

## Workflow for Generating Orthomosaics from FLIR Vue PRO R 13mm Imagery in Agisoft PhotoScan/Metashape

- **Make sure all firmware updates have been installed on the gimbal unit as well as the Flir Camera. A summary writeup of this process and associated files can be found at:** <https://drive.google.com/open?id=1aFSFc0ryMDycI936Ap6GFgypxlCslhRT>
- **See the latest OEM cameras 3DR Gimbal Manual for detailed instructions and settings beyond what is highlighted in this document:** [https://drive.google.com/open?id=1Lt\\_sLSqPcqLWH\\_EQavlcYxDN4aj1I3Gh](https://drive.google.com/open?id=1Lt_sLSqPcqLWH_EQavlcYxDN4aj1I3Gh)

### Section 1: Collecting the Imagery

#### 1.1 Flight Plan

##### Camera parameters:

- Focal Length: 13 mm
- Image Width: 640 pixels
- Image Height: 512 pixels
- Sensor Width: 10.90 mm
- Sensor Height: 8.70 mm
- Pixel Size: 0.0170 mm
- Thermal Time Constant (i.e. Exposure): ~1/100 sec

Side lap: Pix4D suggests ~90% side lap/overlap [1], although this has not yet been proven necessary for Agisoft PhotoScan. 75-80% is likely adequate but has not yet been tested.

Speed: When taking photos every 1 sec at 200 ft a max speed of 4 m/s is required for achieving 90% overlap. As well, the faster the aircraft is moving the more blurry photos will be so a slower speed is preferable. For example, based on the half-pixel rule (see plot below), at 200 ft, the fastest the aircraft should travel is ~4 m/s. A speed of 2-5 m/s is likely adequate (dependent on flight height) for taking FLIR photos but has not yet been tested.

*Note: Because the FLIR is being powered by the Solo, your battery will not last as long. Expect to achieve a ~8-12 min flight per battery.*

You may consider flying a standard camera over your study area as well for reasons discussed in Section 2. *Remember, ~66%-82% overlap, ~66% side-lap and aircraft speeds of 7-9 m/s are suggested when collecting standard imagery.*

Camera triggering: For processing absolute temperature data in Photoscan/Metashape collect raw tiff stills using the intervalometer setting in the FLIR UAS app set to the desired time increment.

- Using the camera trigger command in Mission Planner based on GPS distance is not currently functioning properly and I am working with OEM cameras to fix this issue. If you try to use the camera trigger command, it will overwrite your settings and collect the imagery in rJPG format and not TIFF. We are working on this issue... stay tuned!
- **Note:** if you have camera triggers in your mission plan it will override any intervalometer setting you have and record rJPGs, therefore if you are using the intervalometer you must remove all camera trigger distance commands from your mission planner flight plan in order to collect raw TIFFS.

