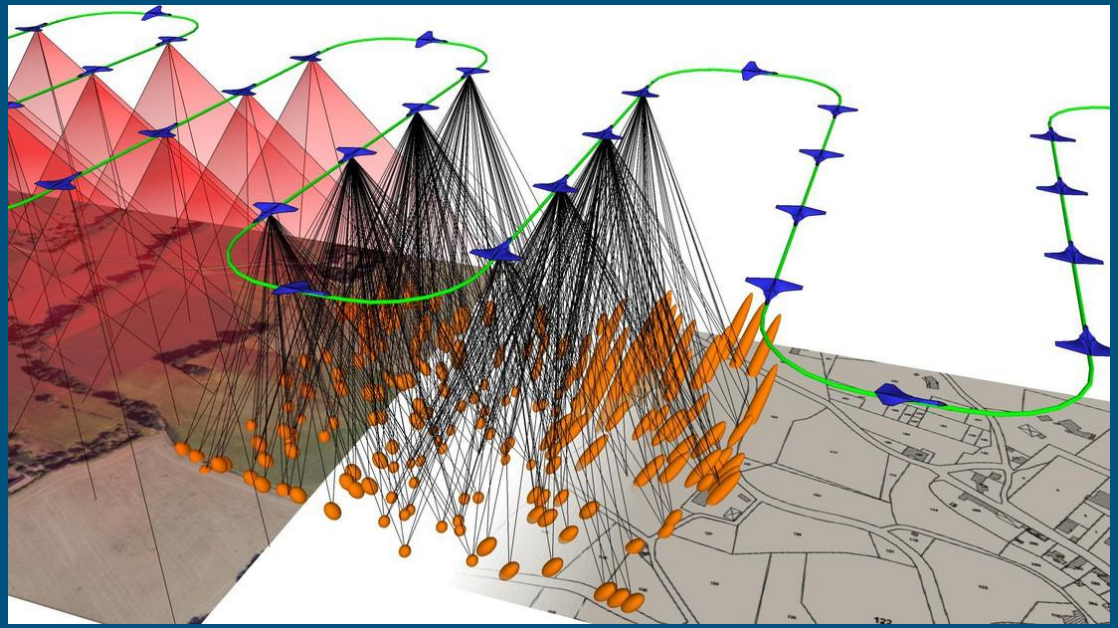
Photogrammetry with Drones

Making your drone photos into
awesome maps, models, & spatial data



Who am I?
Why are we here?

I’m Nick Short and I do geospatial things.

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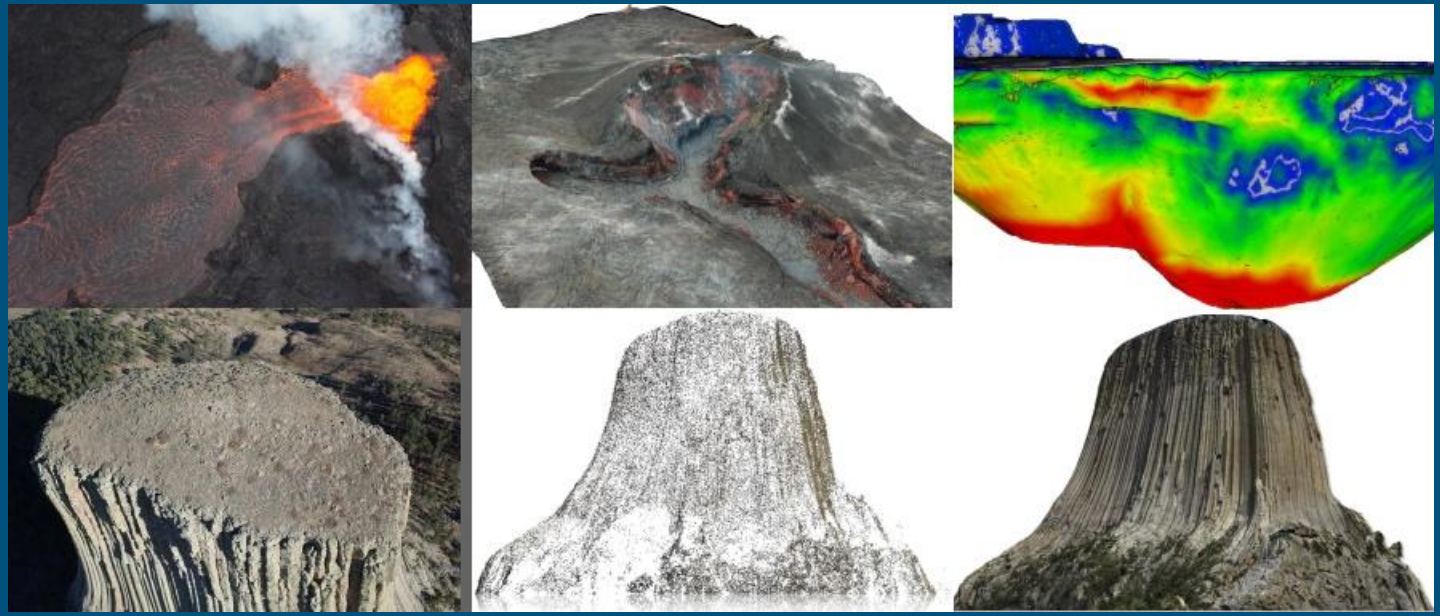
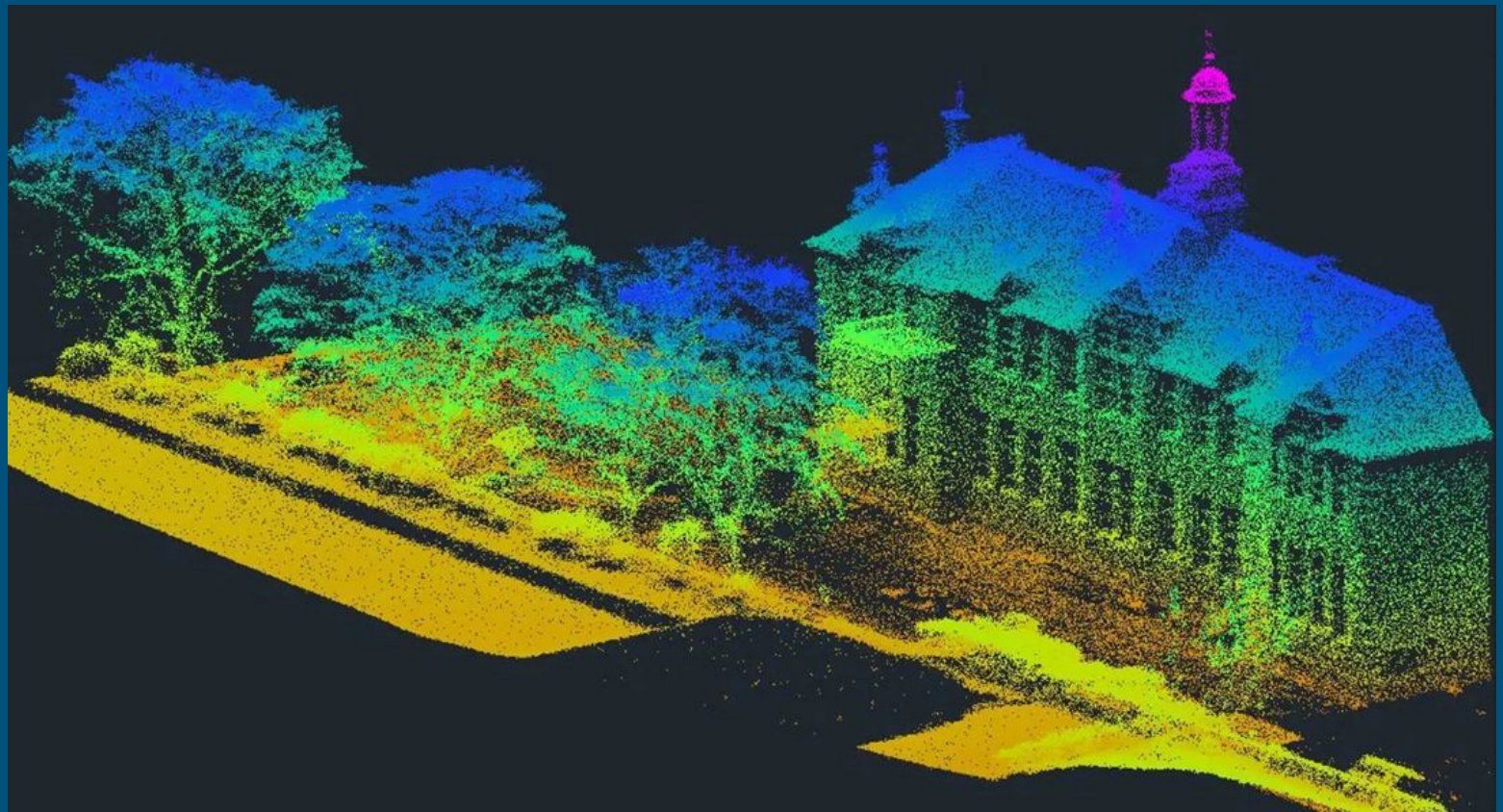
shortnick.github.io

