

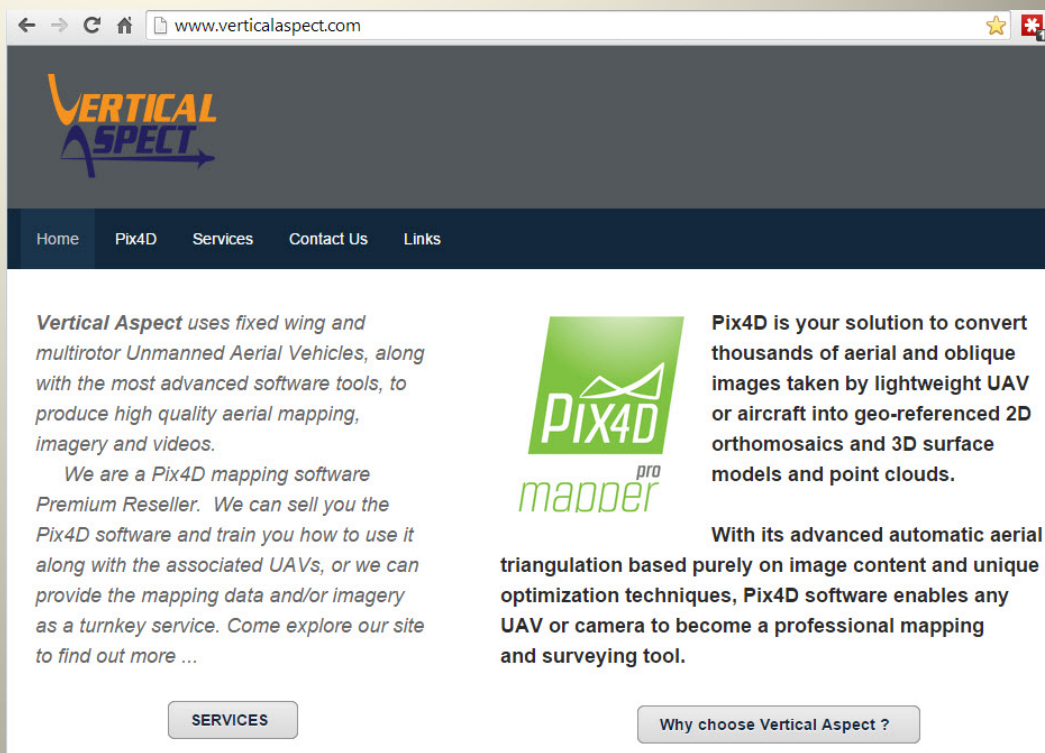
# Aerial Mapping & Modeling using UAV



[www.verticalaspect.com](http://www.verticalaspect.com)  
[support@verticalaspect.com](mailto:support@verticalaspect.com)

(202) 494-8410

- Services
  - Aerial mapping
  - Aerial Imagery
- Pix4D Software
  - Premium Reseller
  - Training
- UAV Training



The screenshot shows the Vertical Aspect website. The browser address bar displays 'www.verticalaspect.com'. The website features the Vertical Aspect logo at the top left. A dark blue navigation bar contains links for 'Home', 'Pix4D', 'Services', 'Contact Us', and 'Links'. The main content area is divided into two columns. The left column contains text describing the company's services: 'Vertical Aspect uses fixed wing and multirotor Unmanned Aerial Vehicles, along with the most advanced software tools, to produce high quality aerial mapping, imagery and videos.' It also states they are a 'Pix4D mapping software Premium Reseller' and offers to sell software, provide training, or offer turnkey mapping services. A 'SERVICES' button is located at the bottom of this column. The right column features the Pix4D logo and text explaining that Pix4D is a solution for converting aerial and oblique images into geo-referenced 2D orthomosaics and 3D surface models. It also mentions that with its advanced automatic aerial triangulation, Pix4D software enables any UAV or camera to become a professional mapping and surveying tool. A 'Why choose Vertical Aspect ?' button is located at the bottom of this column.

Vertical Aspect uses fixed wing and multirotor Unmanned Aerial Vehicles, along with the most advanced software tools, to produce high quality aerial mapping, imagery and videos.

We are a Pix4D mapping software Premium Reseller. We can sell you the Pix4D software and train you how to use it along with the associated UAVs, or we can provide the mapping data and/or imagery as a turnkey service. Come explore our site to find out more ...

**SERVICES**

**Pix4D** is your solution to convert thousands of aerial and oblique images taken by lightweight UAV or aircraft into geo-referenced 2D orthomosaics and 3D surface models and point clouds.

With its advanced automatic aerial triangulation based purely on image content and unique optimization techniques, Pix4D software enables any UAV or camera to become a professional mapping and surveying tool.

**Why choose Vertical Aspect ?**

# Mapping Theory / Techniques / Products

# Graphical Map



## BENEFITS:

- Good for navigation
- Inexpensive to produce
- Easy to interpret
- Non-technical
- No underlying data
- Not to scale / no accurate measurements



# Orthomosaic Map



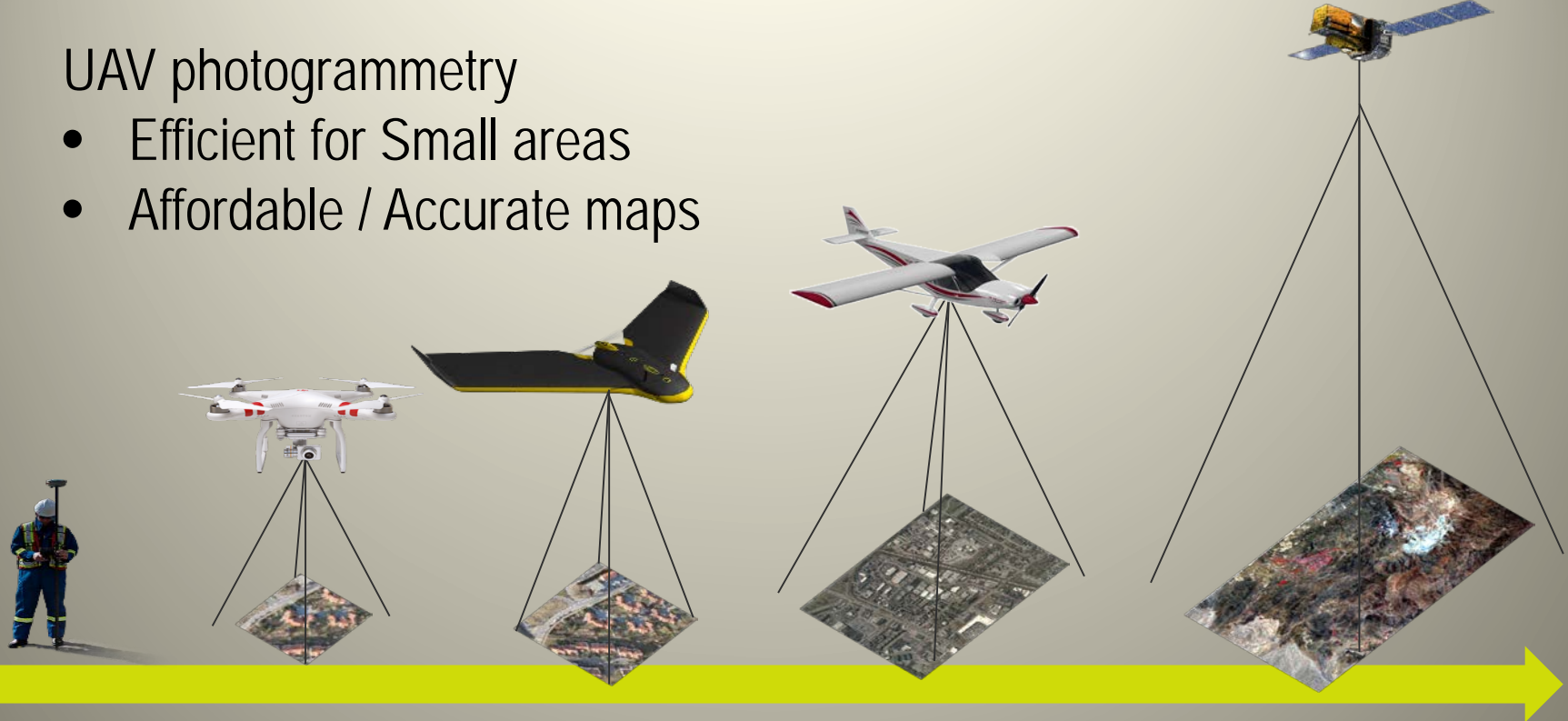
## BENEFITS:

- Referenced to real world location
- Enables accurate measurements
- Rectified to 3D information
- Graphical representation of underlying data
- Underlying data easily exported / converted