### Flight Planning Calculations:

#### USGS FORT UAS Flight Planning

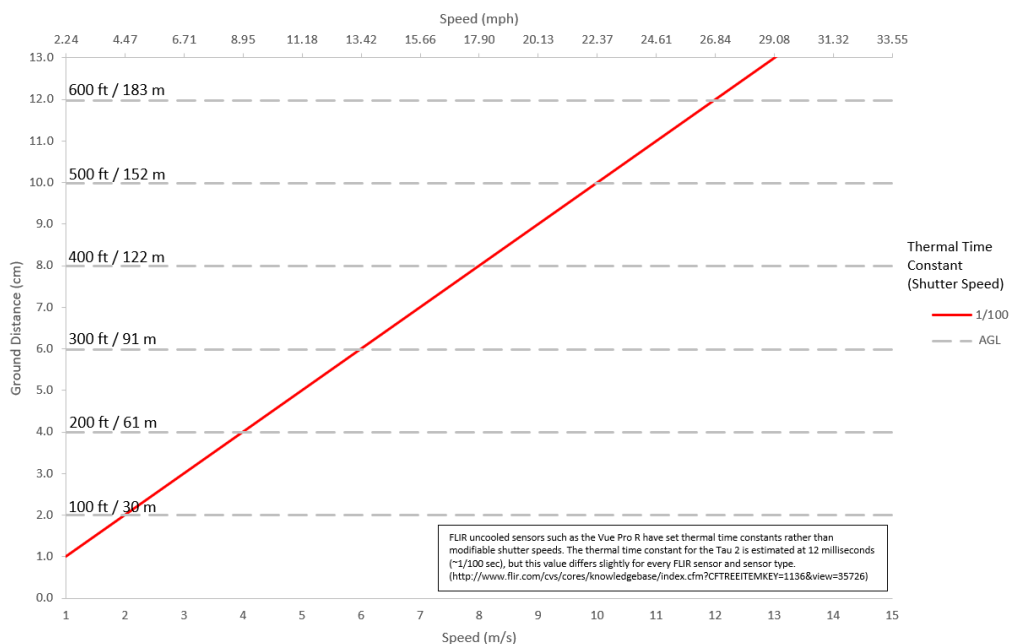
Camera	Vue Pro-R with 13mm lens		LandscapeMount				USGS Mission for a changing world
35 mm Focal eqv= 40.3							
<b>Camera Inputs:</b>	FL (mm)	Img wthd (pix)	Image hgt (pix)	Sensor wthd (mm)	Sensor hgt (mm)	Pix Size (wthd)	Pix Size (hgt)
	13	640	512	10.90	8.70	0.0170	0.0170
<b>Calculations:</b>	GSD wthd (cm)	GSD hgt (cm)	GSD wthd (inches)	GSD hgt (inches)	Photo wthd (ft)	Photo hgt (ft)	
100	3.99	3.98	1.57	1.57	83.8	66.9	
150	5.99	5.98	2.36	2.35	125.8	100.4	
200	7.99	7.97	3.14	3.14	167.7	133.8	
300	11.98	11.95	4.72	4.71	251.5	200.8	
400	15.97	15.94	6.29	6.27	335.4	267.7	
500	19.97	19.92	7.86	7.84	419.2	334.6	
600	23.96	23.90	9.43	9.41	503.1	401.5	
800	31.95	31.87	12.58	12.55	670.8	535.4	
1000	39.93	39.84	15.72	15.69	838.5	669.2	
1200	47.92	47.81	18.87	18.82	1006.2	803.1	
<b>Flight Planning:</b>	1/100 Recommended Shutter Speed			70%	70%	Recommended Overlap	
	1/100 Planned Shutter Speed			75%	75%	% overlap planned	
<b>Flight Speed (m/s)</b>	<b>Flight Speed (mph)</b>	<b>1/2 pix Max Speed</b>	<b>Flt Hgt (AGL)</b>	<b>Dist. Side Transect (ft)</b>	<b>Dist. Forelap (ft)</b>	<b>Cam. Interv. (s)</b>	<b>#xs per mile</b>
4.00	9 mph	1.99	100ft (30.5m)	21ft (6.4m)	16.7ft (5.1m)	1.27	252
		2.99	150ft (45.7m)	31.4ft (9.6m)	25.1ft (7.6m)	1.91	168
		3.98	200ft (61m)	41.9ft (12.8m)	33.5ft (10.2m)	2.55	126
		5.98	300ft (91.4m)	62.9ft (19.2m)	50.2ft (15.3m)	3.82	84
		7.97	400ft (121.9m)	83.8ft (25.6m)	66.9ft (20.4m)	5.10	63
		9.96	500ft (152.4m)	104.8ft (31.9m)	83.7ft (25.5m)	6.37	50
		11.95	600ft (182.9m)	125.8ft (38.3m)	100.4ft (30.6m)	7.65	42
		15.94	800ft (243.8m)	167.7ft (51.1m)	133.8ft (40.8m)	10.20	31
		19.92	1000ft (304.8m)	209.6ft (63.9m)	167.3ft (51m)	12.75	25
		23.90	1200ft (365.8m)	251.5ft (76.7m)	200.8ft (61.2m)	15.30	21
<b>Notes:</b>							
Formula: GSD = Pix Size * Flight Height / Focal Lgth				Camera Input Parameters			
Formula: Photo Footprint = Img pix * GSD				Calculations			
1 mph = 1.467 feet per second				UAS Flight Planning Inputs			

**Holmquist-Johnson, Christopher:**  
Planned airspeed for data collection.

Double check that your planned flight speed is not greater than the 1/2pixel max speed based on flight height and shutter speed (red cells do not meet 1/2pixel rule)