You are here learning about taking pictures with drones to put on a computer for cool projects!

Fly drone, take photos, add software, MAGIC!



Crank Out Point Clouds!



Make Sweet 3D Models!

Overview

What is Photogrammetry?

Your Drone in Brief

Planning Your Flight

- It’s All Triangles, Infinite Triangles, Flying for Photogrammetry

Flying the Mission

- Safety Second (If Not First!), Practical Considerations

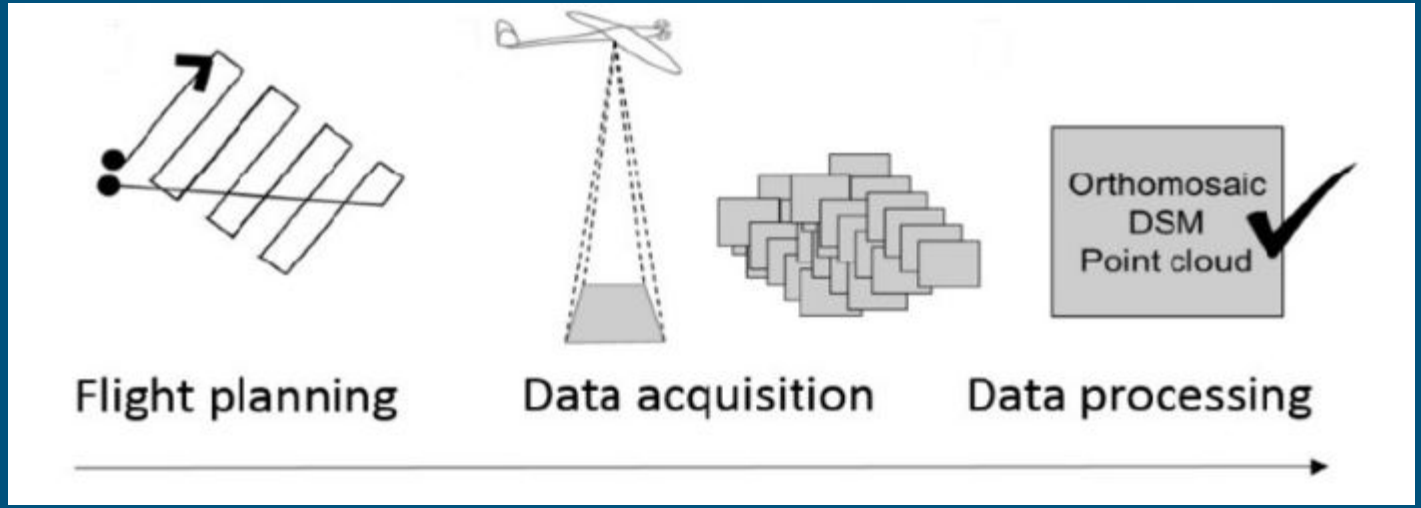
Processing Your Images

- How Software Sees the Images [various slides], Alignment – GPS vs Calculated, How’s the Quality?, Really Cool Products [various slides]

Ok. Now What?

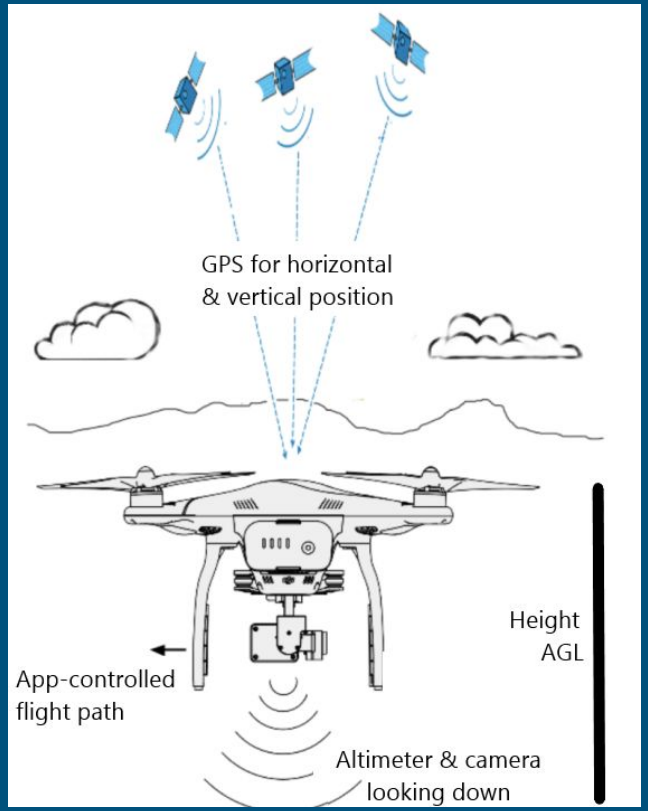
What is Photogrammetry?

Joining many smaller photos (with math) to derive 2D/3D measurements, to make maps, and to create spatial data



Your Drone in Brief

- **Drone:** less than 250 grams, decent camera, can use phone-based apps, e.g. any DJI Mini
- **AGL:** ‘above ground level’, drone altitude or height is relative to the ground where you took off
- **nadir/oblique:** aiming the drone camera straight down/closer to the horizon
- **GSD:** ‘ground sample distance’, the horizontal measurement a pixel represents using specific camera *X* at height *Y* AGL

