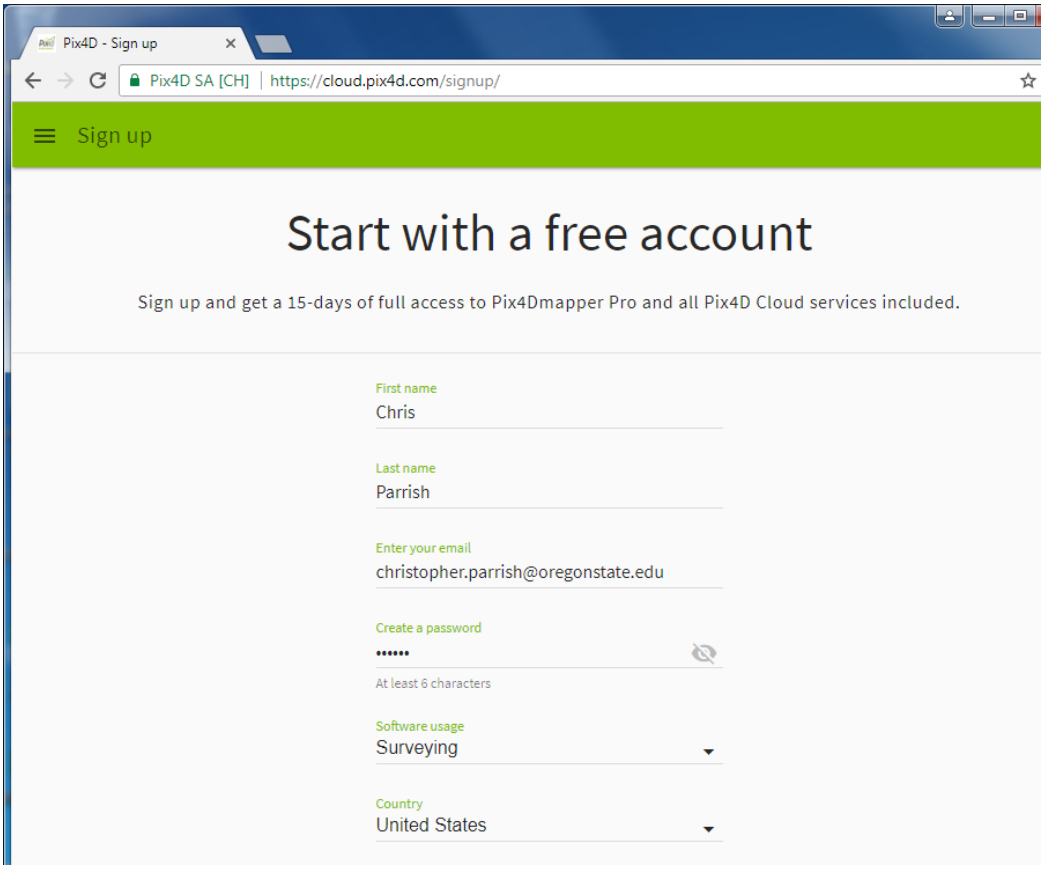
2. Create a folder for this exercise on your D: drive. For example: D:\your_name\
    a. Create a subfolder called \imagery

3. 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 folder on the D drive.

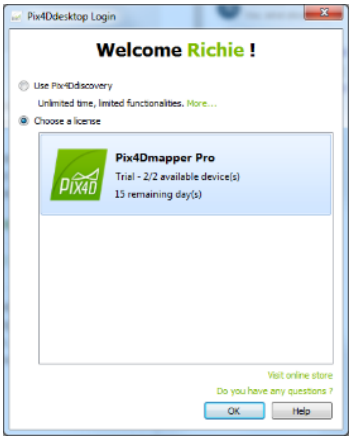
4. Start Pix4D by double clicking its desktop icon 

5. When Pix4D opens, it will ask you to log in or create a new account. If you do not already have an account, click on "Sign up now"
    a. Choose Google Chrome as your browser
    b. Fill out the online form to create a new account, as shown below:

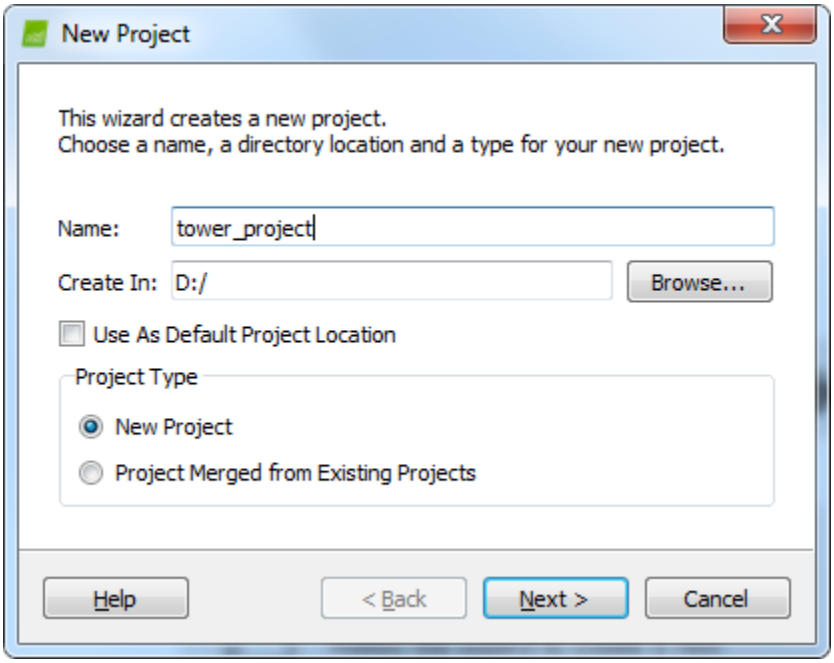


6. You will receive two email messages from Pix4D, the first asking you to confirm your email address and the second saying that your account has been created. Once you get the 2nd email from Pix4D, you can just log into Pix4D with the email address and password you created.

7. When prompted, select "Choose a license" and the Pix4Dmapper Pro, then click ok. (If you get a message about a new version of Pix4D being available, just ignore it.)