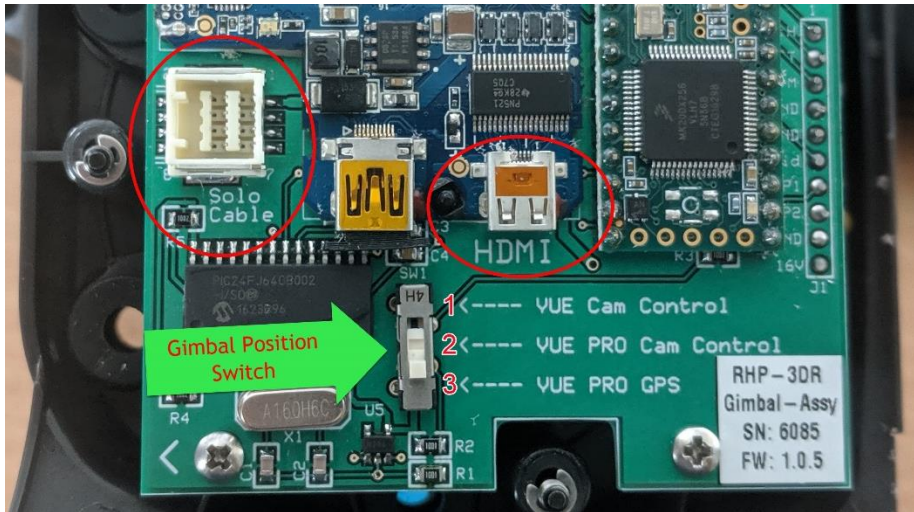
Half Pixel Rule for Sharp UAS Imagery  
FLIR Vue Pro R 13mm

Reference for "Half Pixel Rule":  
[https://dronemapper.com/uas\\_photogrammetry\\_processing](https://dronemapper.com/uas_photogrammetry_processing)



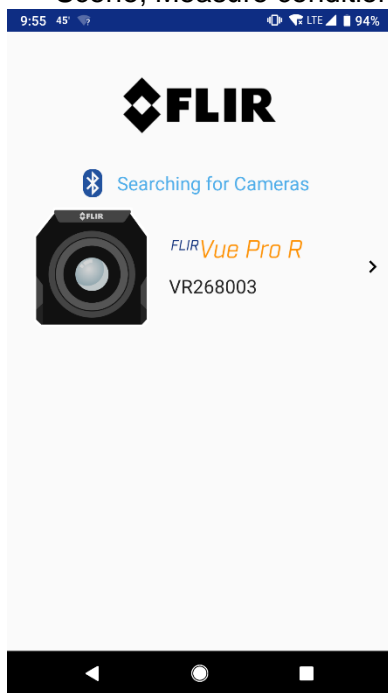
## 1.2 OEM Cameras Gimbal and FLIR UAS app setup

Before attaching the FLIR gimbal to the SOLO change settings on gimbal to position 3 “Vue PRO GPS”

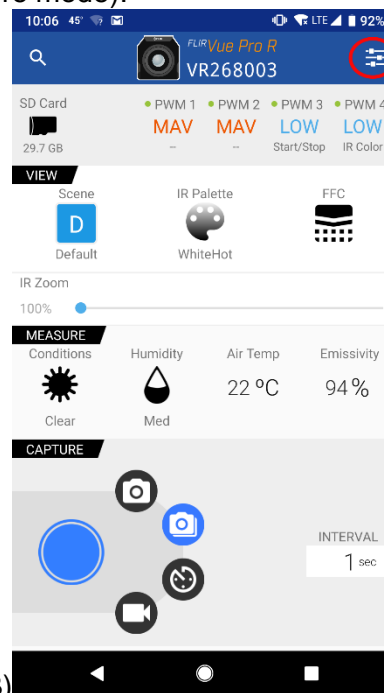


Change parameters in the FLIR Vue App:

- Connect to the VUE PRO/PRO-R using the FLIR UAS app, select the sensor (A) and then navigate to the settings page on the top right corner (B).
  - A number of the settings that will be set in the following screens can also be set on this original “Main” screen but I like to make sure I have gone through all the settings and then use this main screen as confirmation that everything is set how I want them (i.e. Scene, Measure conditions, and capture mode).