# Changing the mapping game

## UAV photogrammetry

- Efficient for Small areas
- Affordable / Accurate maps



*Survey efficiency with respect to Survey area*

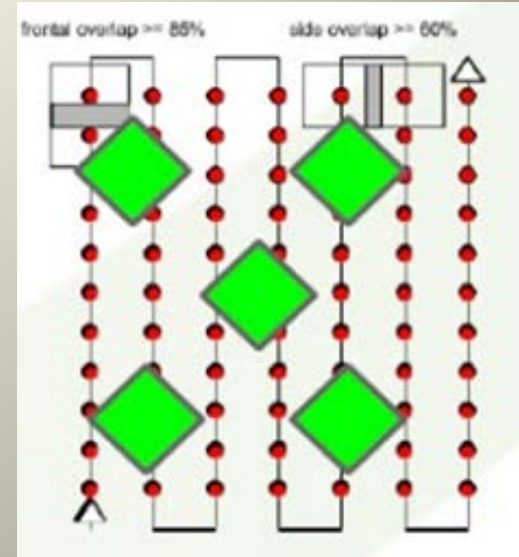
# Ground Control Points (GCP)

## Ground Control Points (GCP)

- Well distributed in dataset
- Visible on multiple images
- 5-8 sufficient for up to 1000 images
- Quality report shows reprojection error

## Obtaining GCPs

- Traditional Survey Methods
- RTK GPS device
- Less accurate
  - Google Earth
  - Smartphone App
  - Handheld GPS device





# Without GCP




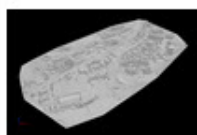


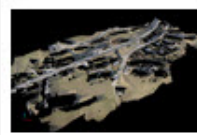

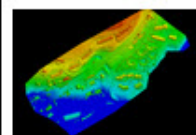
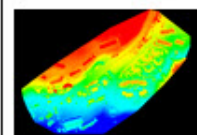
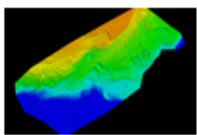




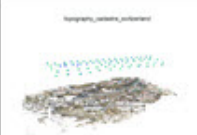
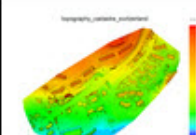
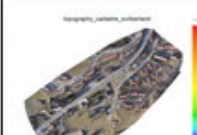

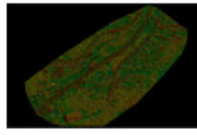
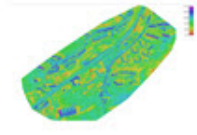





# With GCP



- Output
  - Orthomosaic
  - 3D Point Cloud
  - Topographic
  - Digital Surface Model
- Potential Customers

# Output types

							
Densified Point Cloud	Triangle Mesh	3D Triangulated Mesh	3D Triangulated Point Cloud	Classified Point Cloud - Terrain	Classified Point Cloud - Objects	Raster DSM	Grid DSM
							
DTM	Orthomosaic	Triangle Model	Contour Lines	Contour Lines - DTM	3D PDF - ATT and Cameras	3D PDF - DSM	3D PDF - Orthomosaic
							
Reflectance Map	Index Grid	Colored Index Map	Google Maps Tiles	KML	Mapbox		

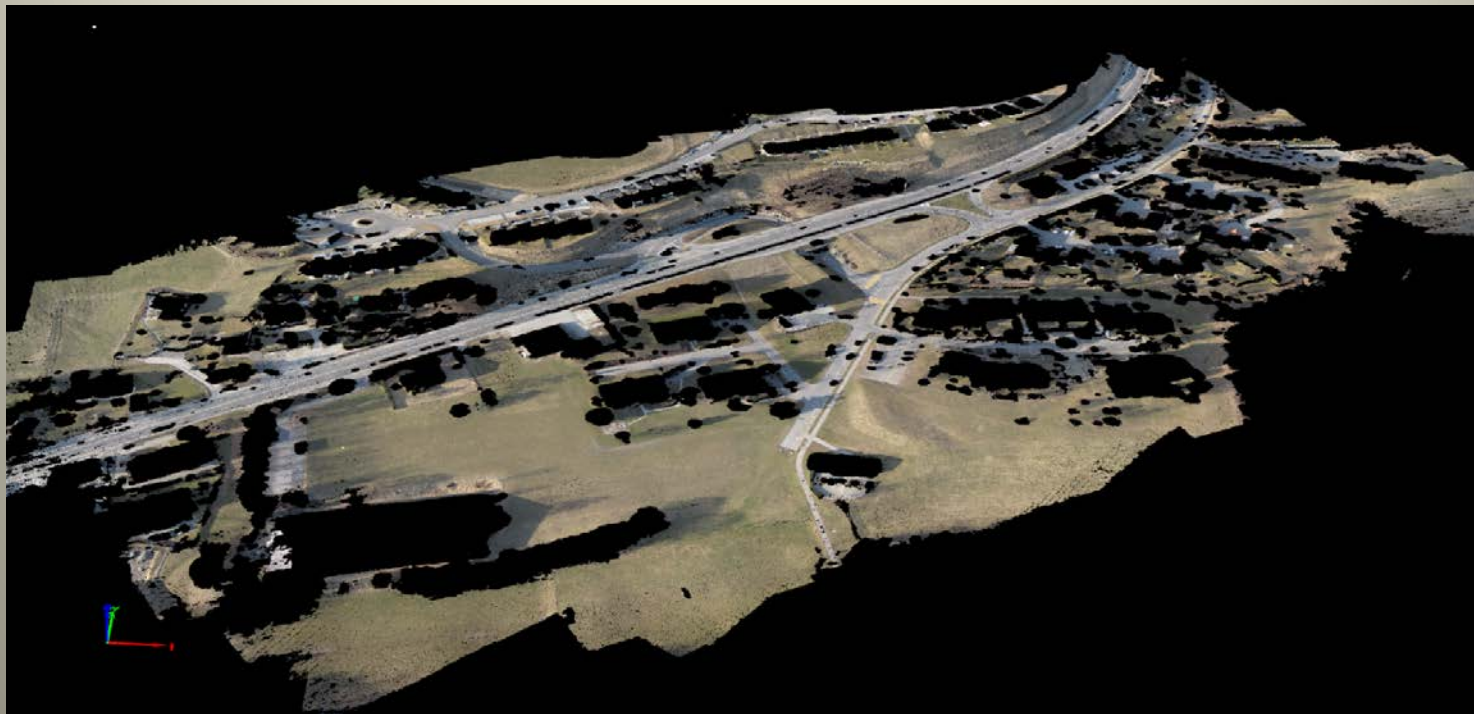


- Digital Surface Model
  - Everything
- Digital Terrain Model
  - “Bare Earth”
  - Used by engineers
- Oblique Models

# Unclassified 3D Point Cloud



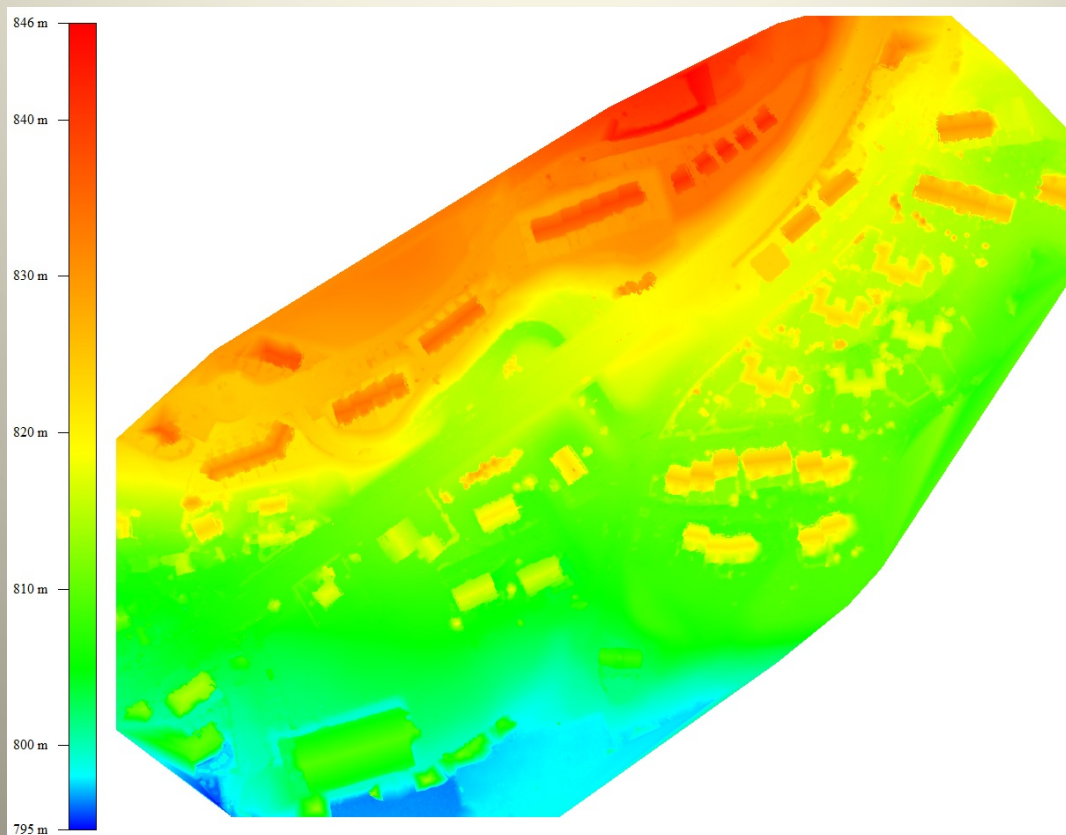
# Classified Point Cloud-Terrain



# Classified Point Cloud - Objects



# Digital Surface Model (with scale)





# Contour Lines



# Contour Lines – (terrain only)







# Planar

(Photo Stitching)

vs.