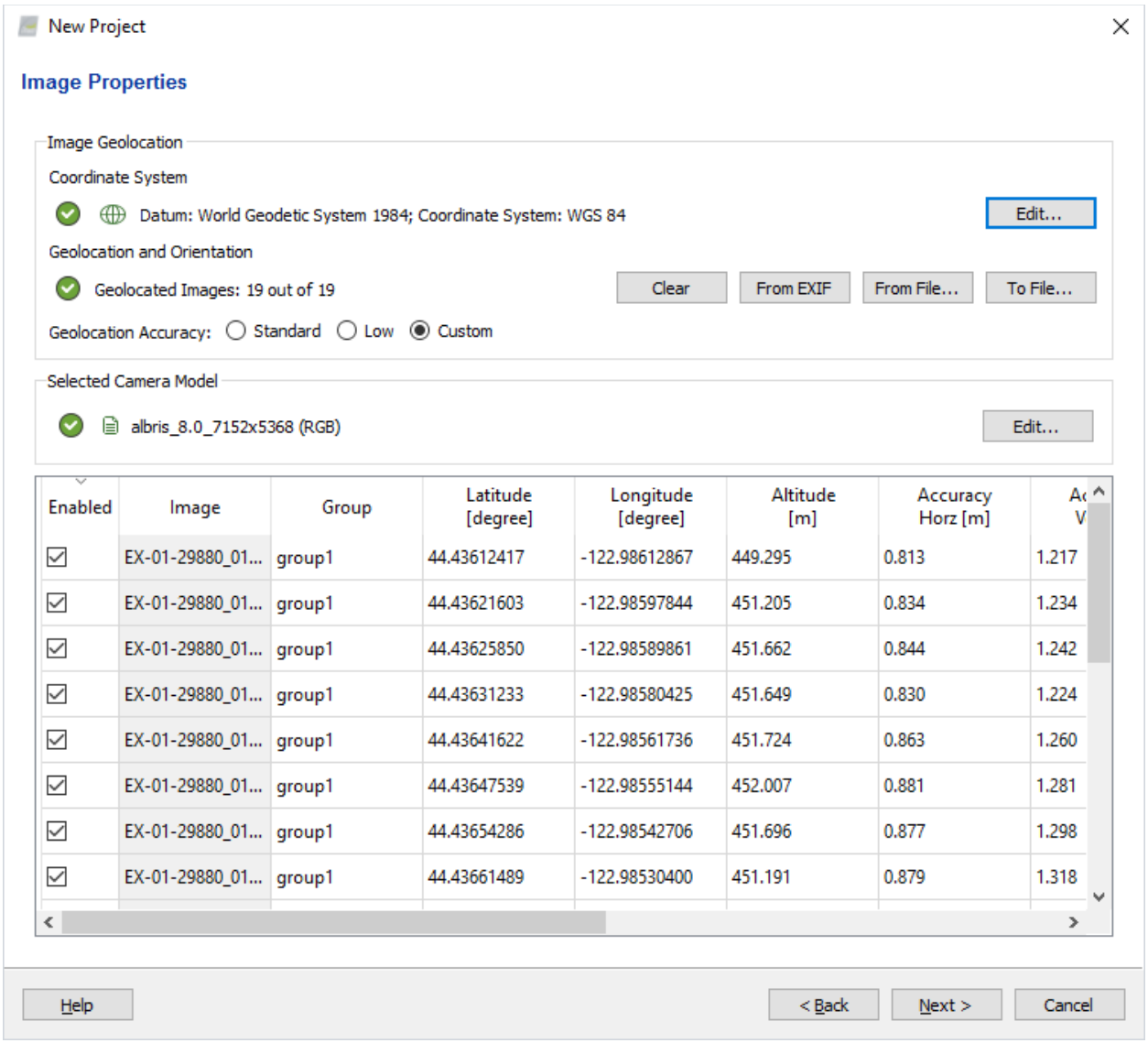


8. Click Project, New Project
    a. Browse to the D:\ drive and name the project: tower_project. Then click Next.



9. At the Select Images window, click Add Images and then select all the images in the imagery folder that you created on the D drive earlier.
    a. Click Next

10. 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 GPS recorded in real-time on the UAS. You should see the following for Image Properties:

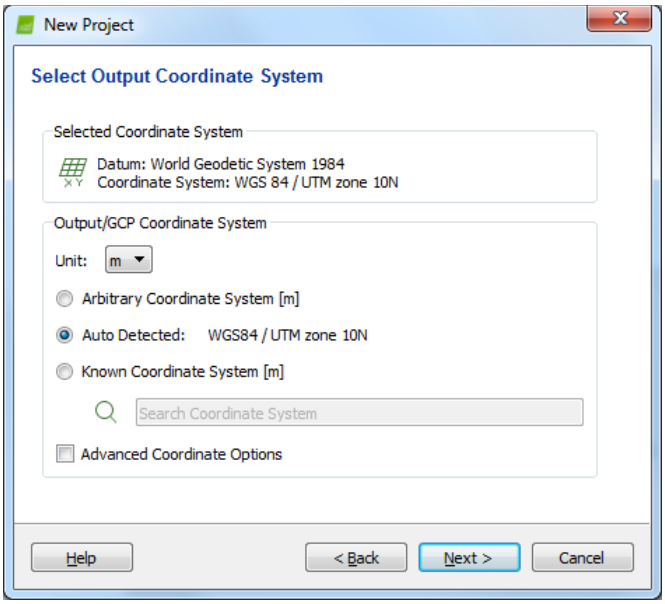


11. Camera Model should be auto-populated (e.g., albris_8.0_7152x5368). Click Edit to look at the camera model info.

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

Q2: What is the camera focal length in mm?