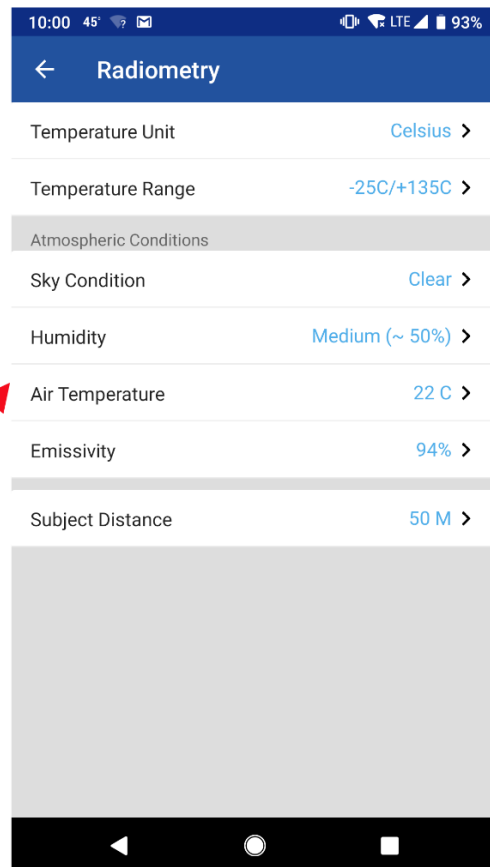
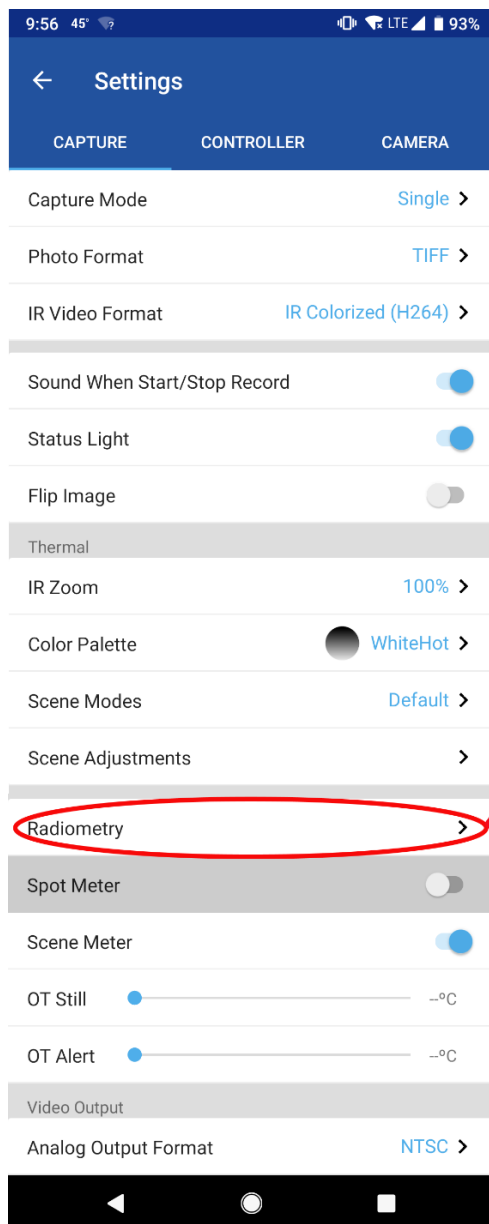
A)



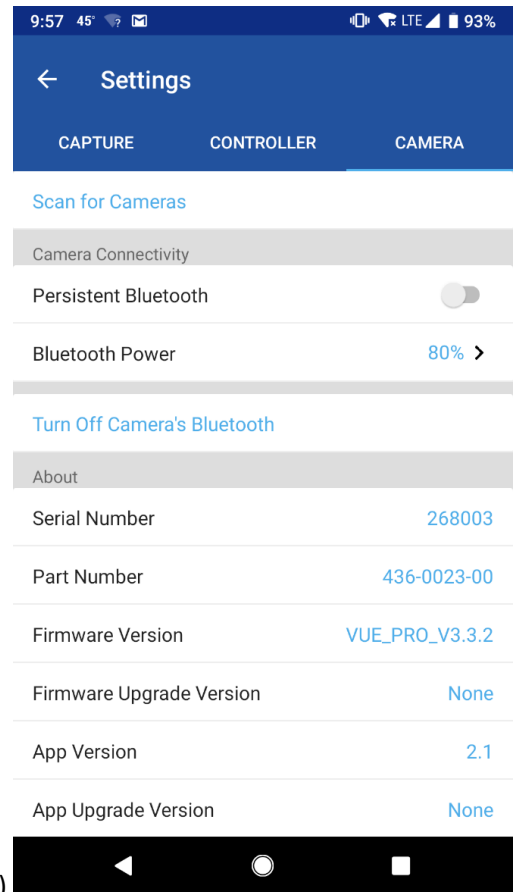
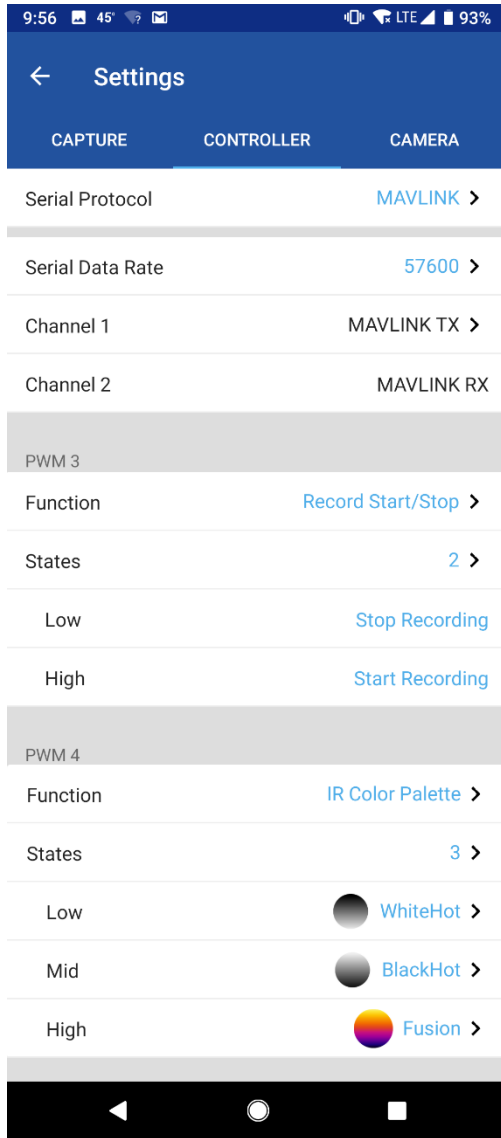
B)