# Orthomosaic

(Orthorectification)

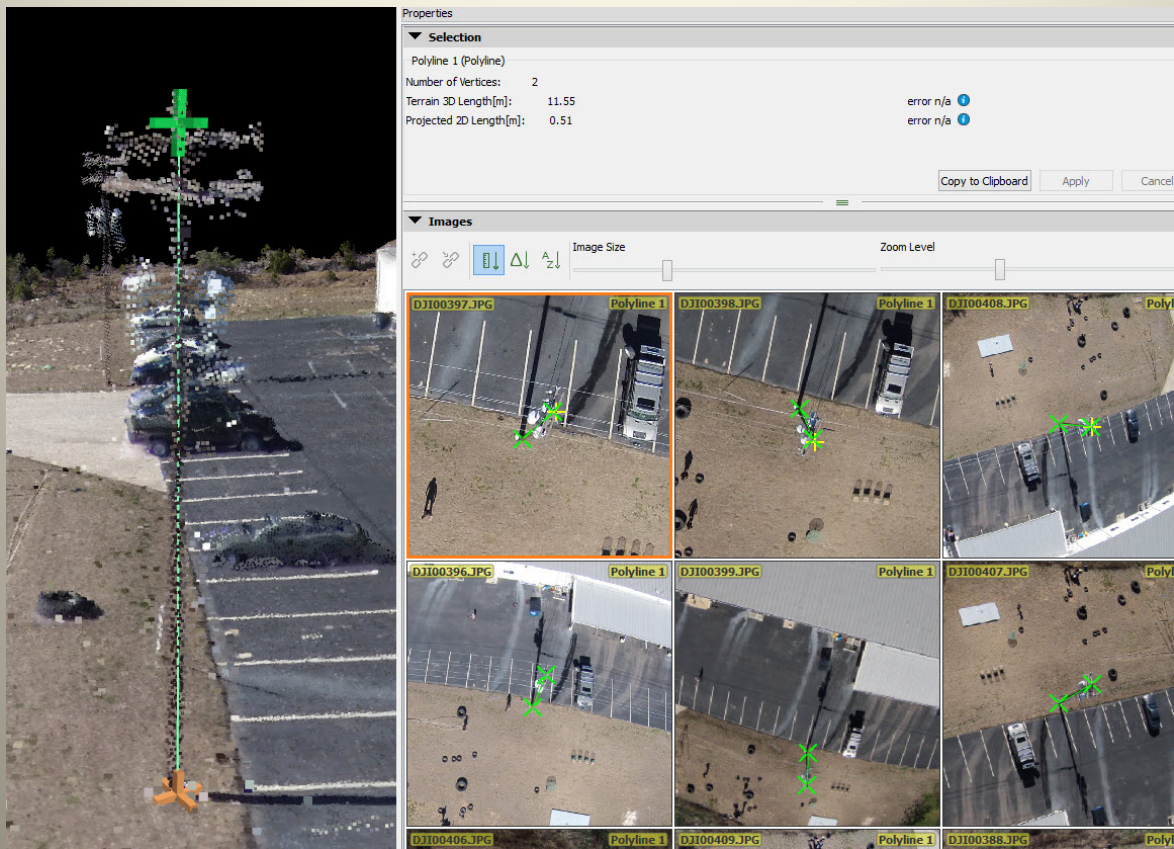


- Works only if terrain perfectly flat
- Only small datasets supported (due to error accumulation)
- No good georeference without GCP
- Distances (measurements) not accurate
- Requires only low number of matches / keypoints (>100)



- Handles any terrain type
- Handles large datasets
- Supports Georeference perfectly
- Preserves distances & becomes measurable
- Requires high number of matches/keypoints (>1000) to generate the 3D model

# Accurate Measurements



The screenshot displays the PIX4D software interface. On the left, a 3D point cloud of a parking lot is shown with a vertical green measurement line and a green crosshair at the top. The main window is divided into two sections: 'Properties' and 'Images'.

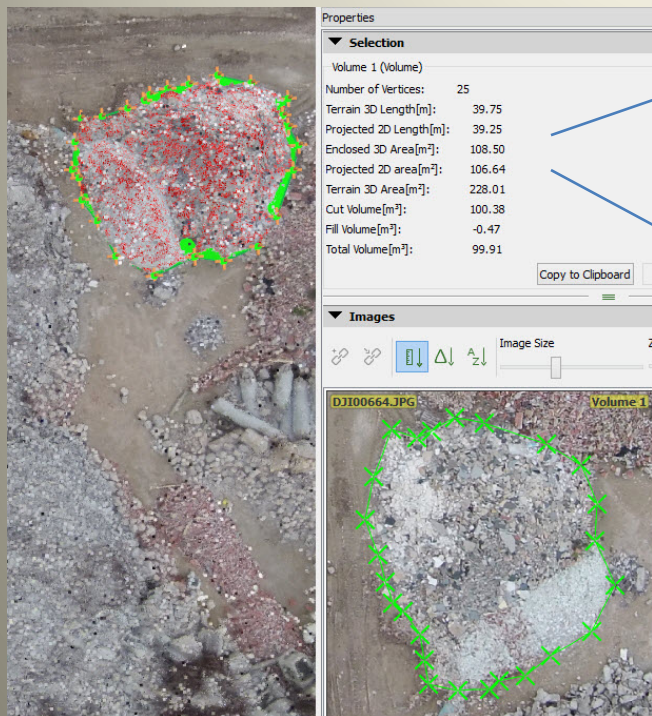
**Properties**

- Selection**
  - Polyline 1 (Polyline)
  - Number of Vertices: 2
  - Terrain 3D Length[m]: 11.55
  - Projected 2D Length[m]: 0.51
  - error n/a
  - error n/a
- Buttons:** Copy to Clipboard, Apply, Cancel

**Images**

- Image Size:** [Icon] [Icon] [Icon] [Icon]
- Zoom Level:** [Slider]
- Image Grid:** A 3x3 grid of image thumbnails showing the parking lot from different angles. Each thumbnail is labeled with a file name (e.g., DJI00397.JPG, DJI00398.JPG, DJI00408.JPG, DJI00396.JPG, DJI00399.JPG, DJI00407.JPG, DJI00406.JPG, DJI00409.JPG, DJI00388.JPG) and 'Polyline 1'.

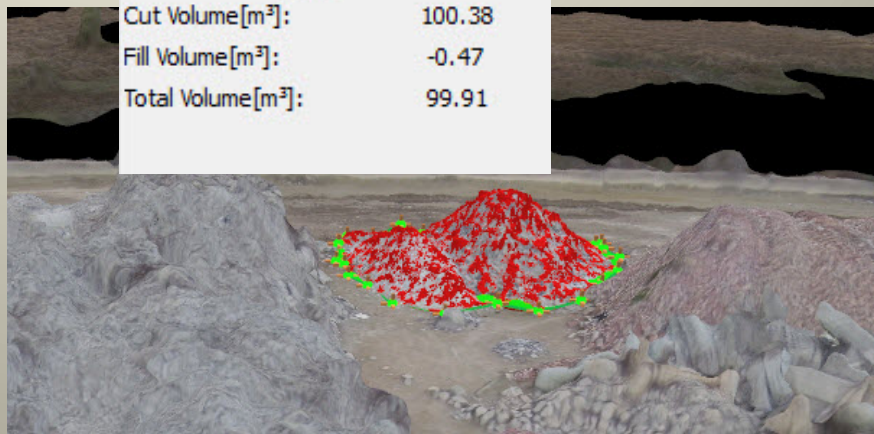
# Stockpile Volume Calculations



## Selection

### Volume 1 (Volume)

Number of Vertices:	25
Terrain 3D Length[m]:	39.75
Projected 2D Length[m]:	39.25
Enclosed 3D Area[m <sup>2</sup> ]:	108.50
Projected 2D area[m <sup>2</sup> ]:	106.64
Terrain 3D Area[m <sup>2</sup> ]:	228.01
Cut Volume[m <sup>3</sup> ]:	100.38
Fill Volume[m <sup>3</sup> ]:	-0.47
Total Volume[m <sup>3</sup> ]:	99.91



