National Unmanned Aircraft Systems (UAS) Project Office

USGS
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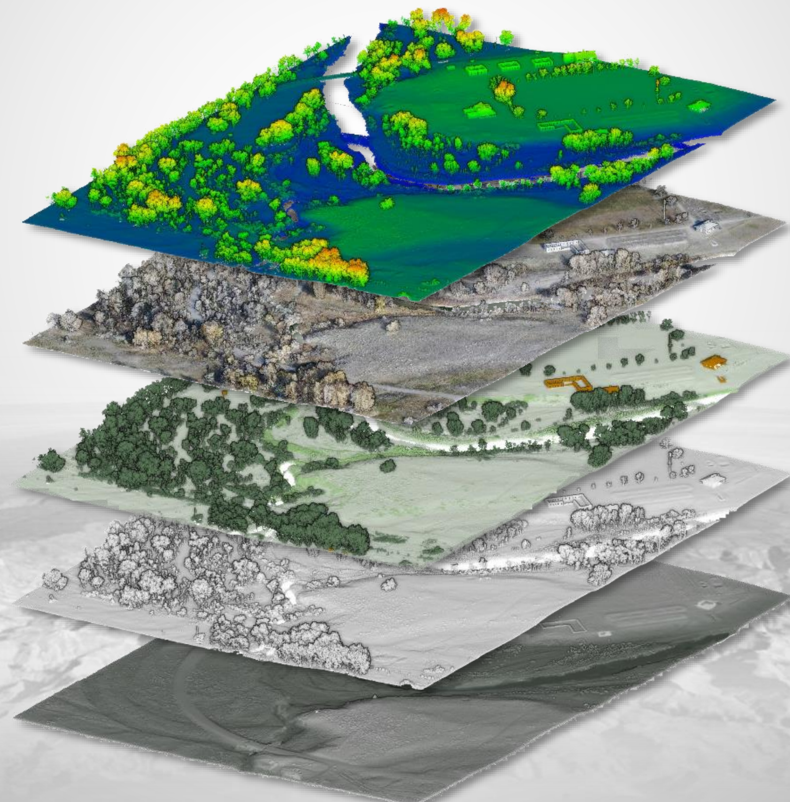


3-D POINT CLOUD DATA
DIGITAL SURFACE MODELS
DIGITAL TERRAIN MODELS
ORTHOIMAGERY
SEGMENTATION AND CLASSIFICATION

UAS PLATFORM RESEARCH
SENSOR INTEGRATION
DATA STANDARDS
GEOSPATIAL PRODUCTS

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2018

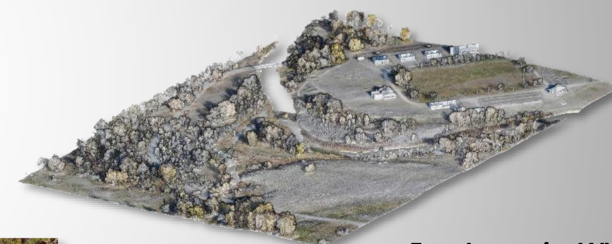
Photogrammetric Principles and UAS

What makes a good photogrammetric UAS product?

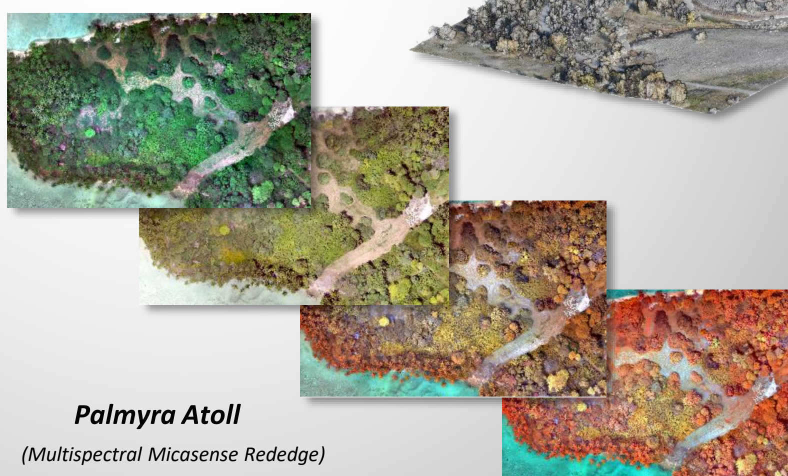
1.) Photography
2.) Geometry
3.) Ground Control / Scale