- A) In the “CAPTURE” settings you can specify the type of capture mode and formats that you prefer. For processing absolute temperature data in Photoscan: collect raw tiff stills and not radiometric JPGs

- In the “Scene Modes” I have found that setting this to “Outdoor” seems to help with the image clarity as it sets the parameters so that the edges of the sensor are not used in the adjustments/corrections
- In the “Radiometry” tab, the settings need to be adjusted to match your emissivity, air temperature, sky condition, humidity and target range (flying height above ground) to the appropriate values.
- *Note: Radiometric JPEGs also contain absolute temperature data, but the temperature data cannot be viewed in any other program besides FLIR Tools and the visible scale recorded is based on an auto gain function that is applying a histogram to the min/max values in the image so this does not work well for trying to stick images together.*
- PhotoScan will generate orthophotos from rJPEGs with various color schemes (i.e. WhiteHot, BlackHot, etc.), but the orthophoto will not contain absolute temperature measurements. See FLIR Vue Pro User Guide [2] for more information on adjusting the scene settings for the rJPEGs.



- B) In the “CONTROLLER” settings make sure the Serial protocol is set to MAVLink, the baud rate is set to 57600 Channel 1 is MAVLink Tx and Channel 2 is set to MAVLink Rx.
- C) In the “CAMERA” settings ...



### 1.3 Powering up the aircraft and sensor initialization prior to 1<sup>st</sup> flight

When you are preparing for your 1<sup>st</sup> flights it is recommended that you use a “non-flight” battery to power up the aircraft and let it initialize, acquire GPS and make sure the FLIR sensor and gimbal are working properly. Let the system sit on the launch pad for ~7-10 minutes while you are doing your other flight preparations to allow the sensor to “warm up” and get a good GPS fix.

When the aircraft is powered on you will see the FLIR gimbal point NADIR while it initializes and then will give 2 beeps and should return to looking forward. Once this happens and the solo is also in “Fly” mode on the controller make sure that you have control of the gimbal and can see the live video feed either in the solo/Tower app or in the Mission Planner HUD if using MP. If the gimbal or solo do not initialize then reboot the system and try again (this usually fixes any issues).

Once everything is all operational then you are ready to swap out your battery, power up, and confirm all your camera settings using the FLIR UAS app and start your mission. ***NOTE: you should confirm your camera settings before every flight as the sensor does not always keep the previous settings when powered off.***

When you are ready to conduct your flights, confirm your camera settings and then prior to take off you can trigger the camera in two ways:

- 1) Manually pushing the “record” button on the side of the sensor (I don’t like this method as much because you are handling the gimbal while powered on and it is trying to stabilize).
- 2) Pushing the record button on the main screen of the FLIR UAS app (this is my referred method as you are already using this app to confirm all your settings prior to takeoff).