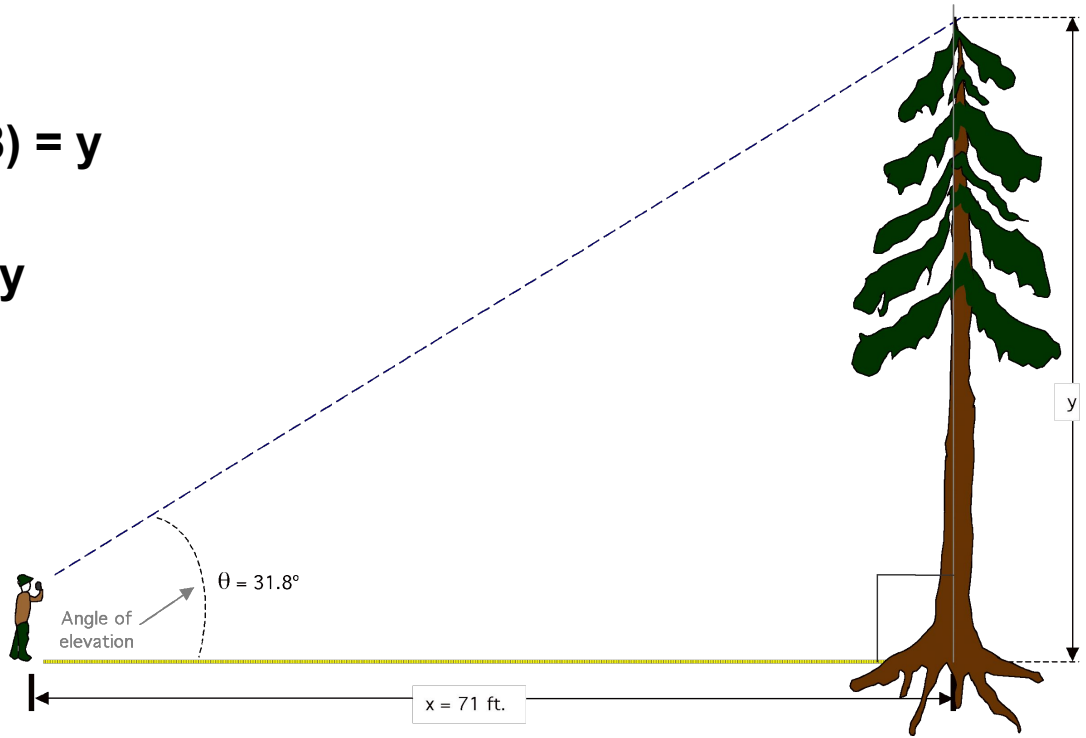


How does this work? It's all triangles

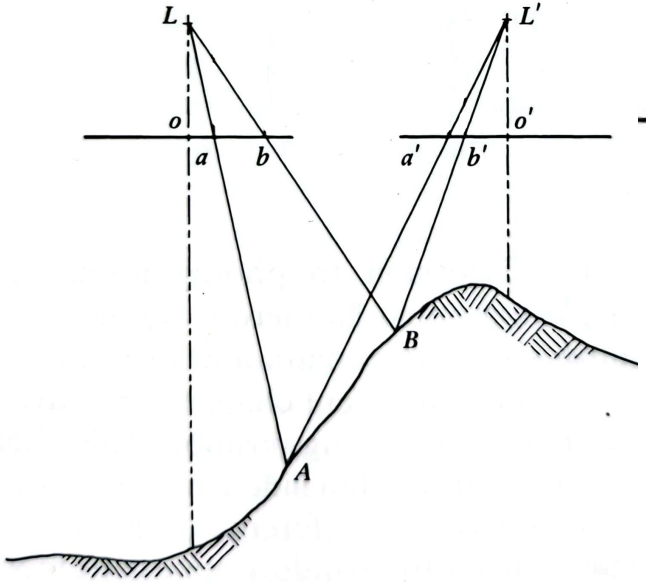
tan(θ) = y/x

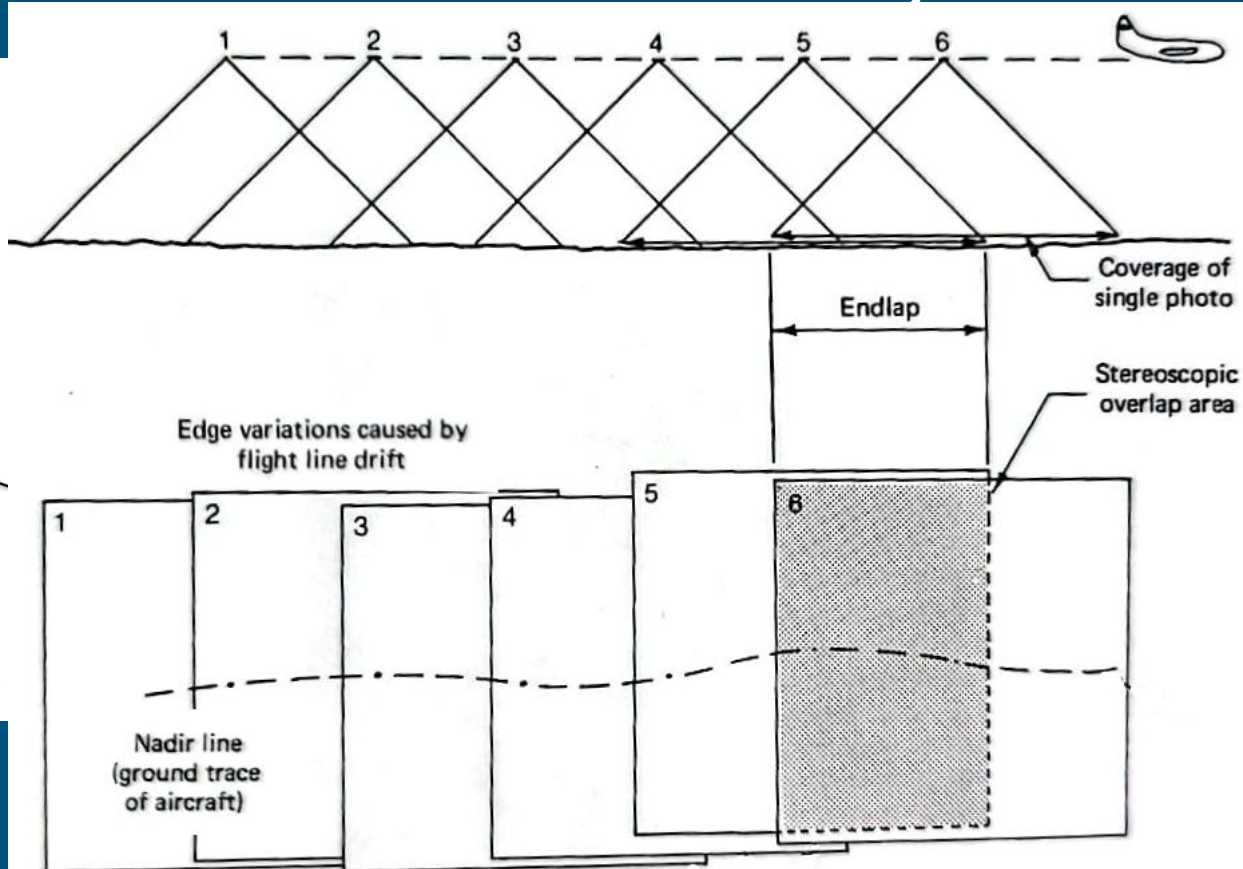
71 * tan(31.8) = y

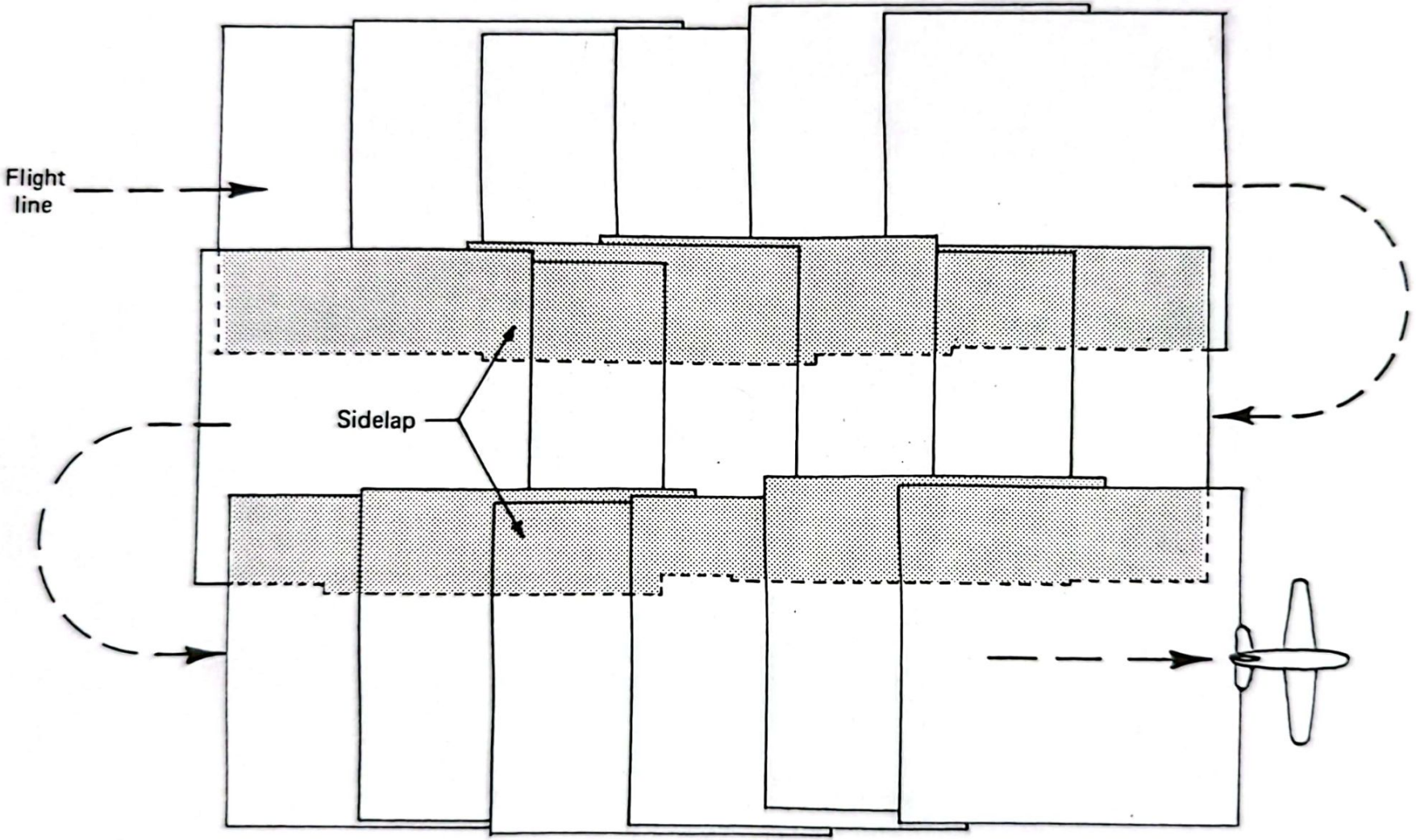
44.02 feet = y



Infinite Triangles – Photos from the Sky

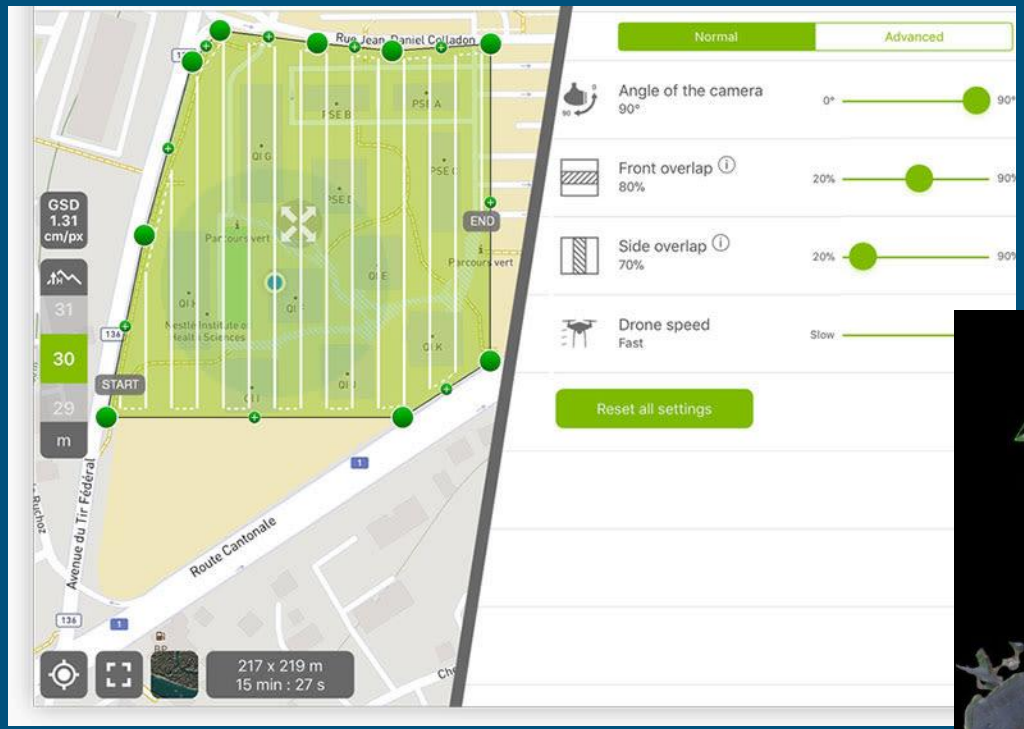


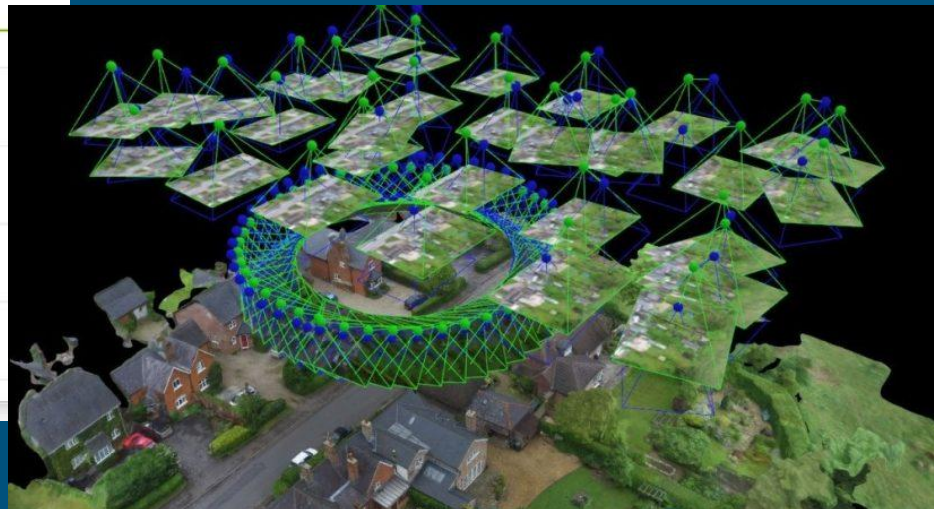



Flight line
Sidelap

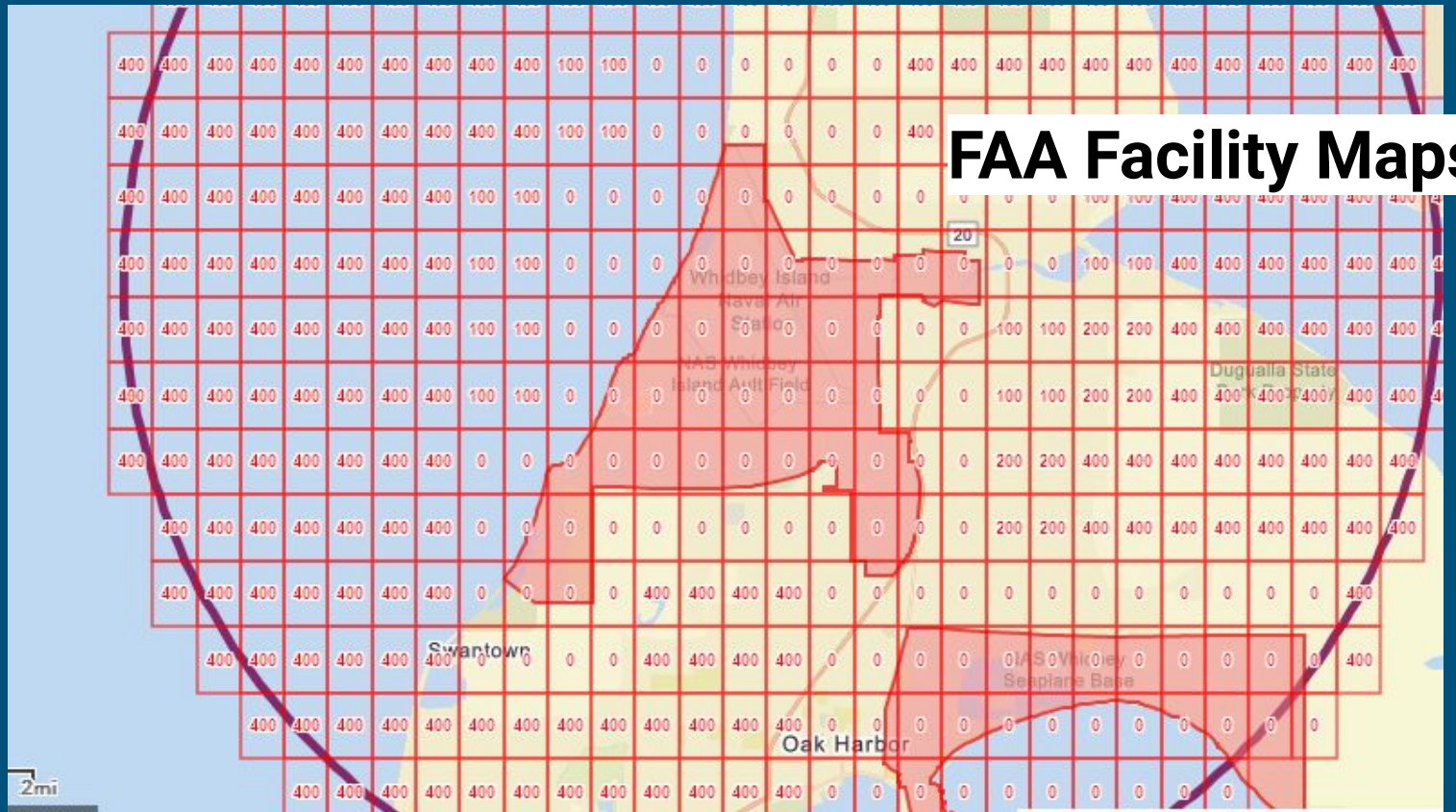
Flying for Photogrammetry

- Device (phone/tablet)