Example Products produced in Photoscan

Devils Tower, WY
(ground based survey)



Fort Laramie, WY
(photo lidar merge)



Palmyra Atoll
(Multispectral Micasense Rededge)

Talking Points

- Rules of Photogrammetry
- Base to Height Ratios
- Flight Patterns
- Camera Calibrations
- Ground Control
- Scale and Targets
- Pre-Processing Imagery

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Photogrammetric Principles and UAS

Photogrammetry is the science of making measurements from photographs.

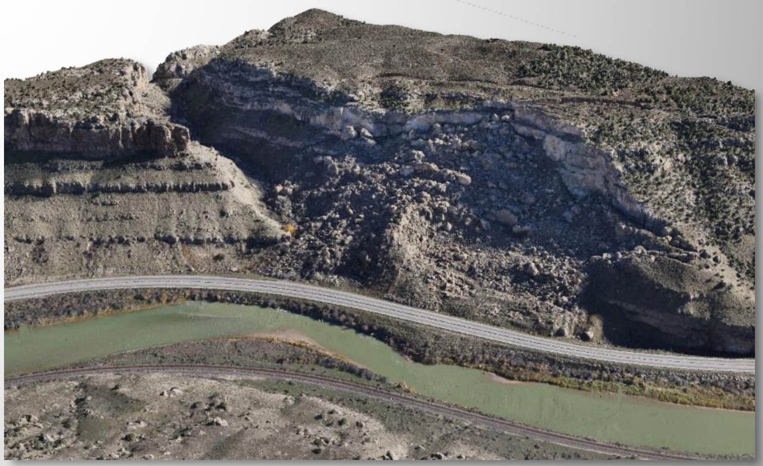
Agisoft Photoscan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images. Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated.

Platte River, NE

Primary Goal: To model a 3D surface, capturing color reflectance accurately, and minimizing sources of error.

- **Photoscan uses computer vision auto matching algorithm to reconstruct a 3D surface. The technique is also sometimes referred to as structure from motion.**

Devils Tower, WY
(ground based survey)



Debeque Landslide, CO

Photogrammetric Principles and UAS

Some Basic Rules of Photogrammetry. (The Matching Algorithm)

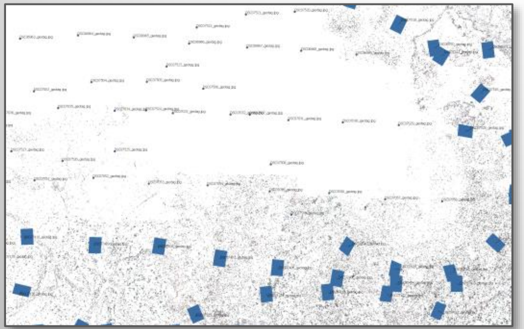
What will break the photo alignment?

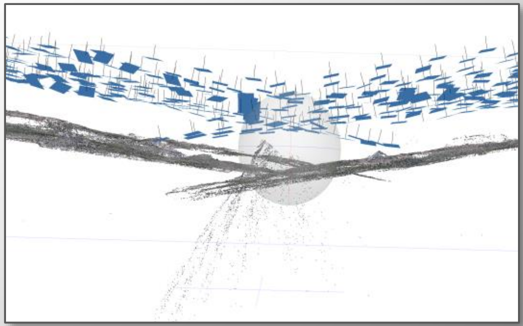
1.) Not having enough overlap. (Min 20% - 50% Ideal)

2.) Too much difference in scale. (More than 2x the scale)

3.) The look angles are too high. (20° angles or more)

4.) The images have poor quality.