# UAV Image Capture

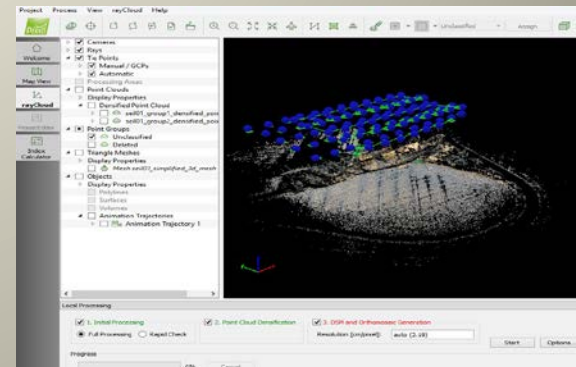
Fixed Wing & Multirotor



Plan & Load  
the mission

Fly – Capture  
images

Process,  
Provide Output



# Fixed Wing vs. Multicopter

---

## Fixed Wing

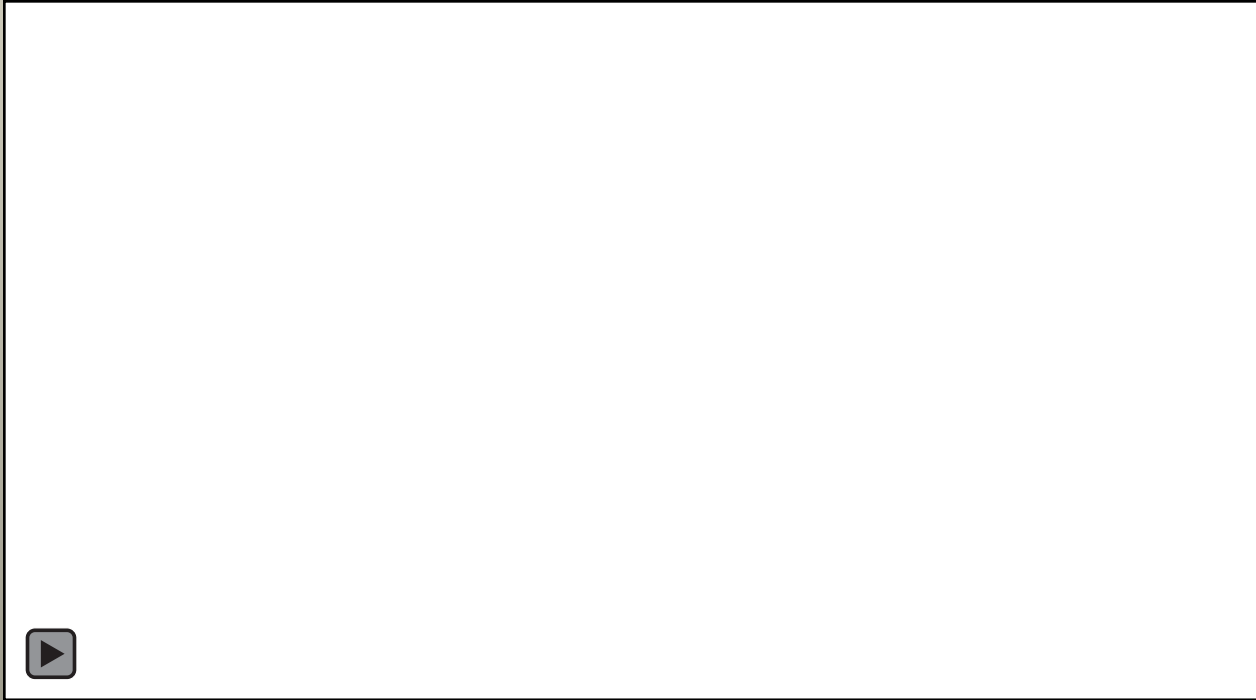
1. Larger area
2. Larger takeoff / landing area
3. Higher Altitudes / less detail
4. Longer Flight Time
5. More expensive

## Multicopter

1. Smaller area
2. VTOL – much smaller takeoff / landing area
3. Lower altitudes / greater detail
4. Shorter Flight Times
5. Lower cost of entry

# 3D Flythrough Video

(Press  
"Play"  
Key  
to  
View



Video) or view at <https://www.youtube.com/watch?v=oDEIT1xvWyyw>





Larger Area, less resolution



Smaller Area, higher resolution



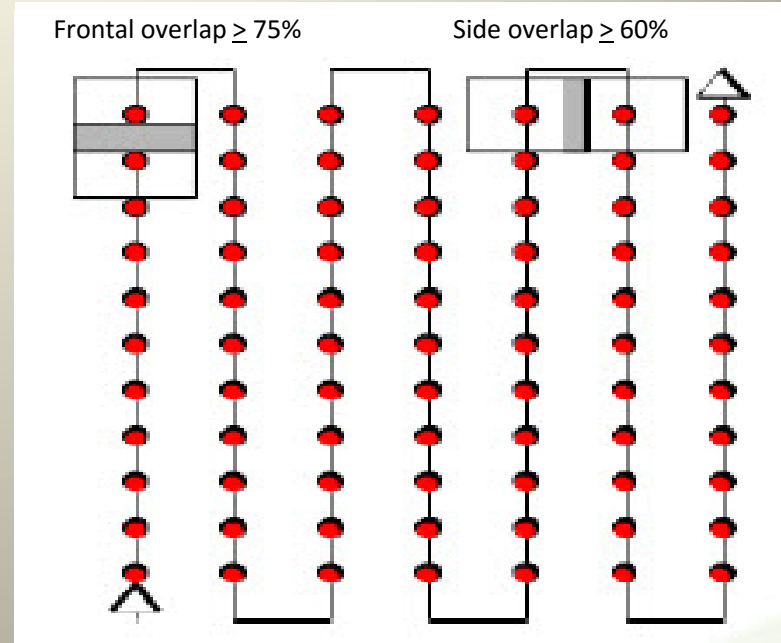
# Generated Files

Pix4uav outputs	Format	Possible use	Examples of compatible software
Raster orthomosaic	geoTIFF (.tiff) KML tiles (.png/.kml)	Area overview Digitize buildings Annotate areas Overlay in GIS package Analyze spectral bands	ArcGIS Global Mapper QuantumGIS AutoCAD Google Earth
Undistorted images	TIFF (.tiff)	Stereo Viewing	LPS
Individual ortho/planar	geoTIFF (.tiff)	Seamline editing	OrthoVista
3D point cloud	.las, .ply, .ascii	Visualization Surface Editing DSM generation DTM generation	ArcGIS Global Mapper AutoCAD Quick Terrain Reader 3D Reshaper Trimble RealWorks Viewer
Raster digital surface model (DSM)	geoTIFF (.tiff)	Analyze surface Measure volumes Generate contour lines Draw breaklines	ArcGIS Global Mapper QuantumGIS Quick Terrain Reader
3D mesh with texture	Wavefront (.obj)	Render in animation package Visualize small projects	AutoCAD Bentley Pointools View CC Viewer 3D Reshaper

- Fixed Wing
  - SenseFly eBee
  - eMotion flight planning / capture
- Multirotor
  - DJI Phantom Vision 2 +
  - Pix4D Capture App



- High accuracy results
  - Requires high overlap between images
  - Consistent altitude
- Recommended Overlap
  - Frontal -  $\geq 75\%$ 
    - *(with respect to flight direction)*
  - Side -  $\geq 60\%$ 
    - *(between flight tracks)*



- Megapixel size less important than image overlap
- Sensor size determines area of coverage at given altitude
- Automated Flight Path necessary for reliability & accuracy