1. 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.



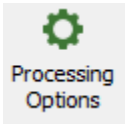
2. Click Next to bring you to the Processing Options Template. (Note: it is not necessary to use a Processing Options Template, but this will save you time in generating some of the standard outputs with default options.)

Q3: What processing option templates are available and what are the outputs of each?

3. 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.

4. 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:

5. 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)

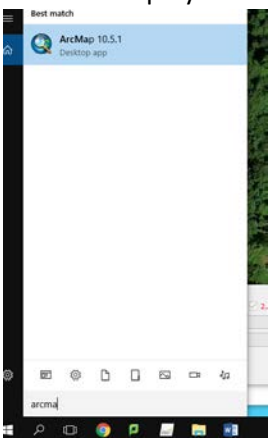
   a. Initial Processing, General:
      i. Full Keypoints Image Scale
      ii. Check Generate Orthomosaic Preview in Quality Report
   b. Point Cloud and Mesh
      i. Image Scale = ½ (Half image size, Default)
      ii. Point Density = Optimal
      iii. Minimum Number of Matches = 3
      iv. Export: 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.

6. Under Local 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.

7. The processing will take up to an hour to complete on the lab computers, so you can move on to Step II: ArcGIS while Pix4D continues working

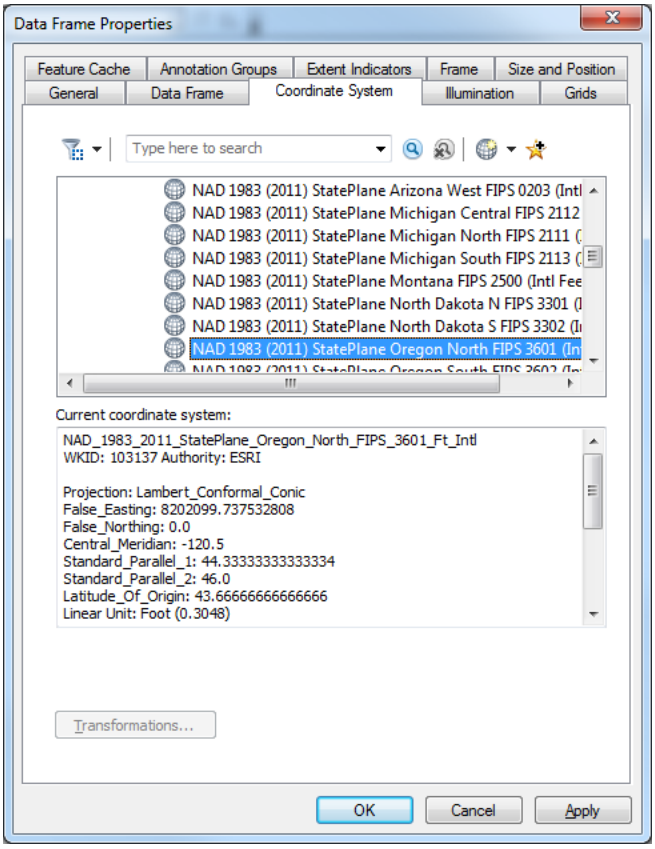
Part II: ArcGIS

1. Start ArcMap by clicking Windows search and typing ArcMap to display ArcMap 10.5.1



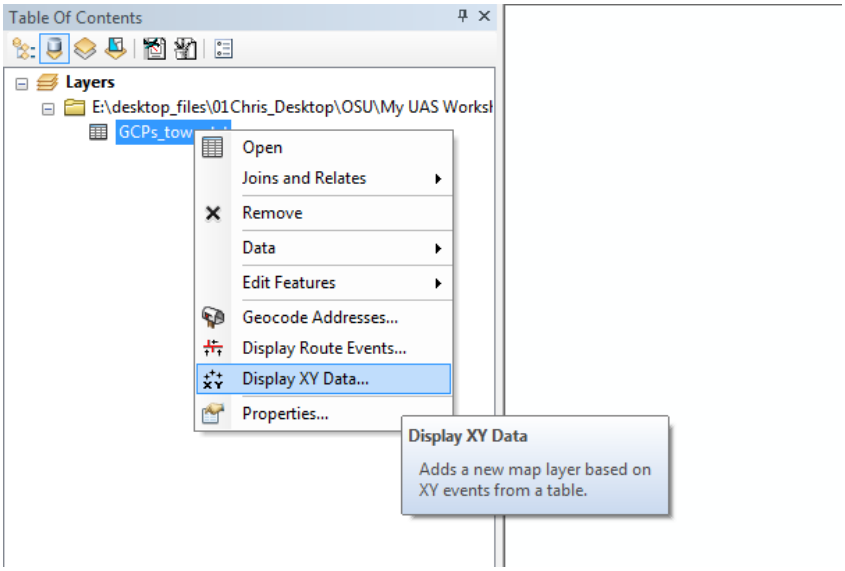
2. In the Table of Contents, right click Layers and select Properties to bring up the Data Frame Properties dialog.

3. Under Coordinate System, select Projected Coordinate Systems, State Plane, NAD 1983 (2011) (Intl Feet), NAD_1983_2011_StatePlane_Oregon_North_FIPS_3601_Ft_Intl. Then click OK.



4. Click on the Add data button  and browse to find the file called GCPs_tower.txt on your D drive (copied from the FTP site in an earlier step). (Hint: if you initially don't see the D drive listed in the Add Data Window, you may have to first click on the Connect to Folder icon  and browse to select it.)