Photogrammetric Principles and UAS

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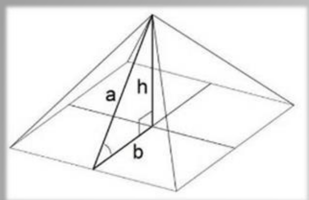
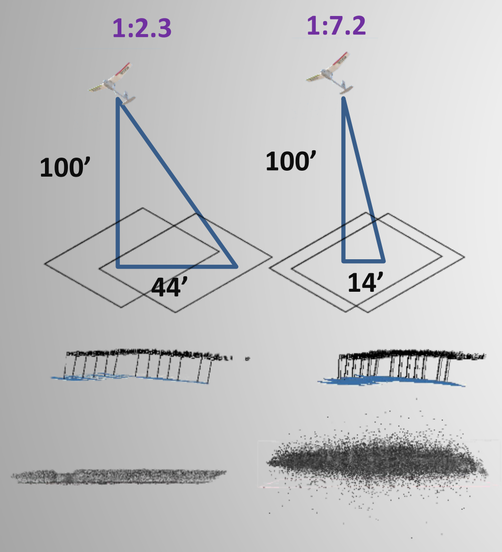
Photogrammetric Principles and UAS



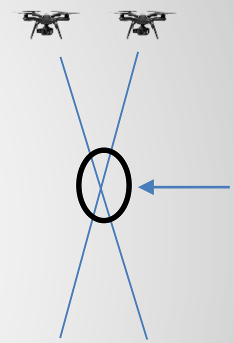
Capturing Your Photos with Good Geometry / Base to Height Ratios

- Good photo geometry is very important for the alignment between photos.
- Stereo overlap (in-lap) 66% side-lap 50%.
- Wide angle lens will improve reconstruction geometry. Stay away from fish-eye lenses.

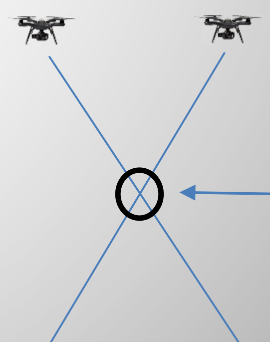
Base to Height Ratio



- Your ability to measure depth (z) goes down when your base to height ratio goes up. This is a direct relationship of photo geometry.
- Geometry with Base to Height Ratio of 1:5 has 5 times more potential for error in Z than 1:1



More uncertainty in your height measurement.



Less uncertainty in your height measurement.

- 1:1 ratio equals about 20% overlap
- 1:2.3 ratio equals about 66% overlap
- 1:5.2 ratio equals about 85% overlap
- 1:7.2 ratio equals about 90% overlap

Technically the best geometry but overlap area is too small

Base to Height Ratio between 1:2.3 and 1:5.2 is ideal.

Holy overlap batman! Your uncertainty in (z) depth is high.

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Camera Orientation

Landscape mode – flight direction parallel to long axis of sensor.

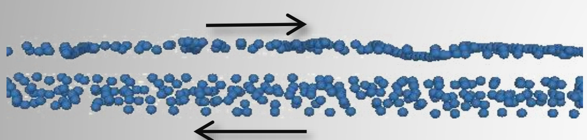
Portrait mode – flight direction parallel to short axis of sensor.

- Multiple Camera orientations will help map the lens distortion by locating the center position (principle point) within your lens calibration model. Rotating your camera at 0°, 90°, 270° is ideal.
- Having redundancy in your photo collects provides you with more information to solve for a accurate camera calibration.

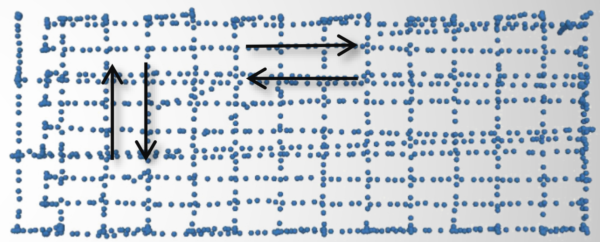
Photogrammetric Principles and UAS

Capturing Your Photos with Good Geometry

- Having consistent base to height ratios improves the model.
- Changing your orientation improves your camera calibration
- Changing height is good, but not more than double the scale. The alignment will break.
- Adding redundancy provides the software with more information.



- Photos taken at different distances will have different look angles and more redundancy, overall you'll have more information to solve for your lens distortion parameters.
- Use separate camera calibration groups



- Adding perpendicular collects provides more redundancy by adding more look angles.