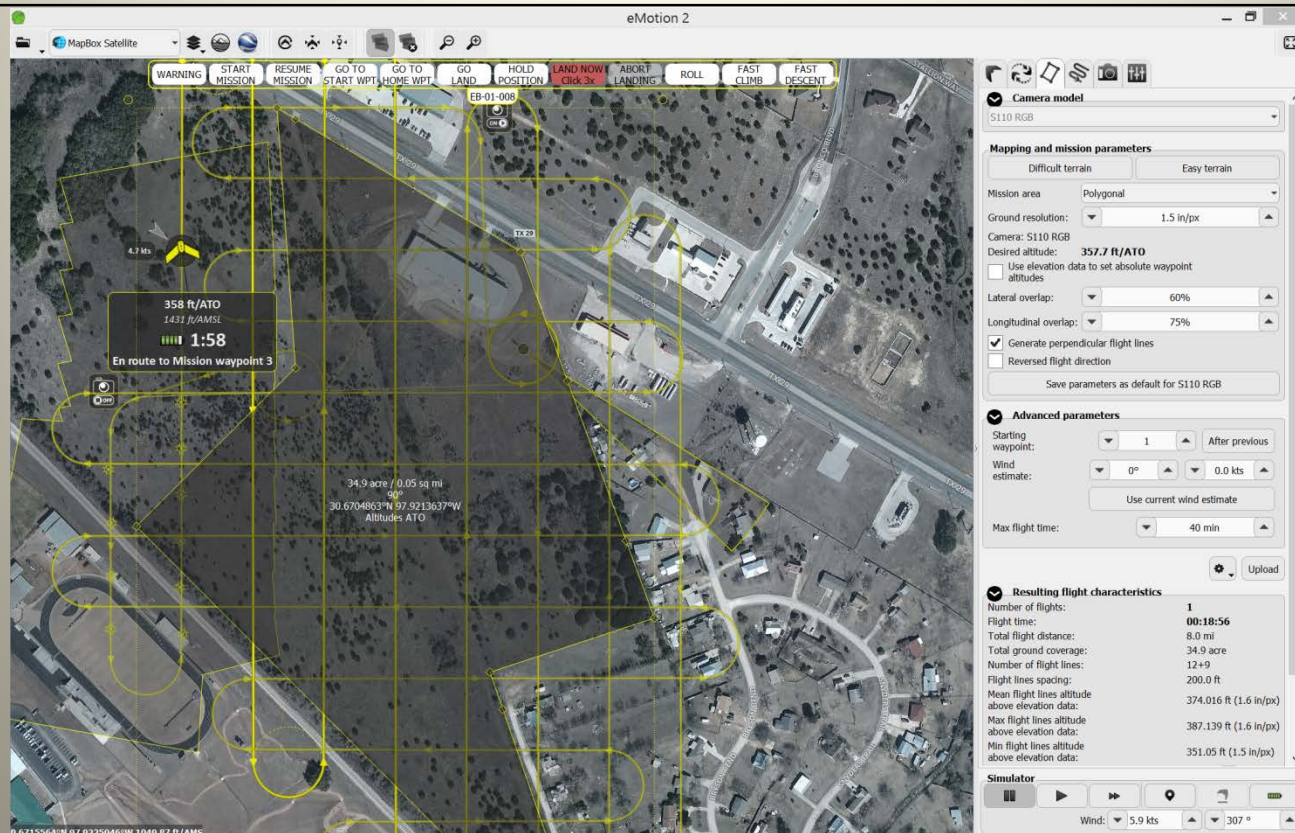
# Safety Considerations

- Autonomous Flight Required for proper data collection
- DO's
  - Fly within Line of Sight
  - Remain below 400' AGL and outside of controlled airspace
  - Use spotter to handle people, have them keep their distance during takeoff and landing
  - Be prepared to take control of aircraft if autonomous flight fails
  - Give yourself a cushion on battery level
- BE PREPARED
  - For the possibility of the aircraft losing power
  - Fixed wing – more options & less weight than multirotor
- DO NOT
  - Fly linearly over major roads
    - Cross them at right angles
  - Allow people to distract you during flight
  - Fly over crowds of people



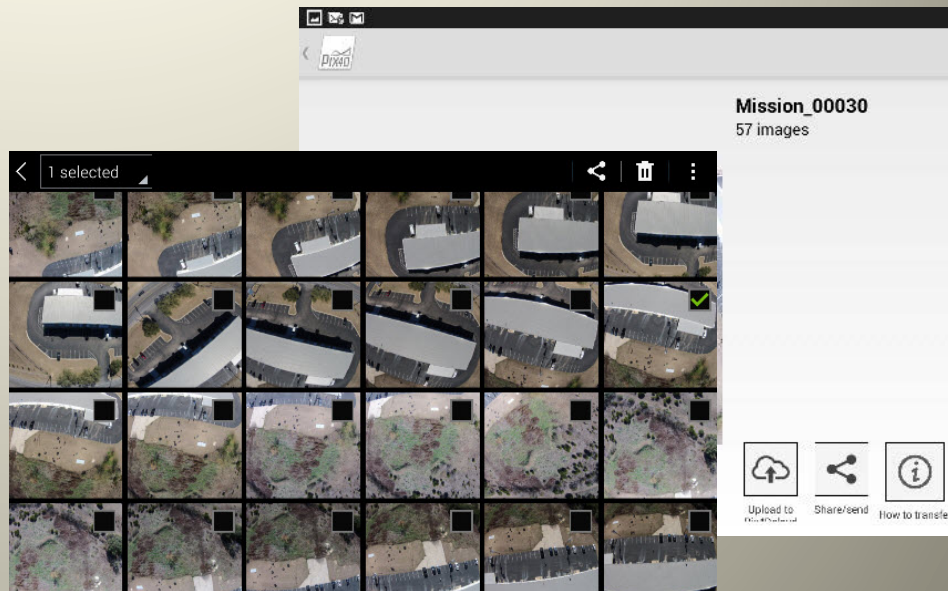
# Sample Fixed Wing Capture (SenseFly eBee)

# Sample eBee Mapping Flight



# Post Flight Processing

- Transfer to tablet
  - Annotates images with more accurate GPS geotags
  - Creates .p4d file
- Upload to PC for processing
  - Pix4D cloud (initial quality check) & later retrieval)
  - Dropbox
  - Manual transfer





# Field Reporting (Optional)

From: Pix4D Cloud Services <cloud\_services@mail133-7.atl131.mandrillapp.com> on behalf of Pix4D Cloud Services <cloud\_services@pix4d.com> Sent: Tue 3/3/2015 11:00 AM  
 To: Vertical Aspect Support  
 Cc:  
 Subject: Project Mission\_00030 processed

Message dsm\_Mission\_00030.png (226 KB) ortho\_Mission\_00030.png (290 KB)



Dear Vertical Aspect,

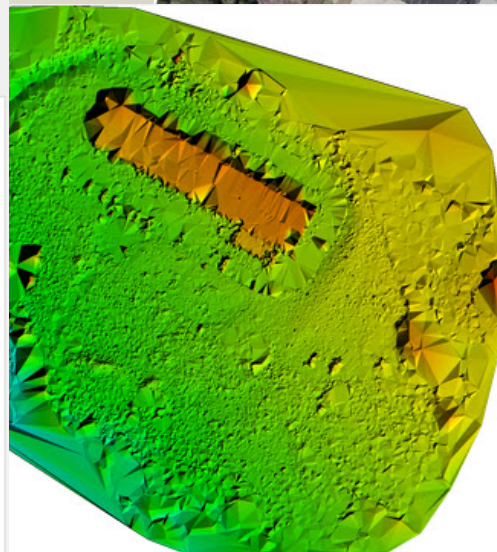
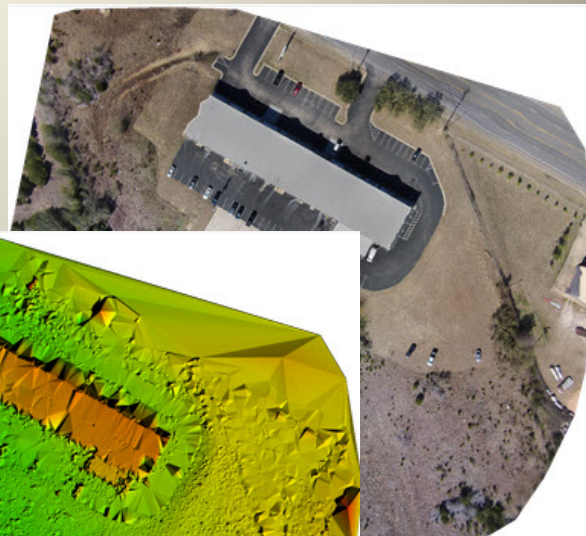
**Good news!** Mission\_00030 has been processed. Find here attached a preview of the orthomosaic and DSM.

## Go further!

Want to assess your project in detail, improve it with many edition features, perform precise measurements directly in the software and save output results such as point clouds, vector objects, contour lines, DTMs, meshes and more? Just download your project and open it on your desktop computer with **Pix4Dmapper Pro**.

Thanks for choosing Pix4Dmapper and lots of success with your projects.