5. In the Table of Contents, right click GCPs_tower.txt and click Display XY data

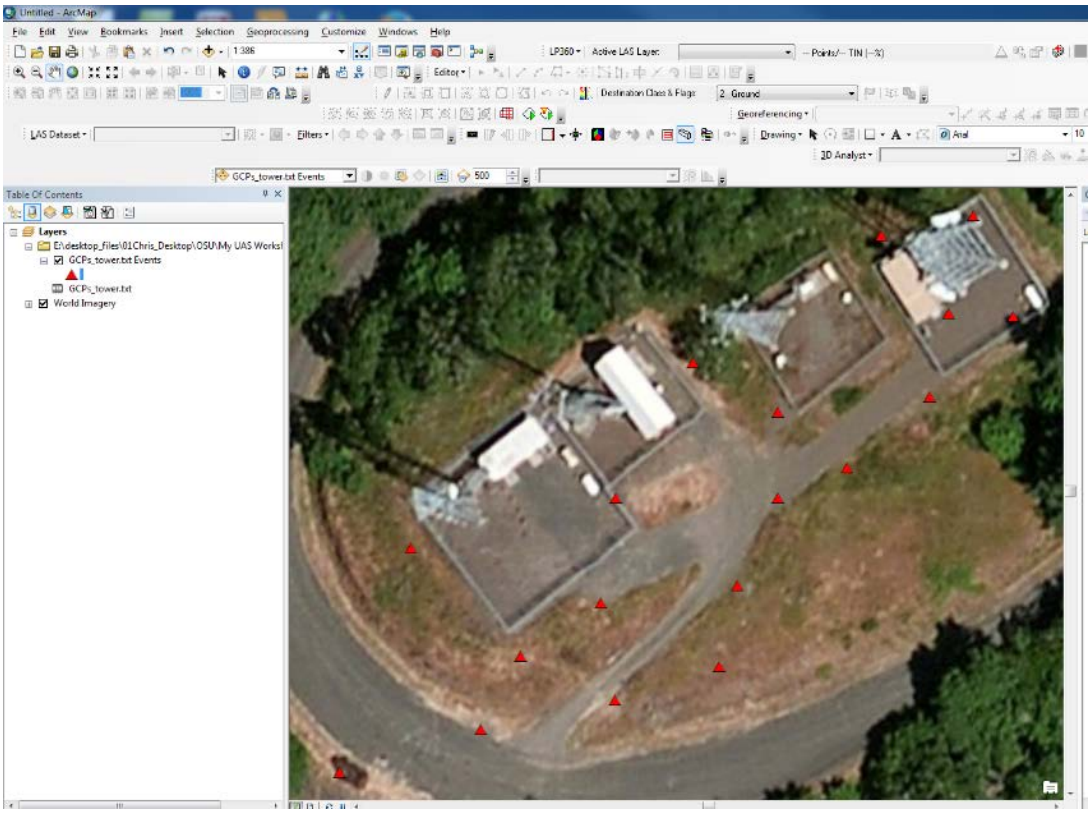


   a. X Field = Easting
   b. Y Field = Northing
   c. Z Field = Elev
   d. Click OK

8. You should now have the GCPs for this project displayed. If desired, you can click their symbol in the Table of Contents and change the symbol to something else, such as a triangle.

9. Click the pulldown menu on the Add data icon  , and select Add Basemap, Imagery.

10. You should now have the GCPs for this project displayed over the Esri World Imagery, as