*Redundancy is important! (Photos collected between 66% overlap, and 85%) Having more look angles will help construct a better DSM.   Also Note: Having redundancy in our collects is important for a high quality camera calibration, and it will also allow you to remove any poor quality photos that may have been taken during the collect and still have proper overlap.

Photogrammetric Principles and UAS

Capturing Your Photos with Good Geometry / Tools

What will be my ground sample distance?

$$GSD = \frac{\text{pixel size x flight height (AGL)}}{\text{focal length}}$$

Unmanned Aircraft System Flight Planning

Camera	Ricoh GR						
Camera Inputs:	FL (mm)	Img wdth (pix)	Image hgt (pix)	Sensor wdth (mm)	Sensor hgt (mm)	Pix Size (wdth)	Pix Size (hgt)
	18.3	4928	3264	23.70	15.70	0.0048	0.0048

Calculations:	GSD wdth (cm)	GSD hgt (cm)	GSD wdth (inches)	GSD hgt (inches)	Photo wdth (ft)	Photo hgt (ft)
50 ft	0.40	0.40	0.16	0.16	64.8	42.9
100 ft	0.80	0.80	0.32	0.32	129.5	85.8
200 ft	1.60	1.60	0.63	0.63	259.0	171.6
300 ft	2.40	2.40	0.95	0.95	388.5	257.4
400 ft	3.20	3.20	1.26	1.26	518.0	343.2
500 ft	4.01	4.01	1.58	1.58	647.5	429.0
600 ft	4.81	4.81	1.89	1.89	777.0	514.8
700 ft	5.61	5.61	2.21	2.21	906.6	600.5
800 ft	6.41	6.41	2.52	2.52	1036.1	686.3
900 ft	7.21	7.21	2.84	2.84	1165.6	772.1
1000 ft	8.01	8.01	3.15	3.15	1295.1	857.9

Flight Planning:	Speed (mph)	Speed (kts)	Flt Hgt (ft.-AGL)	Dist. Side Transect (ft)	Dist. Forelap (ft)	Cam. Interv. (s)
50 ft	10	9	50	32.4	14.6	0.99
100 ft			100	64.8	29.2	1.99
200 ft			200	129.5	58.3	3.98
300 ft		Speed (m/s)	300	194.3	87.5	5.97
400 ft		4.4704	400	259.0	116.7	7.95
500 ft			500	323.8	145.8	9.94
600 ft			600	388.5	175.0	11.93
700 ft			700	453.3	204.2	13.92
800 ft			800	518.0	233.4	15.91
900 ft			900	582.8	262.5	17.90
1000 ft			1000	647.5	291.7	19.88

ADAM TECHNOLOGY

Object Distance Calculation Spreadsheet

Camera Name: Ricoh GR

Camera Details	Width Height			
Number of pixels:	4928 × 3264		Image size:	16.1 megapixels
Image sensor dimensions:	23.7 × 15.7	mm	Field of View Crop/Lens multiplier:	1.5 x 1.5
Actual focal length of lens x adapter:	18.3 mm		Equivalent 35mm camera focal length:	28 mm
Actual aperture:	f/ 5.6		Equivalent 35mm camera aperture:	f/8.5
Focus distance:	60.96 ft		Depth of field:	9.79ft - Infinity
Desired circle of confusion (diameter):	3.5 pixels		Hyperfocal distance:	11.71 ft
Size of each pixel in CCD array:	4.81 × 4.81	um		

Required Conversion: Distance -> Pixel Size | Project Type: Aerial Strips

Model Details			Accuracy Estimates	
Desired flying height:	400	ft	Estimated image accuracy:	0.3 pixels
Ground coverage of each Image:	518 × 343.2	ft	Distance between camera stations:	176.1 ft
Ground pixel size:	1.3 × 1.3	inche	Flying height/base ratio:	2.27 : 1
Desired target size:	7.6	inche	Estimated plan accuracy:	0.4 inches
Desired target + border size:	20.2	inche	Estimated height accuracy:	0.9 inches
Nominal DTM point density:	5	inches per point	Estimated overall accuracy:	1 inches
Photoscale:	6664 : 1			
	133			