The Pix4D team





# Initial Processing

Project
Process
View
Map View
Help

Satellite

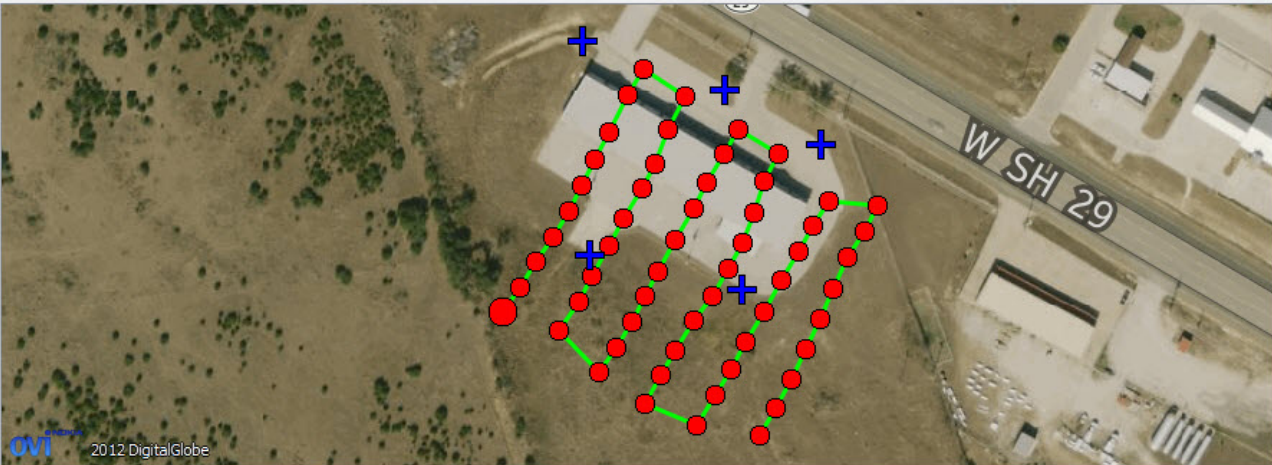
Welcome

Map View

rayCloud

MosaicEditor

Index Calculator



2012 DigitalGlobe

Local Processing

☒ 1. Initial Processing
☒ 2. Point Cloud Density
☒ 3. DSM and Orthomosaic Generation

☒ Full Processing
☐ Rapid Check

Resolution [cm/pixel]:

Start

Options...

Help

Progress

0%

Cancel

Project Information

Project Summary

Project:
Name: Mission\_00030-wGCP
Type: Aerial nadir
Workspace: D:/Pix4d missions/TABLET MISSION DATA/Mission\_00030-UAV Direct
Output Datum: World Geodetic System 1984
Output Coordinate System: WGS 84 / UTM zone 14N

Layers

☒ Images
☒ GCPs
☐ Processing Areas
☐ Point Cloud Density Area
☐ Orthomosaic Area

WGS84 - (30.6726703, -97.922446) WGS84 / UTM zone 14N - (603222.463, 3393821.70) [m]

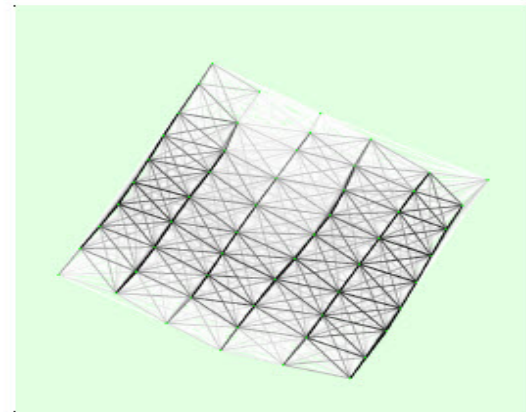
## 3D Points from 2D Keypoint Matches

### Summary

Project	Mission_00030-wGCP
Processed	2015-Mar-02 14:10:46
Camera Model Name	PHANTOMVISIONFC200_5.0_4608x3456-UAVDirect (RGB)
Average Ground Sampling Distance (GSD)	2.28 cm / 0.89 in
Area Covered	0.0222 km <sup>2</sup> / 2.2177 ha / 0.0086 sq. mi. / 5.483 acres
Image Coordinate System	WGS84
Ground Control Point (GCP) Coordinate System	WGS84
Output Coordinate System	WGS84 / UTMzone 14N
Processing Type	full Aerial nadir
Feature Extraction Image Scale	1
Camera Model Parameter Optimization	optimize externals and all internals

### Quality Check

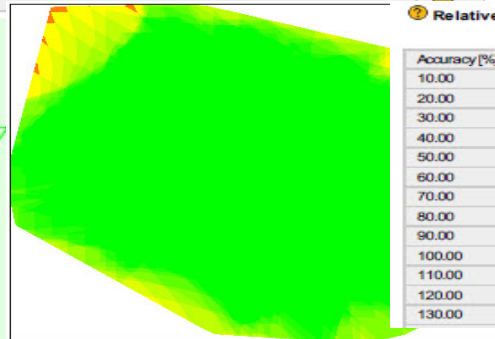
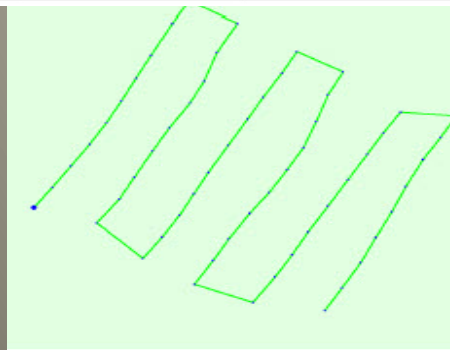
Images	median of 39147 keypoints per image	✓
Dataset	57 out of 57 images calibrated (100%), all images enabled	✓
Camera Optimization	0.63% relative difference between initial and final focal length	✓
Matching	median of 11314.1 matches per calibrated image	✓
Georeferencing	no 3D GCP	⚠



Number of matches: 25 222 444 666 888 1111 1333 1555 1777 2000

### Relative Geolocation Variance

Accuracy [%]	Images X [%]	Images Y [%]	Images Z [%]
10.00	1.75	5.26	54.39
20.00	10.53	17.54	94.74
30.00	26.32	45.61	100.00
40.00	45.61	61.40	100.00
50.00	57.89	71.93	100.00
60.00	71.93	85.96	100.00
70.00	82.46	94.74	100.00
80.00	87.72	98.25	100.00
90.00	98.25	100.00	100.00
100.00	100.00	100.00	100.00
110.00	100.00	100.00	100.00
120.00	100.00	100.00	100.00
130.00	100.00	100.00	100.00



Number of overlapping images: 1 2 3 4 5+

# Initial Point Cloud

Project Process View rayCloud Help

PIX4D

Welcome

Map View

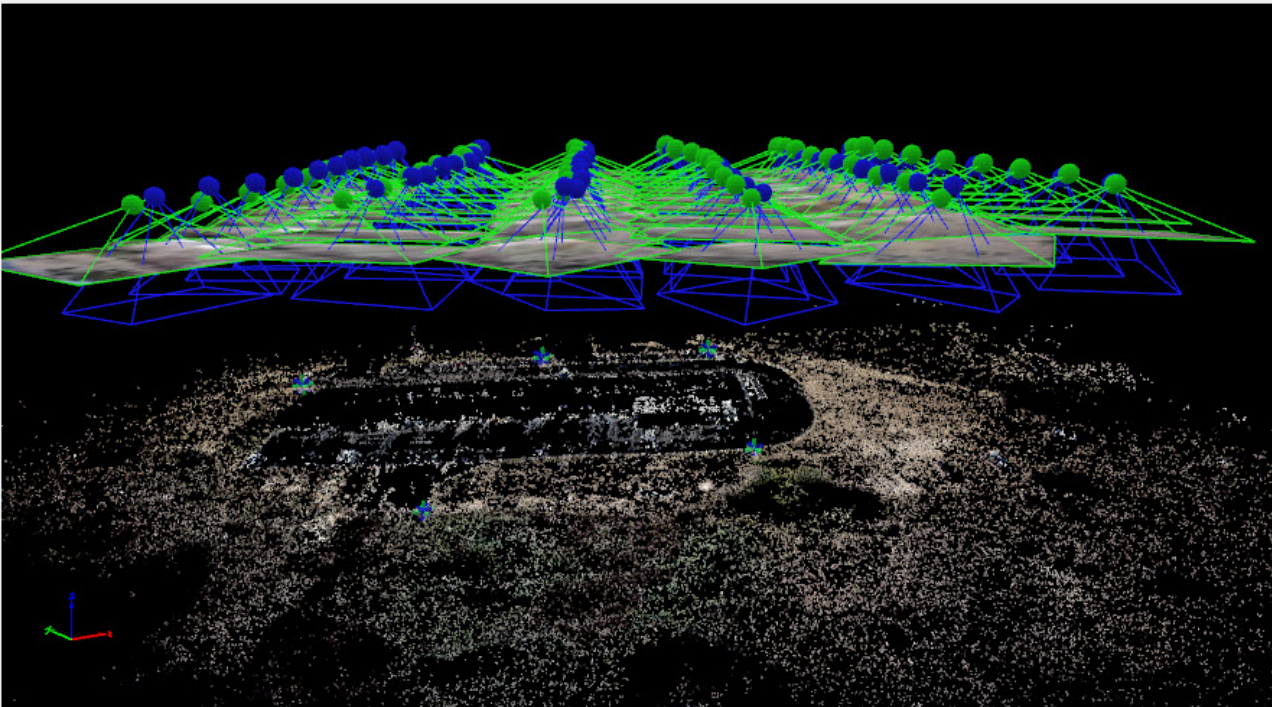
rayCloud

MosaicEditor

Index Calculator

- ☒ Cameras
- ☒ Rays
- ☒ Tie Points
  - ☒ Manual / GCPs
  - ☒ Automatic
- ☐ Processing Areas
- ☐ Point Clouds
  - ☐ Display Properties
  - ☐ Densified Point Cloud
    - ☐ Mission\_00030-wGCP\_densified
- ☒ Point Groups
  - ☒ Unclassified
  - ☐ Deleted
  - ☒ Terrain
  - ☒ Objects
- ☐ Triangle Meshes
  - ☐ Display Properties
  - ☐ Mesh Mission\_00030-wGCP\_simplified
- ☐ Objects