- App for your drone
- Remote & Drone





Flying the Mission - Safety Second, If Not First



Added safety note

Please be very careful about where and how you fly. Follow the FAA Recreational Flyer rules, and check the FAA Facility Maps before every flight. Dumbest, shortest version:

- Only fly your drone where you can see it (100% of the time).
- Never fly over 399’ above the ground/over the Facility Map local limit.
- Never fly over groups of people or roads.
- There is no ‘right of way’ in the air. If *anything* happens, you are responsible for the results.

Every pilot I’ve ever met has at least one story about losing an aircraft or machines not doing what they’re told. Please plan accordingly. All the best in doing cool stuff & having fun! - NCS

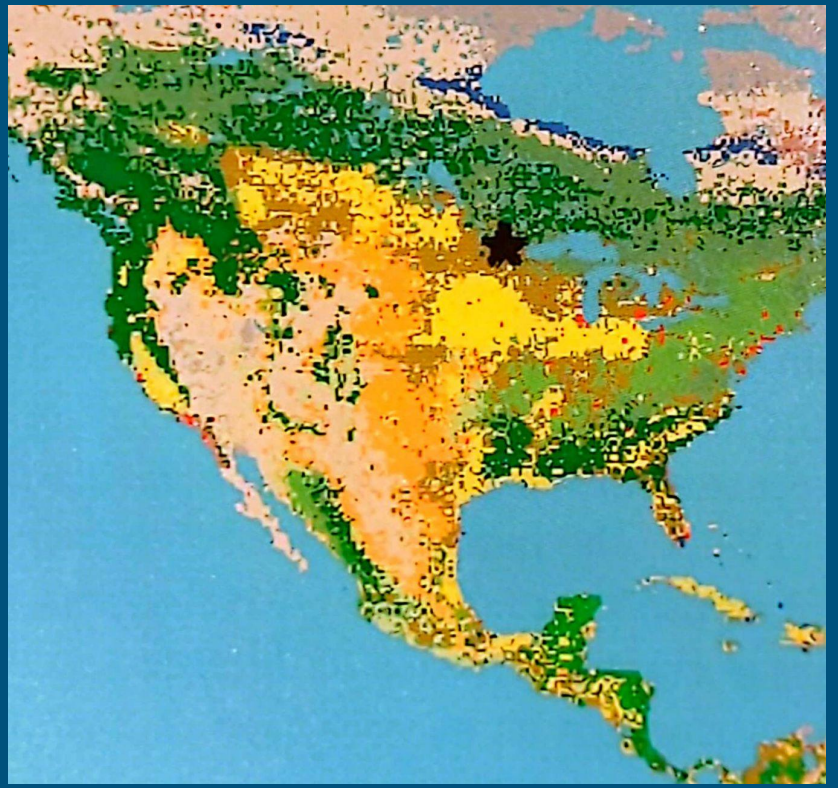
Practical Considerations

- Go slow and think it all through
- Expect complications, failure, and changes
- Gear
- Weather
- Lighting
- Conditions on the ground