Area Details for Strip Planning			
Width and height of area:	5000 × 2000 ft	Distance between camera stations:	176.1 ft
Desired horizontal overlap:	66% = 341.9 ft	Distance between strips:	274.6 ft
Desired vertical overlap:	20% = 68.6 ft	Number of images per strip:	28
Desired flying speed:	22.37 mph	Number of strips:	8
Max. movement during exposure:	0.3 pixels	Total number of images:	224
Min. required shutter speed:	1/ 1000 seconds	Total distance flown:	39959.8 ft
Capture interval:	5.36656 seconds		

Photogrammetric Principles and UAS

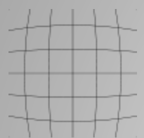
Current Cameras / Recommendations

	Camera	Sensor Size	MegaPixel	In-Lap	Sidelap	Bands
	MicaSense Rededge 3	4.8mm x 3.6mm	3.2 mp	67%	70-75%	5 Total / Alignment: 1
	Flir Vue Pro	10.9 mm x 8.7mm	0.32 mp	67%	75-90%	1 Total / Alignment: 1
	Pentax Ricoh GR II	23.7mm x 15.7mm	16 mp	67%	50%	3 Total / Alignment: 3
	Sony a7R	35.9mm x 24.0mm	36 mp	67%	50%	3 Total / Alignment: 3
	Sony RX1R II	35.9mm x 24.0mm	42 mp	67%	50%	3 Total / Alignment: 3
	Phase One IXU 150	43.8mm x 32.9 mm	50 mp	67%	50%	3 Total / Alignment: 3

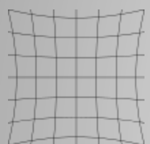
Photogrammetric Principles and UAS

Camera Calibration and Correcting Lens Distortion

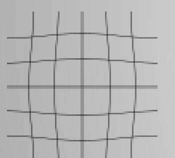
All cameras have some amount of lens distortion. This error needs to be minimized and modeled.



Barrel Distortion

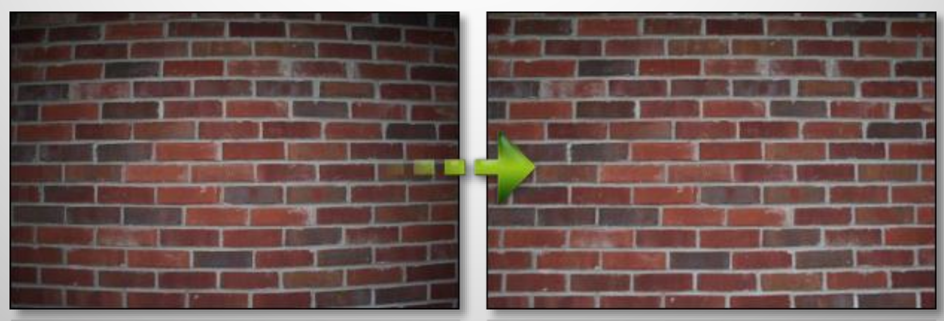


Pincushion Distortion



Complex Distortion

- **Photoscan estimates internal and external camera orientation parameters during photo alignment.**
- **A good camera calibration is critical for surveying with a camera. Variation of photo orientation will help find better measurements during the self calibration process.**
- **Lens change in size and shape when environmental conditions change. Metric cameras minimize those effect, but those factors still exist.**
- **"Optimization" is a least squares bundle adjustment.** **The software takes measurements and corrects for radial and tangential distortions.**



Photogrammetric Principles and UAS

Camera Calibration and Correcting Lens Distortion

Coefficients are mathematic expressions of the physical conditions of a lens.

Fc - Focal Length in x, y in pixels
Cx - Principal Point X
Cy - Principal Point Y
K1 - Radial distortion coefficient
K2 - Radial distortion coefficient
K3 - Radial distortion coefficient
K4 - Radial distortion coefficient
P1 - Tangential distortion coefficient
P2 - Tangential distortion coefficient
Skew – Skew transformation

Camera Types (mathematical models) for various lens. Photoscan currently has 3 types.