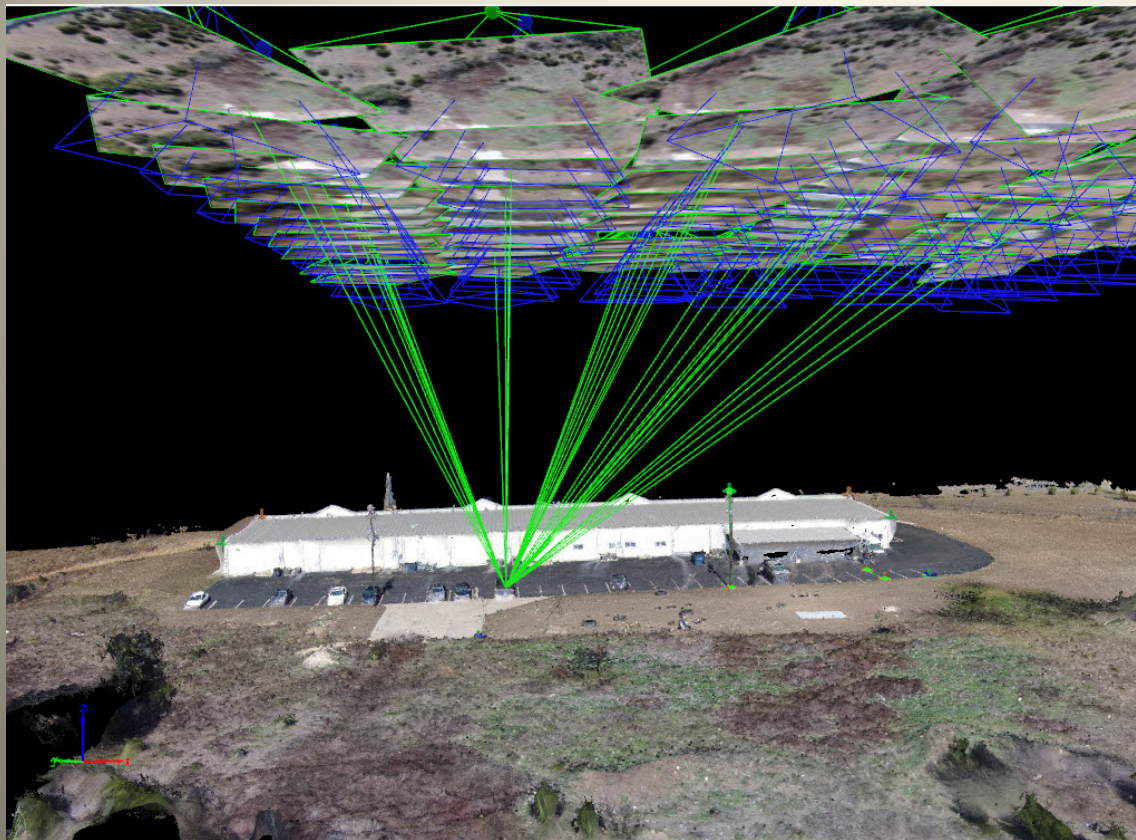
Unclassified Assign



WGS84 / UTM zone 14N - 603281.26, 3393727.60, 301.63 [m]



# Ray Cloud



Properties

▼ Selection

Densified Point

Number of Images Visible In: 39

Computed Position[m]: 603344.16, 3393754.50, 307.13

Help

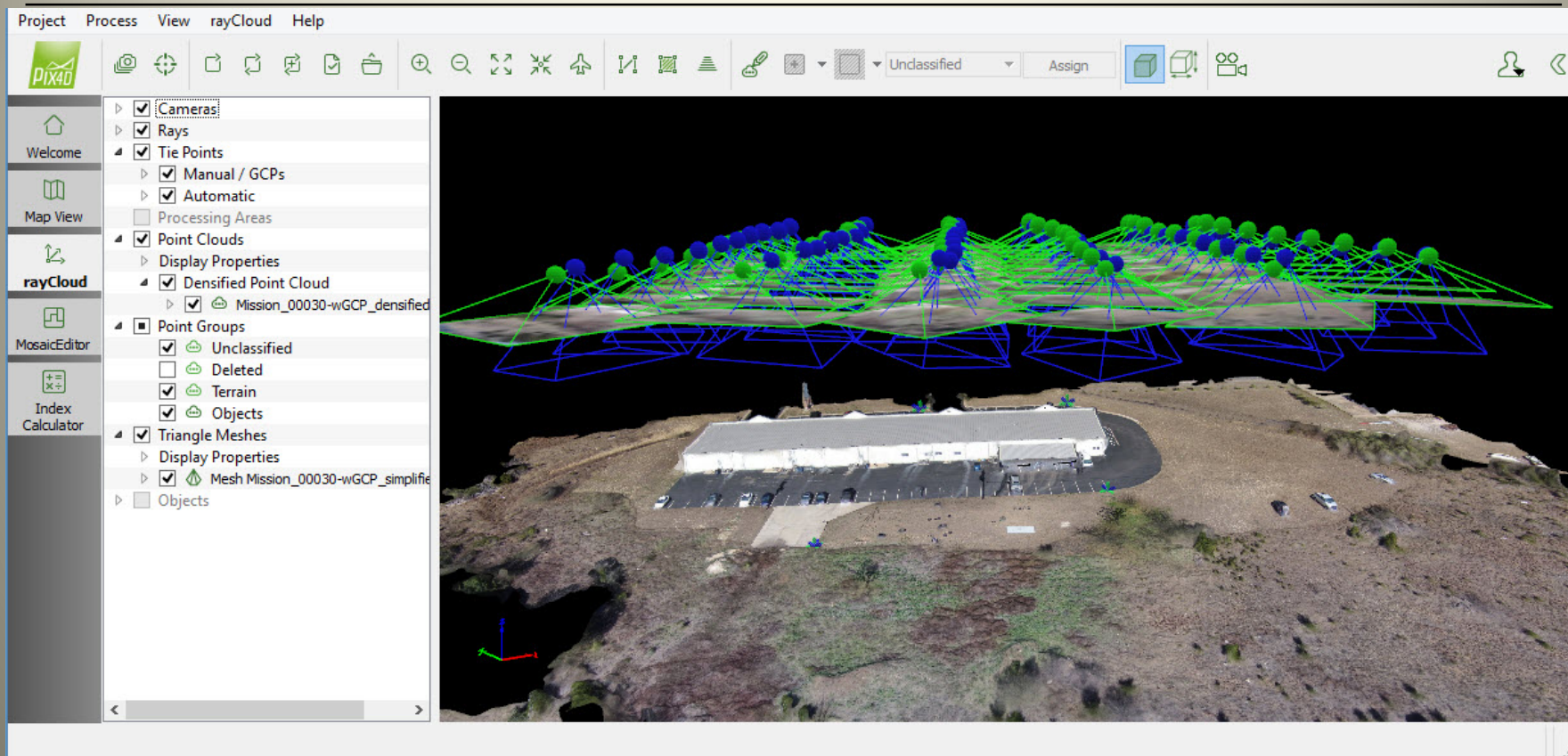
▼ Images

Image Size      Zoom Level

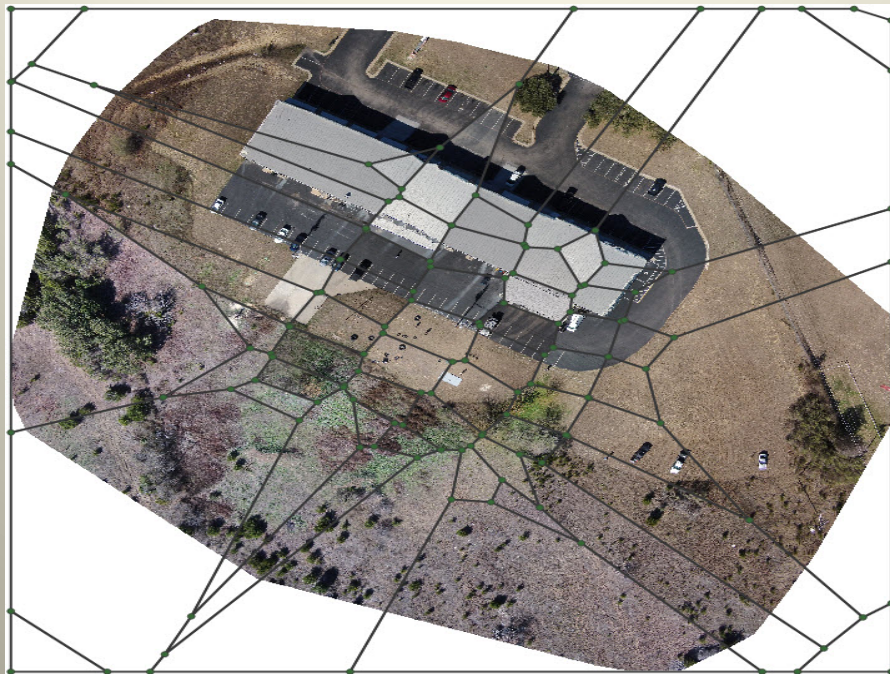
<p>DJI00387.JPG</p>	<p>DJI00388.JPG</p>	<p>DJI00378.JPG</p>
<p>DJI00379.JPG</p>	<p>DJI00389.JPG</p>	<p>DJI00386.JPG</p>
<p>DJI00377.JPG</p>	<p>DJI00397.JPG</p>	<p>DJI00398.JPG</p>