shown below. This is as far as you can get in ArcGIS until the Pix4D processing is completed.



Part III: Analyzing Results of Pix4D processing

1. By this time, hopefully the Pix4D processing is completed. If at least the first step (1. Initial Processing) is finished, you can continue on to the first few steps listed below (examining the Quality Report and examining the point cloud in the rayCloud viewer.)

2. Review the Quality report:

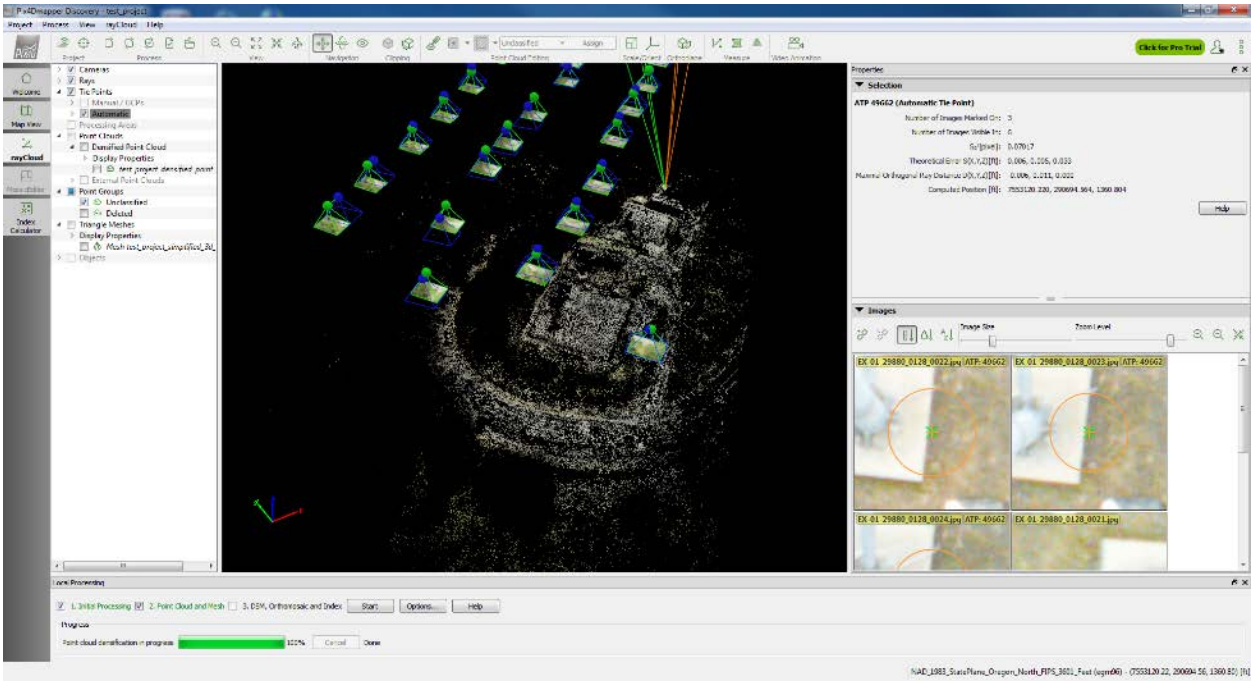
- Things to look for include:
    - Geolocation error
        - Mean, sigma, and RMS