1.) Frame
2.) Fisheye
3.) Spherical

Photogrammetric Principles and UAS

Camera Calibration and Correcting Lens Distortion

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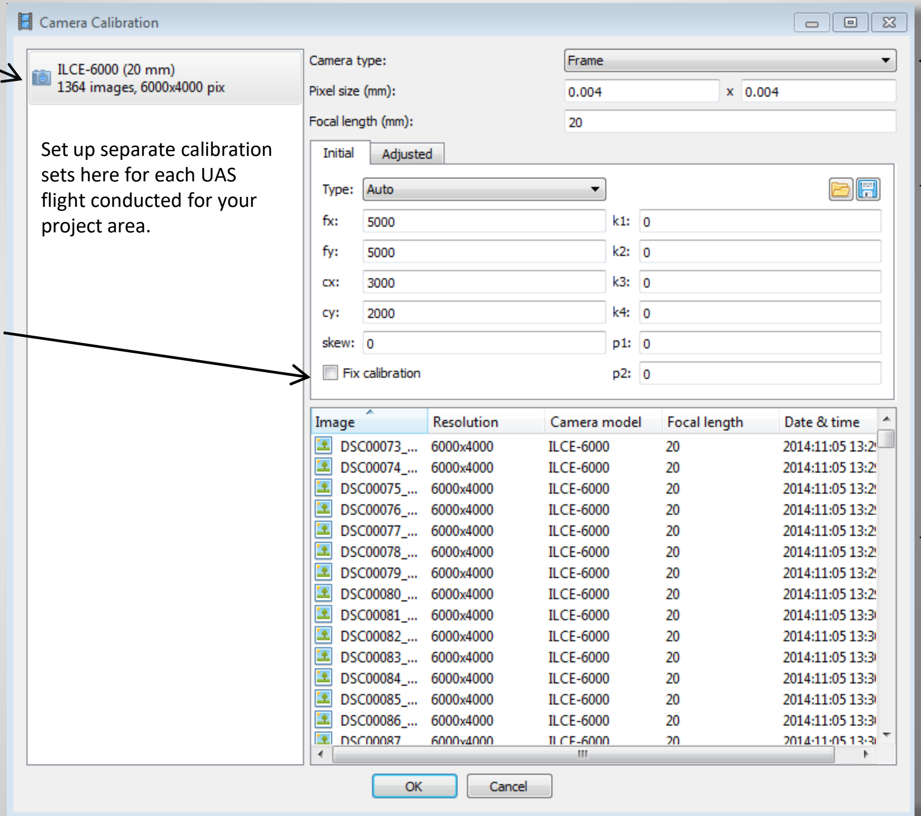
Photogrammetric Principles and UAS

Photoscan Camera Calibration and Lens Distortion Corrections

Multiple Camera Calibration Sets

At this step we want to select our different UAS flights into separate camera calibration groups.

Over Ride Option (Fix Calibration)



Camera (Model Type)

Export / Input Camera Model

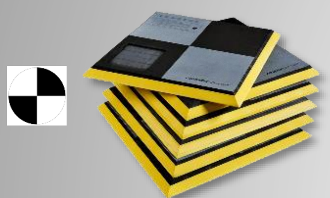
Image Sets Per Camera Model

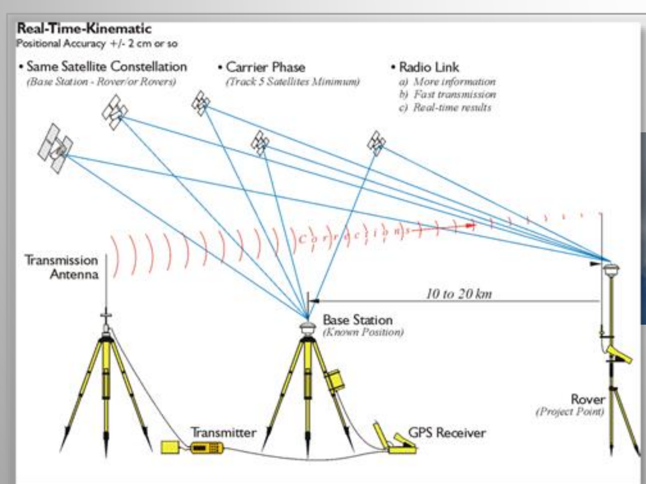
Note: The size of the sensor does not get calibrated. The size of your sensor can change (a very small amount) over time.