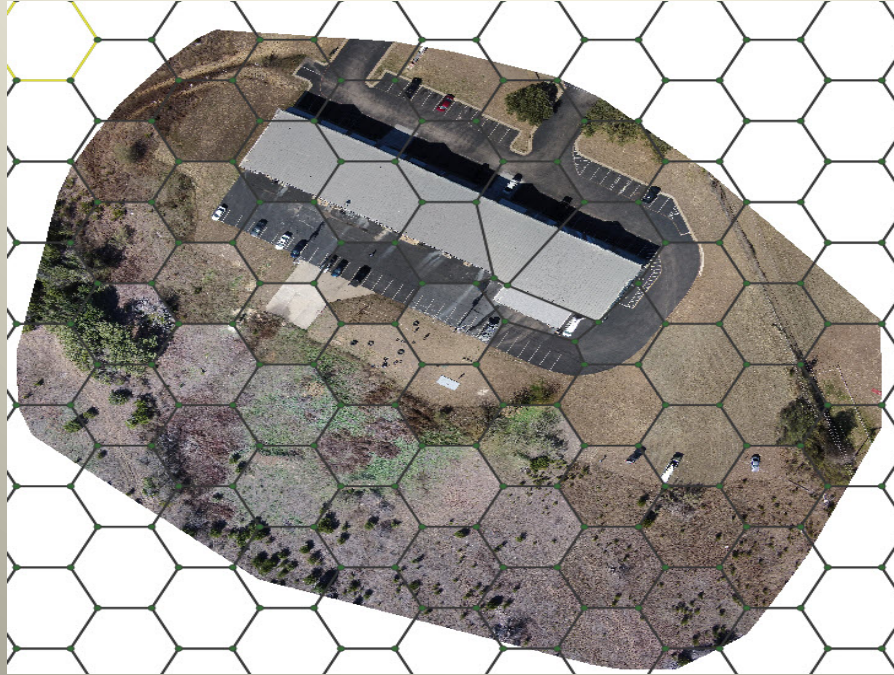
# Densified Point Cloud



# Mosaic Mesh – Initial



# Mosaic Mesh – Reset



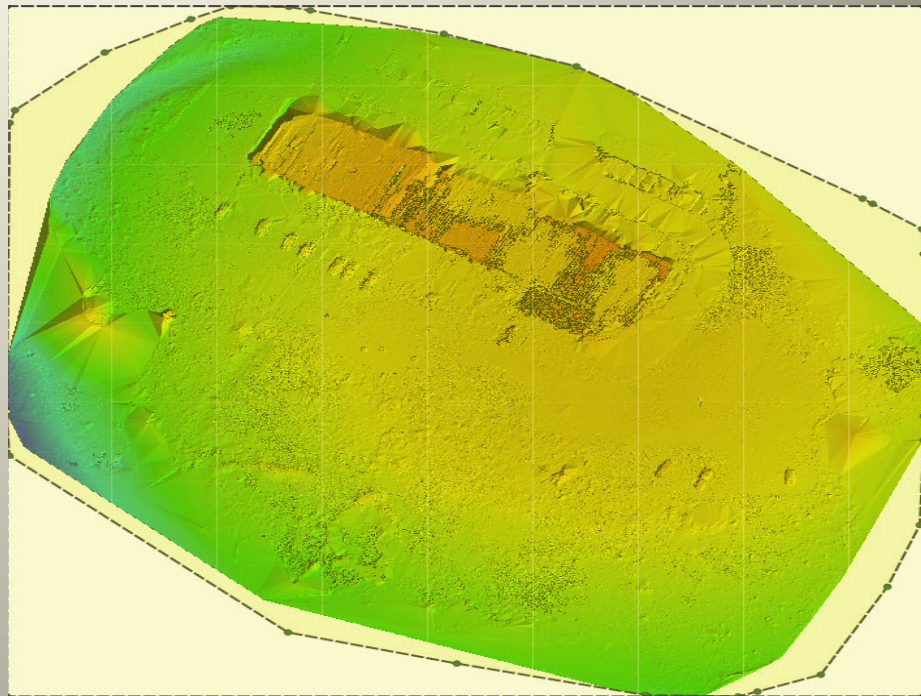
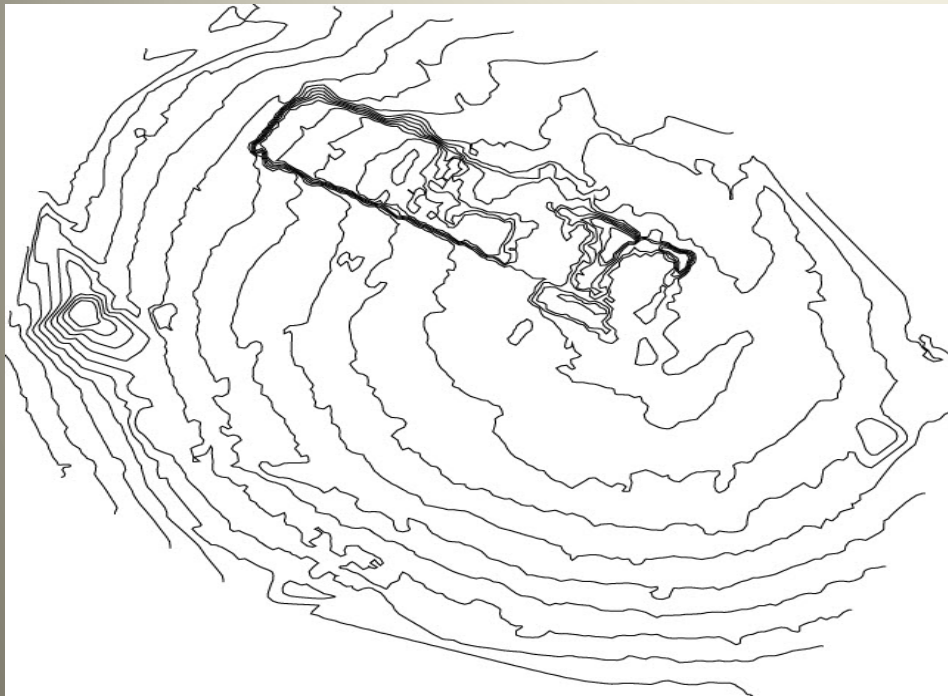


# Mosaic - Blended





# Contour and DSM

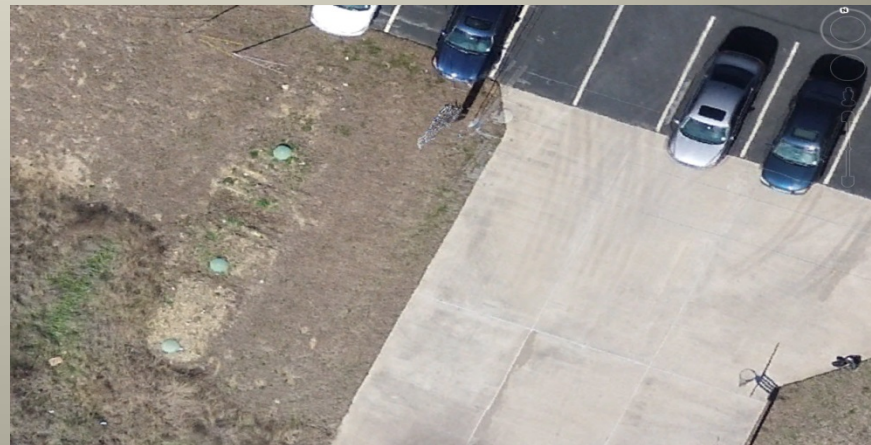




Google Earth



Pix4D Overlay



# Questions?



Jeff Campbell  
(202) 494-8410

[www.verticalaspect.com](http://www.verticalaspect.com)

or e-mail us at

[support@verticalaspect.com](mailto:support@verticalaspect.com)