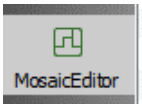
Q4: What percentage of images are listed as having been calibrated?

Q5: What is the meaning of the warning symbol next to Georeferencing?

3. 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



4. Click the MosaicEditor tab 

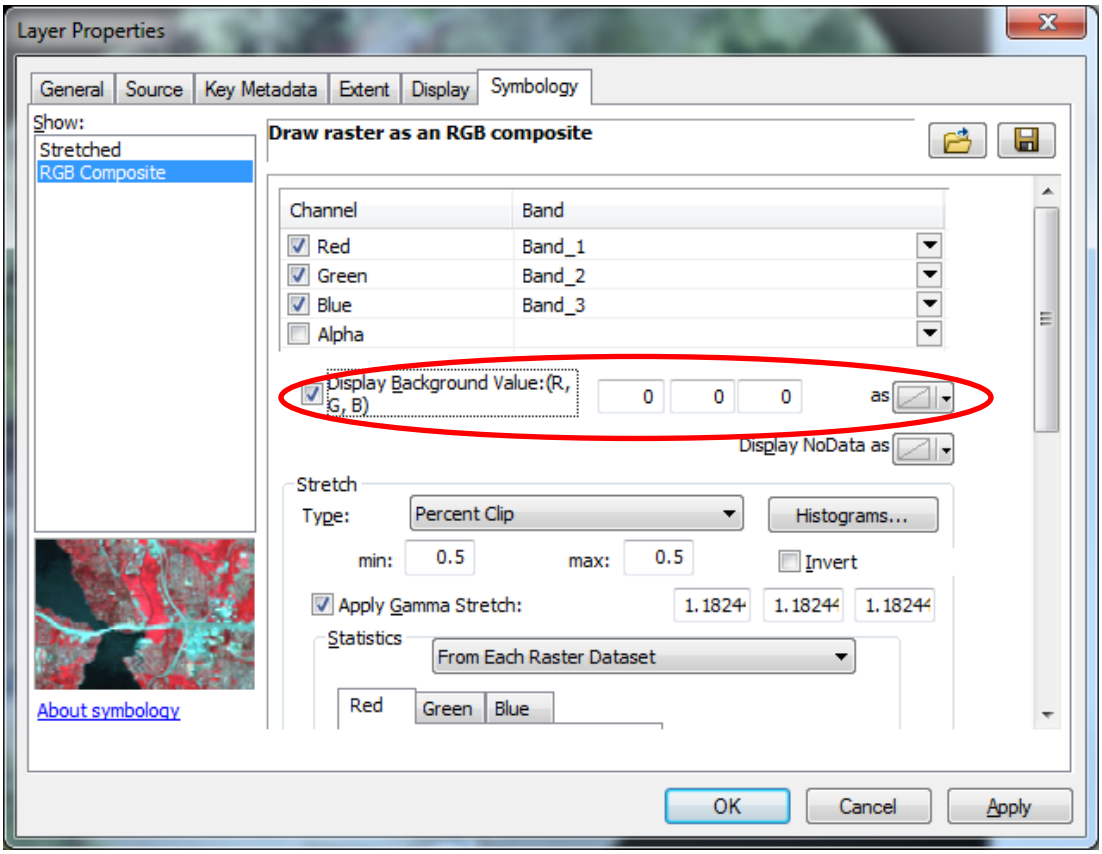
to start the process of generating an orthomosaic