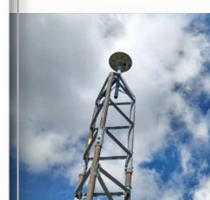
Photogrammetric Principles and UAS

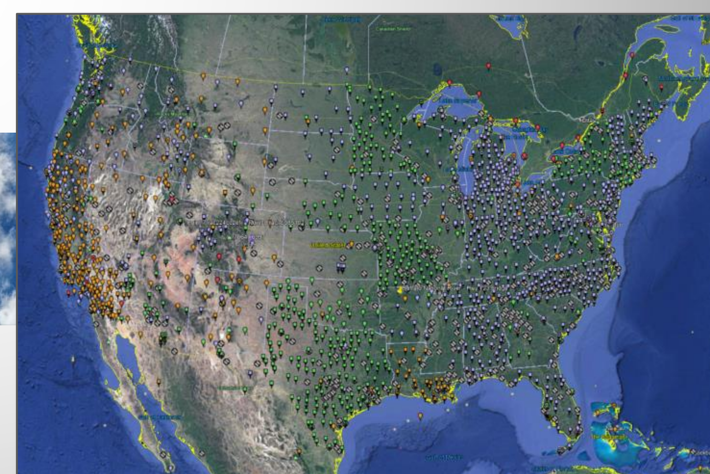
Ground Control, Scale, and Coordinate System

We have many difference GPS Sources









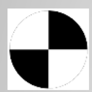
Photogrammetric Principles and UAS

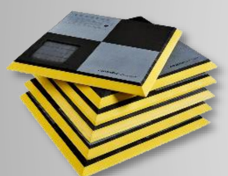
Ground Control, Scale, and Coordinate System

Photoscan can automatically detect pattern targets.