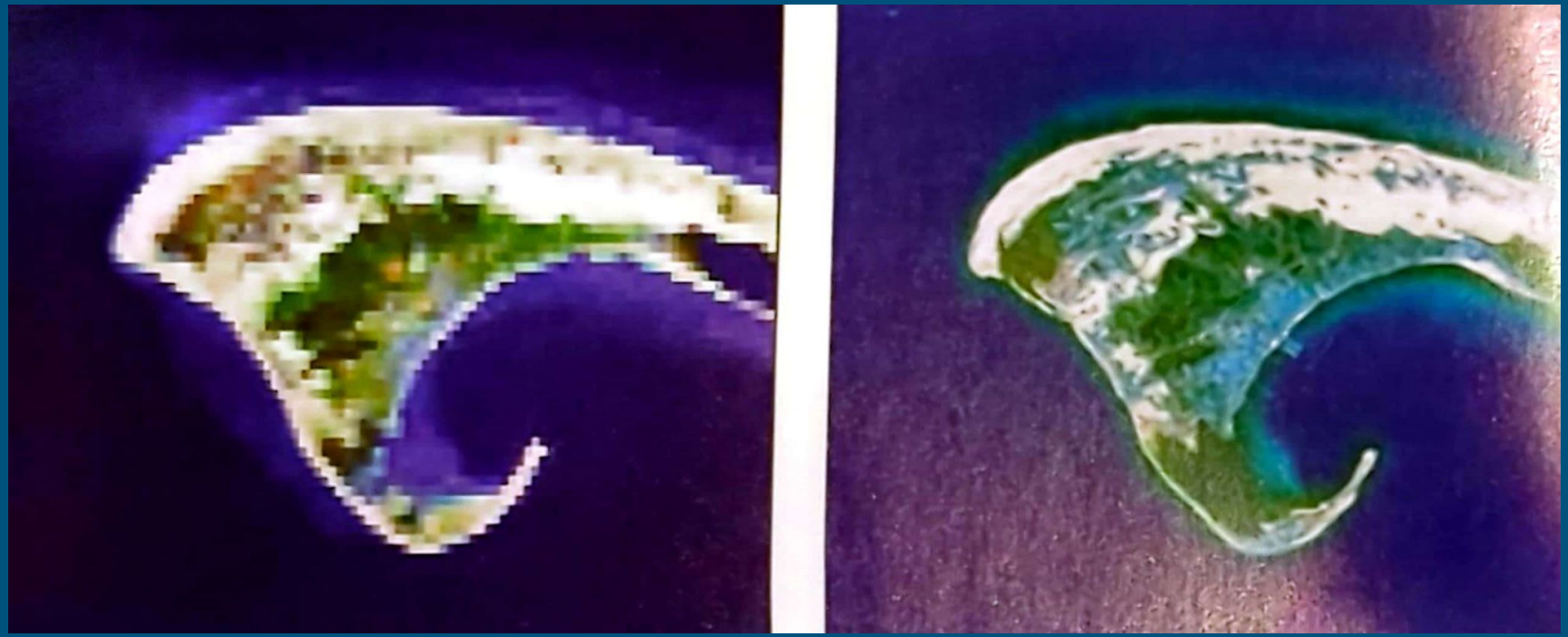
Processing Images - What do you see?

Human: It’s a low-resolution image of
North America.

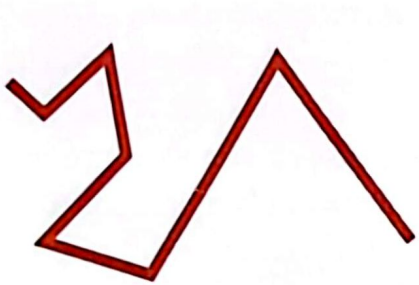
Computer: It’s a bunch of pixels with differing RGB values.



Fewer Pixels vs More Pixels



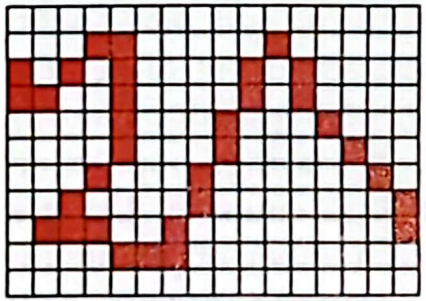
What the computer sees



Vector-based line

Flat file

```
4753456  623412
4753436  623424
4753462  623478
4753432  623482
4753405  623429
4753401  623508
4753462  623555
4753398  623634
```