Once you hit the record button you should hear a “beep” every time the camera triggers if you set this up in the “capture” settings to Sound when Start/Stop record. This is really the only way you know for sure that the camera is triggering and collecting data. When you return home to land you should still hear the sensor beeping which confirms that it has been collecting images the entire time. Once you have landed you can use the physical button on the side of the sensor to stop the recording or it will also stop when you power down the aircraft.

### 1.4 Collecting Imagery for Thermal Inertia Measurements

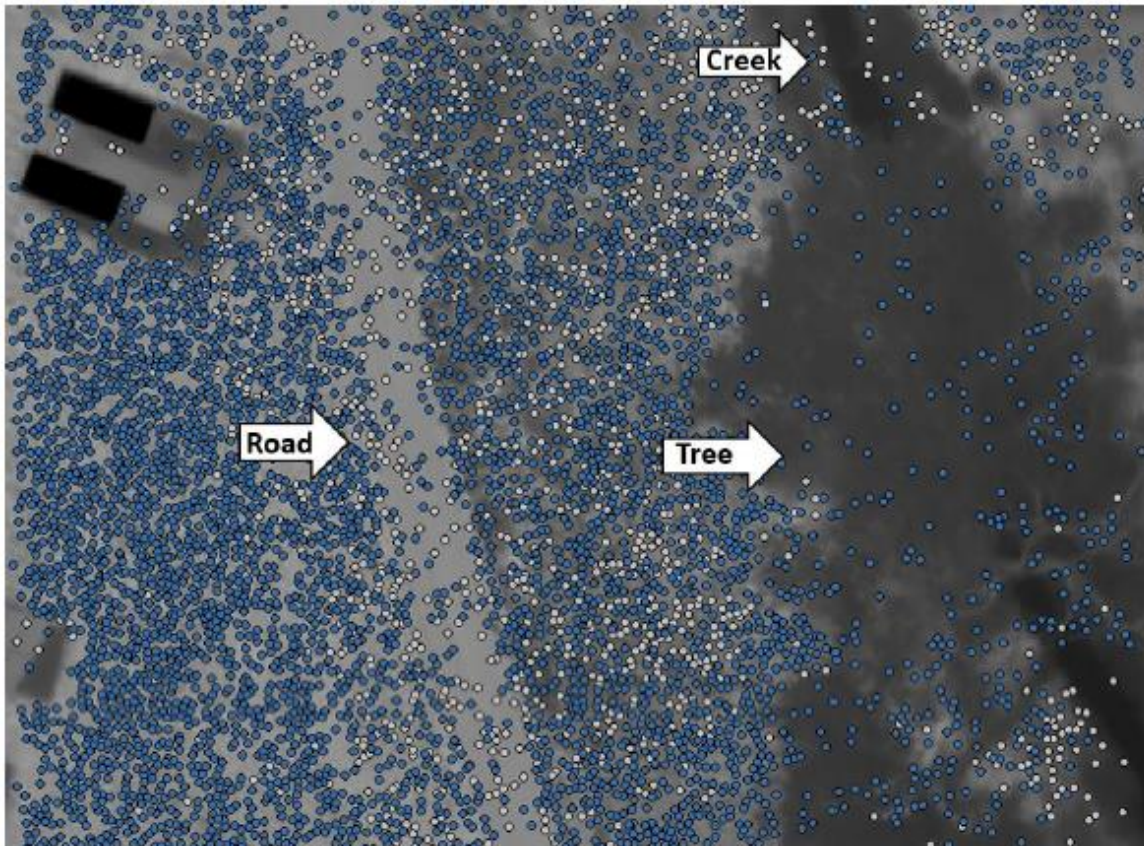
If collecting imagery for thermal inertia measurements it is best to fly the same flight plan(s), once at solar noon and once at midnight [3].

## Section 2: Processing the Imagery in Agisoft PhotoScan/Metashape

### 2.1 Processing with FLIR imagery only

*Note: if using only FLIR imagery to generate a model the model's accuracy will be low. However, with standard cameras you generate higher resolution images and need less overlap for model generation which means images have a smaller base to height ratio. Therefore, it is possible to generate a more accurate DEM and thus a more accurate FLIR orthophoto by implementing both standard and FLIR imagery as discussed in Section 2.2. Since the existing 3DR solo setup does not collect thermal and visible images simultaneously it can be difficult to match images between different sensor data collection flights, especially if ground control is not used.*