<u>Part III: Viewing SfM-Generated Ortho in ArcGIS</u>

1. Back in ArcMap (you should still have the project open), hit the Add data button  and browse in your D drive directory structure to find: \tower_project\3_dsm_ortho\2_mosaic\tower_project_transparent_mosaic_group1.tif

2. Click Yes to create image pyramids, if prompted.

3. To set the background color to transparent, in the Table of Contents, right click tower_project_transparent_mosaic_group1.tif, and click Symbology. Then set the Background color (0,0,0) to No Data Value and click Apply.



Q6: How well does the orthomosaic you generated in Pix4D align with the Esri World Imagery basemap?

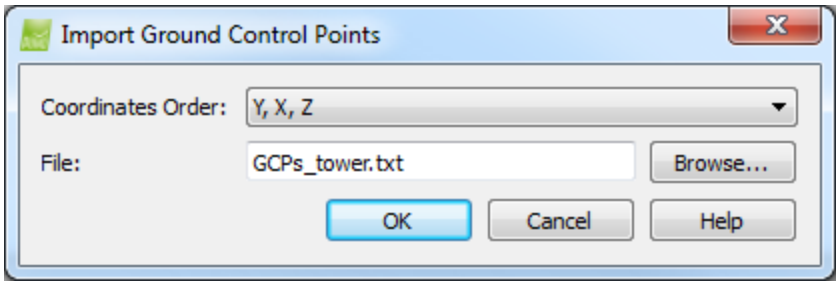
Q7: How well does your orthomoaic align with the GCPs? If there appears to be a systematic offset, what could be the cause.

Part IV (Optional): Improving Georeferencing with GCPs

1. As you probably discovered in Part III of this exercise, 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.

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:

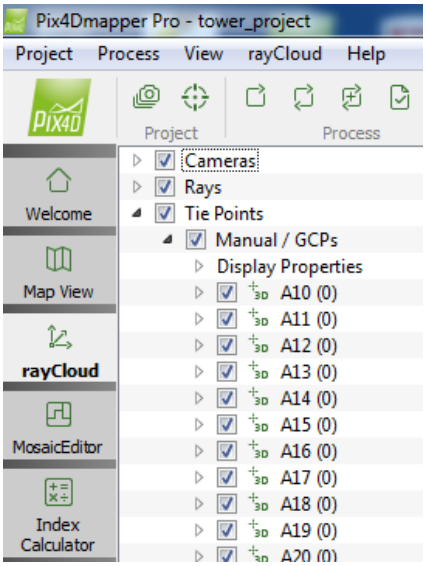


4. If the Datum is not auto-detected, click Edit and select Datum = North Americal Datum 1983; Coordinate System NAD 1983 StatePlane Oregon North FIPS 3601

5. Click Start to start reprocessing (click Yes when asked if you wish to overwrite existing files)

6. Once processing is completed, mark the GCPs in the rayCloud

7. On the left sidebar, under Manual / GCPs, expand the menu. The list of GCPs is displayed:



8. Select a GCP by clicking it from the list. The right sidebar will display its properties and the list of images in which it is visible.

9. Navigate on the images to find the exact location of the GCP:
   - Zoom out: Move the mouse scroll wheel backwards.
   - Pan: Using the mouse left clicking
   - Click the correct location with the left mouse button. A yellow circle will appear denoting the GCP location.

- Mark the exact position of the GCP on at least 2 images using the left mouse click.

10. You need to mark at least 3 GCPs on at least 2 images each.
    a. Click Apply each time you finish marking a GCP on at least 2 images

11. When done marking GCPs on images, click on Process, Reoptimize and say yes to overwrite existing results. You can just click Start again to reprocess everything. It will go faster this time, and, when you're done, you should have a better georeferenced orthomosaic and point cloud.

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