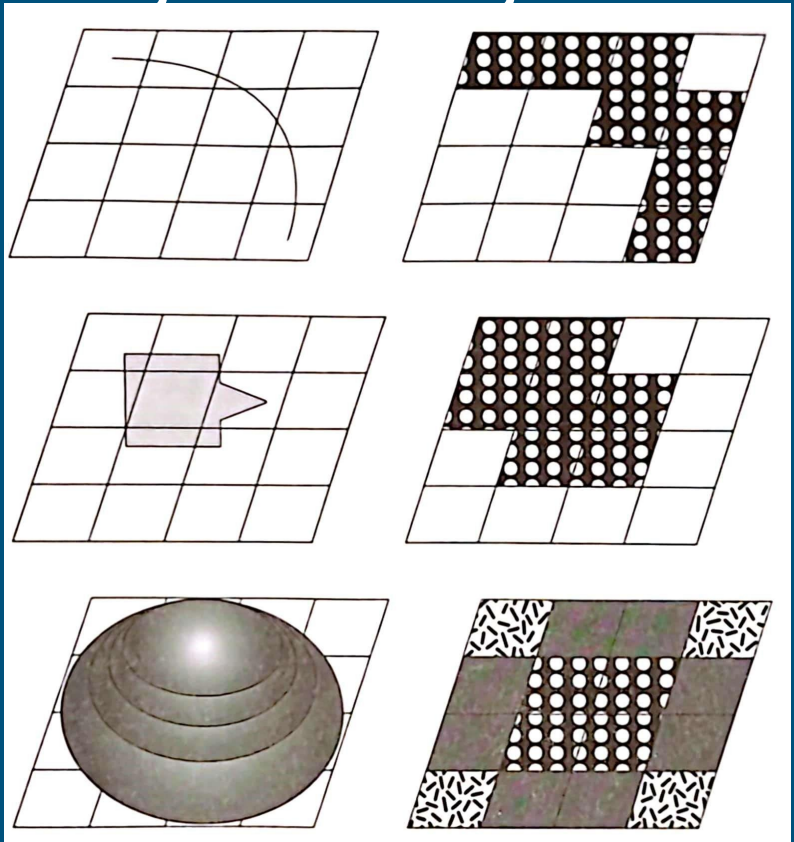


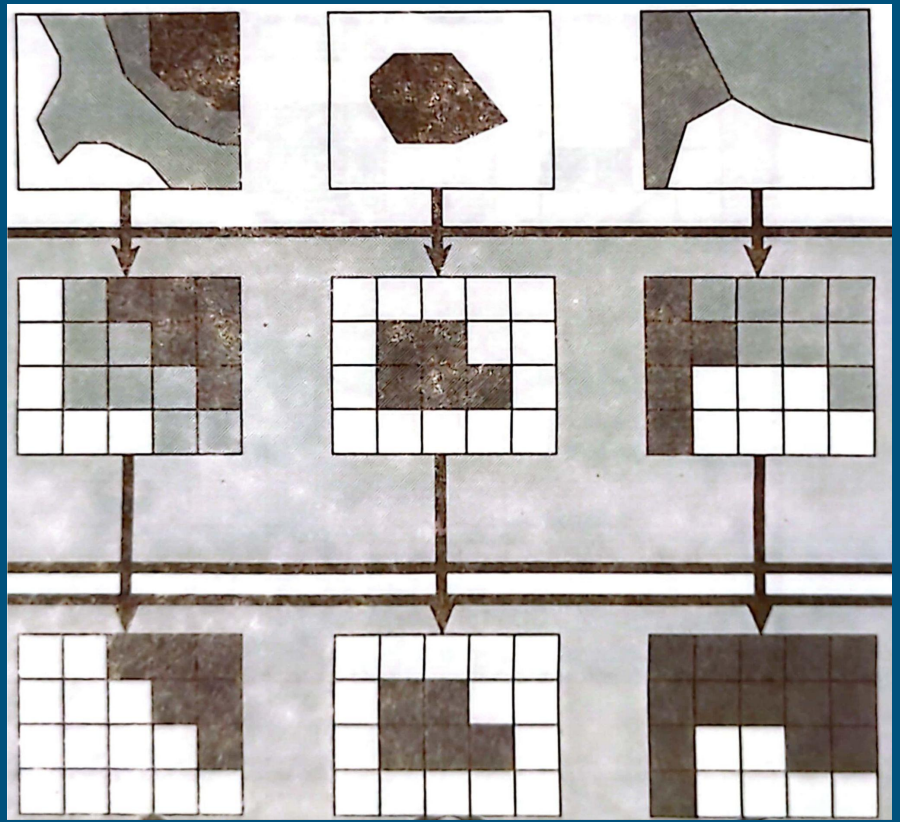
Raster-based line

Flat file

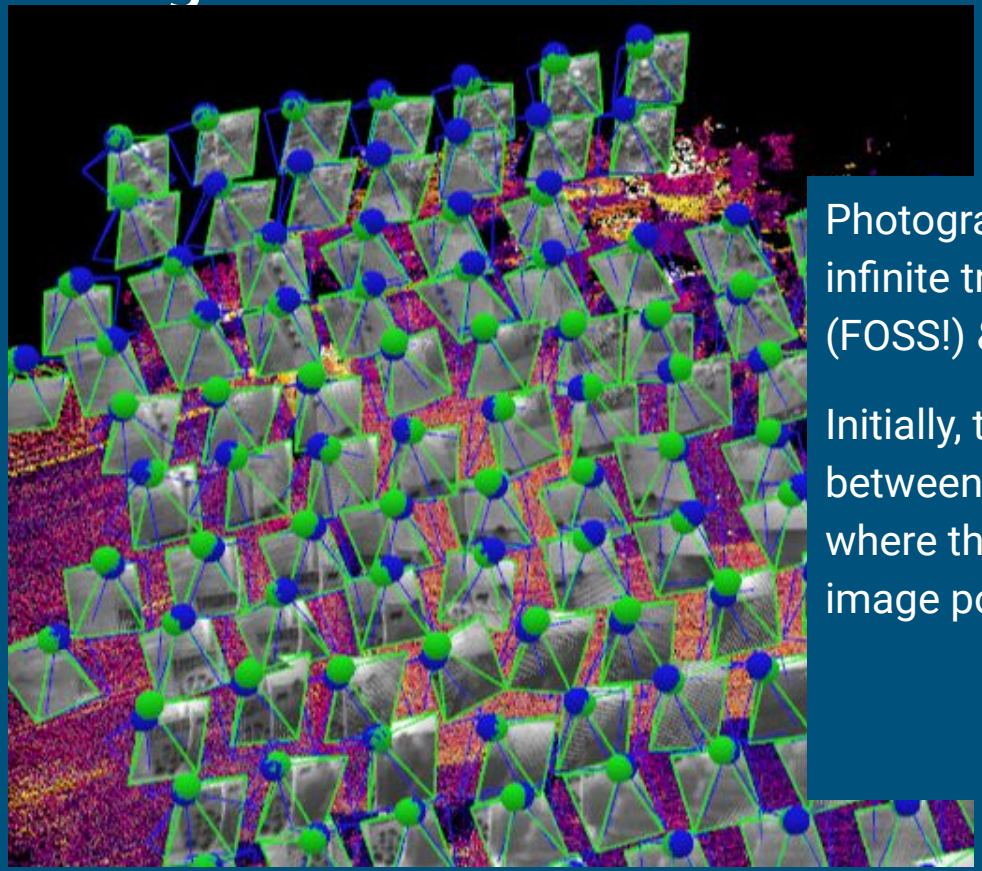
```
0000000000000000
0001100000100000
1010100001010000
1100100001010000
0000100010001000
0000100100000100
0001000100000010
0010000100000001
0111001000000001
0000111000000000
0000000000000000
```

‘Objects’ are just clumps of similar pixels





Alignment GPS vs Calculated Position



Photogrammetry software is where the magic of infinite triangles and pixel objects meet. WebODM (FOSS!) & Pix4D (paid) are two big ones.

Initially, the software calculates differences between the stated GPS position of images and where the math of the ‘infinite triangles’ put the image position. This *should* be a small difference.

How’s the Quality?

Quality Check

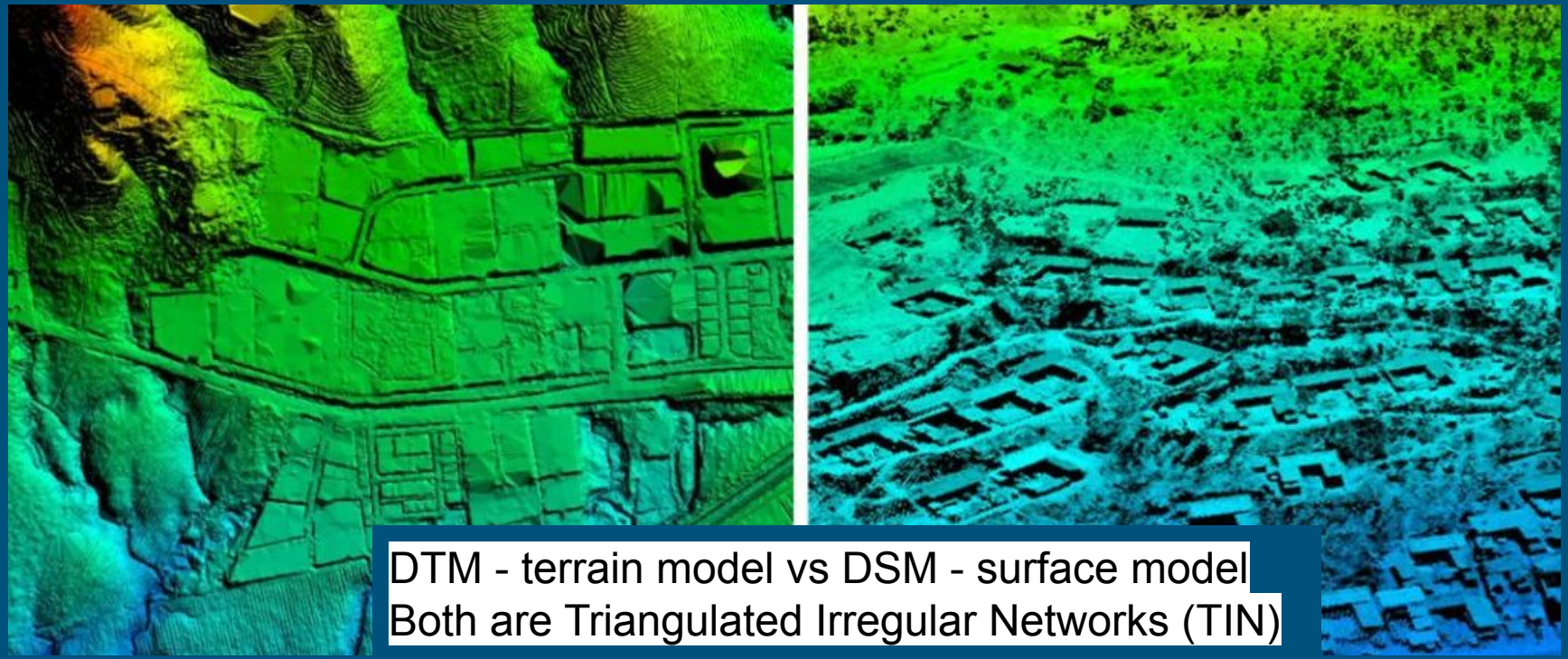
Images	median of 74692 keypoints per image	✓
Dataset	242 out of 242 images calibrated (100%), all images enabled	✓
Camera Optimization	0.2% relative difference between initial and optimized internal camera parameters	✓
Matching	median of 23625.6 matches per calibrated image	✓
Georeferencing	yes, 14 GCPs (14 3D), mean RMS error = 0.034 ft	✓

Absolute Geolocation Variance

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-0.03	0.00	23.75	1.25
-0.03	-0.02	0.00	5.00	0.00
-0.02	-0.02	0.00	5.00	5.00
-0.02	-0.01	6.25	3.75	5.00
-0.01	-0.01	15.00	3.75	12.50
-0.01	0.00	32.50	2.50	26.25
0.00	0.01	26.25	6.25	23.75
0.01	0.01	13.75	5.00	16.25
0.01	0.02	2.50	6.25	6.25
0.02	0.02	3.75	0.00	1.25
0.02	0.03	0.00	10.00	2.50
0.03	-	0.00	28.75	0.00
Mean [m]		0.000000	0.000000	-0.000000
Sigma [m]		0.007670	0.057283	0.011045
RMS Error [m]		0.007670	0.057283	0.011045