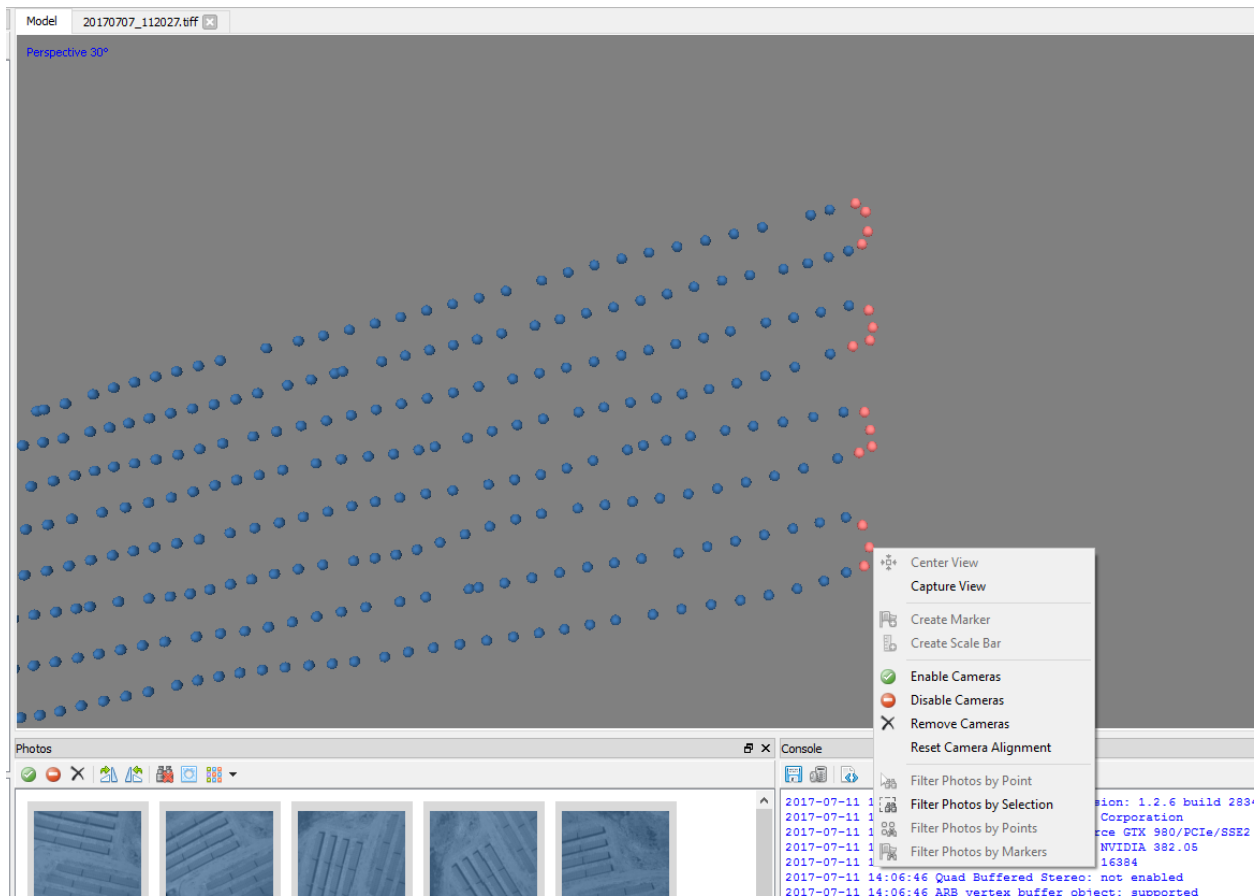
*Note: The 3D model's accuracy will be lower than what could be generated with standard imagery, but should produce an adequate orthophoto. Areas with low texture (roads, water etc.), and trees will have difficulty finding tie points (see image below).*



#### Import photos:

- Import all photos
- If your photos are **not geotagged**, select all of the cameras and uncheck the box next to the camera names.
- To view the images go to the Workspace tab... right click on the Chunk and click "Raster Calculator..."
  - In Formula tab in the "Expression:" type " $0.04 * B1 - 273.15$ " and check "Enable transform"
  - In the Palette tab change the histogram range to Auto set the Preset to Gray. Hit Apply.
    - Note: if the histogram does not show up, close the window and re-open the raster calculator and Palette tab and this should refresh the histogram.

- You can now remove take-off and landing photos as well as blurry photos caused by the drone making turns. To specifically target blurry photos caused by turning you can select the points that represent the camera locations at the beginning and end of every transect where the drone would be turning, right click and choose "Filter Photos by Selection".