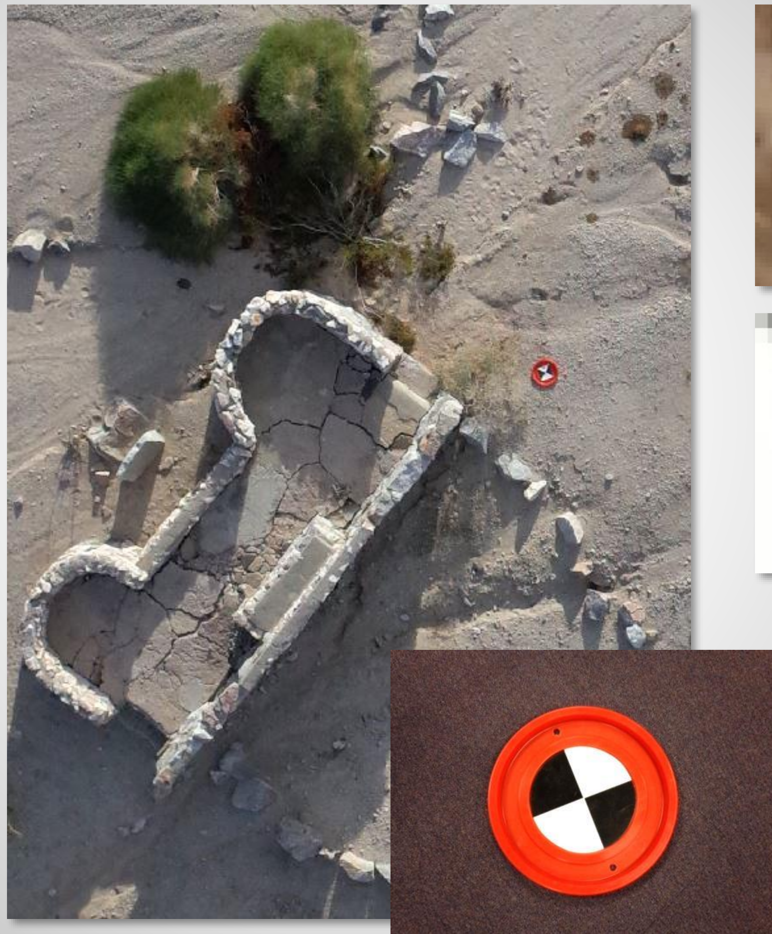
Circular

Cross





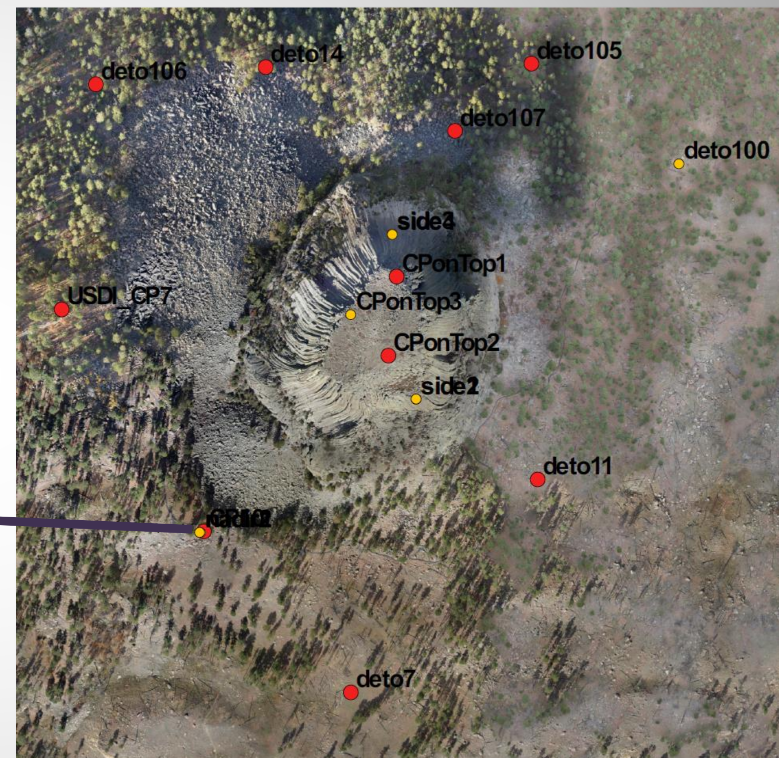
- Tip – Distribute your control points through out the edges of your study site. Pick a few in the center as well.
- Tip – If placing manually, set your GCPs markers on photos that have the target near the center of the photo. Pick the clearest, sharpest photos.



Some UAS system are introducing RTK hardware into the air vehicle platform. The positional data is imbedded into the .exif information.

Photogrammetric Principles and UAS

Ground Control, Scale, and Coordinate System

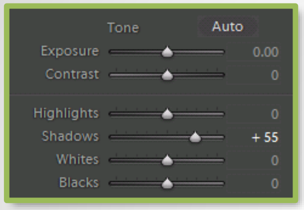


Photogrammetric Principles and UAS

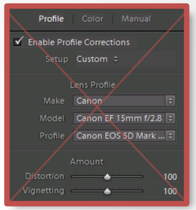
Pre-Processing your images before Photoscan Processing (Photoshop / Lightroom / Bridge)

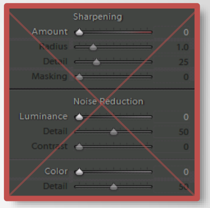
What can you do?

- You MAY make exposure changes, highlight and shadow adjustments, and remove chromatic aberration.



- You CANNOT sharpen, rotate, use noise filter adjustments, or use lens corrections!





Radiometric Corrections – The goal with these corrections is to obtain the most realistic reflectance values.

- ***Atmospheric Corrections - Atmospheric effect caused by absorption and scattering of solar radiation.***
- ***Sensor Sensitivity - Also known as vignetting, is illumination fall off around the perimeter of the lens.***

Illumination fall off

Corrected

Its important to remember any processing will result in a loss of detail.

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March 2017

National Unmanned Aircraft Systems (UAS) Project Office

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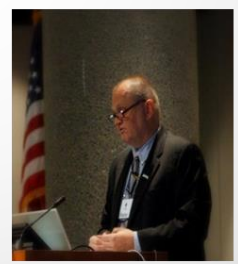

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