### Set Coordinate/Projection:

### Camera Calibration:

- Tools... Camera Calibration
- Change Camera type to Frame, Pixel size to 0.017 x 0.017 and the Focal length to 13

### Align Photos:

- Settings: high, reference (if images are geotagged) or generic, 60,000, 0
- Optimize cameras with default boxes checked.
- Images over trees and water will have fewer projections than images over bare ground or short vegetation (i.e. grasses).

### Gradual Selection:

- Reconstruction Uncertainty (removing points with bad geometry)...
  - Note: at 200 ft (61m) traveling at 5 m/s and taking photos every second you have a base to height ratio of 1:12.1 (an good base to height ratio is 1:2.3), at 7 m/s you have a base to height ratio of 1:8.7.*



- For a good base to height ratio (1:2.3) you want to bring you reconstruction uncertainty down to 10. For images of bare ground or short vegetation you may be able to bring the reconstruction uncertainty down to 10 without losing too many projections, however images of tree canopy or water may require a higher reconstruction uncertainty value of 20-30.
- Optimize after deleting points.
- Projection Accuracy
  - Projection accuracy is based on how crisp and clear images are [ref].
  - Because FLIR images are more blurry, the projection accuracy needs to be higher than for standard cameras. A value of 4-6 is usually achievable without deleting too many points.
  - Optimize after deleting points.
- Tie Point Accuracy
  - Normally you would change the tie point accuracy here from 1 to .1 for crisp images. However because the FLIR images are not as crisp, a value of .5 is chosen.
  - Optimize with all boxes checked.
- Add ground control if available.
- Reprojection Error
  - You may be able to only get down to 0.5 (goal is 0.3).
- You may need to manually select random points that are obviously off and delete them.

#### Generate dense point cloud:

- Settings: High, Aggressive

#### Generate mesh:

#### Generate orthophoto:

Make sure to export the orthophoto as a TIFF with the Raster Transform set to None.

### **2.2 Processing with Standard and FLIR imagery**

- Generate dense point cloud, mesh and DEM with standard imagery using workflow suggested by the USGS UAS Office [4]. Imagery must be geotagged or ground control must be used.
- Export georeferenced orthophoto.
- From the orthophoto choose 5-10 features and record their xyz location (using ArcMap, GlobalMapper, or another GIS software).
- Make a copy of project.
- Delete all photos and import thermal photos.
- Change images so they are viewable as described in Section 2.1 and delete appropriate photos. Assure that the camera calibration settings are correct.
- Align thermal photos... Settings: high, referenced, 60,000, 0
- Add ground control points at locations gathered from previously generated orthophoto, be sure to uncheck the boxes next to the cameras so their locations are not being used and optimize the model. This is to assure that the FLIR photos will align properly with the standard imagery model when the orthophoto is being generated.
- Generate orthophoto... Settings: Geographic, Set Coordinate System/Projection, Mesh, Mosaic
- Make sure to export the orthophoto as a TIFF with the Raster Transform set to None.

## Section 3: Analyzing the Imagery

### Converting to absolute temperature:

Because the FLIR Vue Pro R is already radiometrically calibrated, it takes a simple equation to convert the 16 bit DN to absolute temperature.

**That equation is as follows [5]:  $0.04 * DN - 273.15$**

### Thermal inertia calculations:

## References

- [1] <http://www.flir.com/cvs/cores/knowledgebase/index.cfm?CFTREEITEMKEY=1136&view=35726>
- [2] <http://www.flir.com/science/blog/details/?ID=74352>
- [3] <https://support.pix4d.com/hc/en-us/articles/210140893-How-to-process-Thermal-Datasets-in-Pix4Dmapper#gsc.tab=0>
- [4] [https://dronemapper.com/uas\\_photogrammetry\\_processing](https://dronemapper.com/uas_photogrammetry_processing)
- [5] [https://www.oemcameras.com/media/attachment/file/3/d/3dr\\_solo\\_gimbal\\_manual-10mar2017.pdf](https://www.oemcameras.com/media/attachment/file/3/d/3dr_solo_gimbal_manual-10mar2017.pdf)
- [6] <http://www.flir.com/uploadedFiles/sUAS/Products/Vue-Pro/FLIR-Vue-Pro-and-R-User-Guide.pdf>
- [7] <https://uas.usgs.gov/pdf/PhotoScanProcessingDSLRLMar2017.pdf>
- [8] <https://support.pix4d.com/hc/en-us/articles/210140893-How-to-process-Thermal-Datasets-in-Pix4Dmapper#gsc.tab=0>