Really Cool Product - Orthophoto

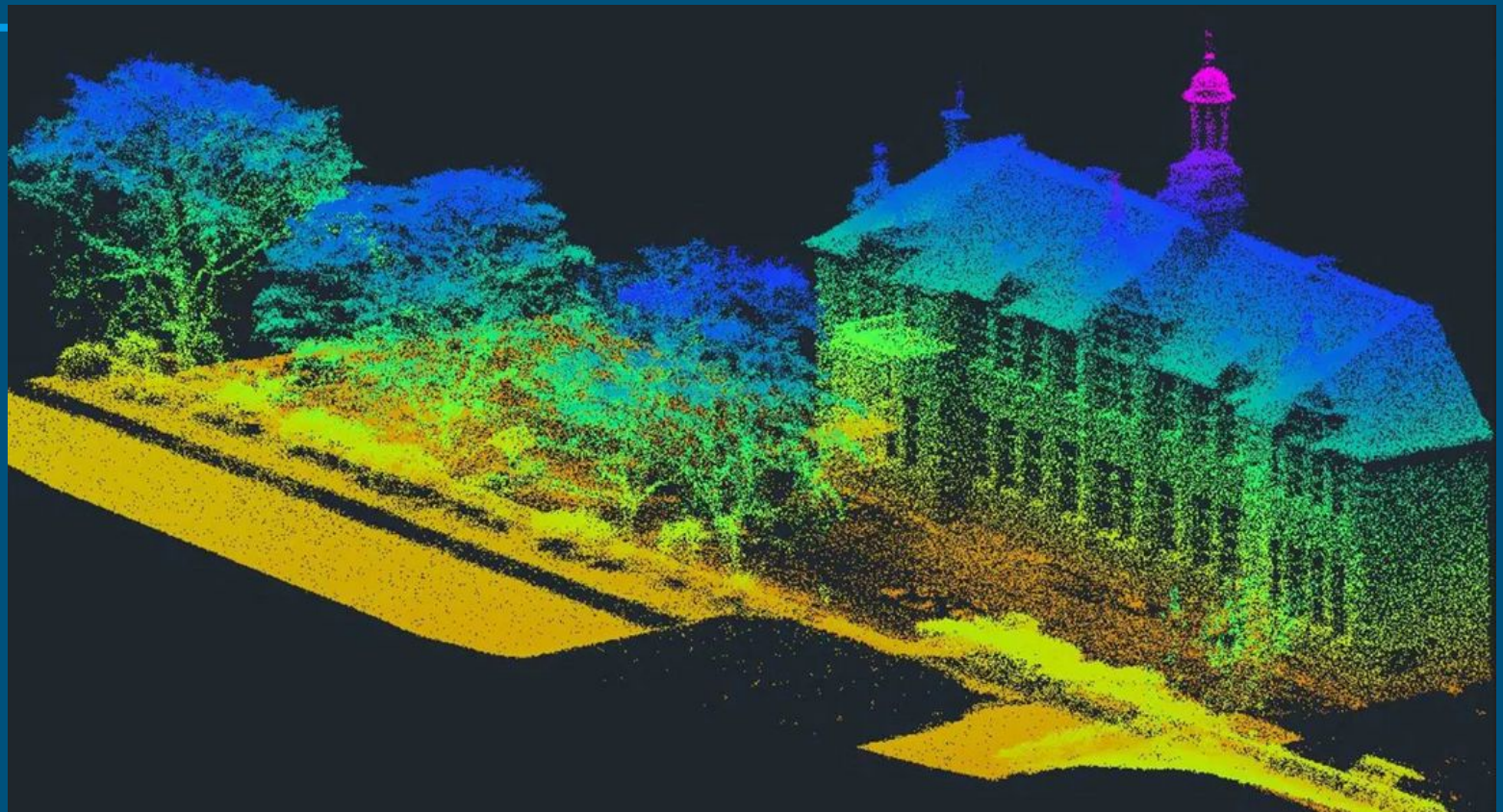
Really Cool Product -
Digital Elevation Model, DSM, DTM



DTM - terrain model vs DSM - surface model
Both are Triangulated Irregular Networks (TIN)

Really Cool Product -
3D Mesh with draped imagery

Really Cool Product – Point Cloud



Ok. Now What?

Go wild! Please use this creatively for your own personal projects.

Model that creepy house on the edge of town for your video game.

Make a nice big map of Uncle Mort’s back 40.

Capture a building or large piece of art in spectacular digital detail.

Document and track the changing natural world.

Best of all: do something that nobody else has done yet.

These are extra slides

Didn’t have time to talk about everything I wanted, so here’s some extra slides I had planned. - NCS

Failure modes/troubleshooting

Not seeing sides of objects - plan flights lower and tilt camera further from nadir

Issues with vertical surfaces - tilt camera off nadir, capture objects from more angles

Detail not visible - fly lower/slower, details must be larger than GSD and appear in several images.

Photogrammetry rejects initial images - moving & low-detail objects (eg foliage & water) are bad targets, try increasing overlap and collecting more images

Processed model is weirdly curved - add manual tie points to images before processing

Not seeing through roofs/foliage - it’s not an X-ray, you want LiDAR

Jargon

- **Endlap/sidelap:** portions of images that overlap front & back/on sides
- **Relative vs absolute accuracy:** Relative accuracy is all the objects measured are correctly related to each other, absolute accuracy is correctly placing each object in its real world location
- **Structure From Motion:** combining multiple images to compute/infer physical models, eg photogrammetry
- **Georeferencing:** placing the images/products at geographic locations
- **CRS:** a coordinate reference system (such as Mercator, WGS84, many variations of State Plane) is the way things are located in relation to the Earth's surface

3 parts of the process: planning a mission, flying for photos, processing

Supplies:

- Computer w- internet access
- Drone
- Apps on tablet or phone
- Computer with a lot of RAM
- Photogrammetry software

Safety & Regulations

- Recreational Flyers - Drone Safety from the FAA
  - https://www.faa.gov/uas/recreational_flyers
- FAA Part 107 for anything non-recreational
  - Don’t plan to do ANY work for compensation (even non-cash compensation) if you don’t have your Part 107 license
  - There are many websites that will get you enough education to pass your Part 107 test. It’s also possible to do from just FAA published materials, but it’s not as convenient.
  - https://www.faa.gov/uas/commercial_operators

Maps are not an entry level business opportunity

State regulations for land survey includes most high precision maps

RCW 18.43.020 defines land survey to include “the survey of land areas for the purpose of determining the topography thereof, the making of topographical delineations and the preparing of maps and accurate records thereof, when the proper performance of such services requires technical knowledge and skill.”

Even if you have a Part 107, selling any geospatial product that could be even maybe be used in a legal sense (building, property lines, measurements for setbacks, elevations, drainage/septic planning, etc) has to be stamped by a licensed land surveyor or civil engineer in most US jurisdictions. ‘Fun’/artistic/representational things like nice photos or 3D visual models are not regulated this way, but still require a Part 107 license to sell.

Rule of thumb: no matter how good you get, tell anybody looking at your data that they can’t trust it to be any more accurate than +- 3 feet.

Planning a flight - What am I flying for and can I do it?

What do you want to see?

Define the exact objects and horizontal limits of what you want to document.

How detailed does it need to be?

Can I see my drone in the air? Maintaining Line of Sight at all times is legal requirement.

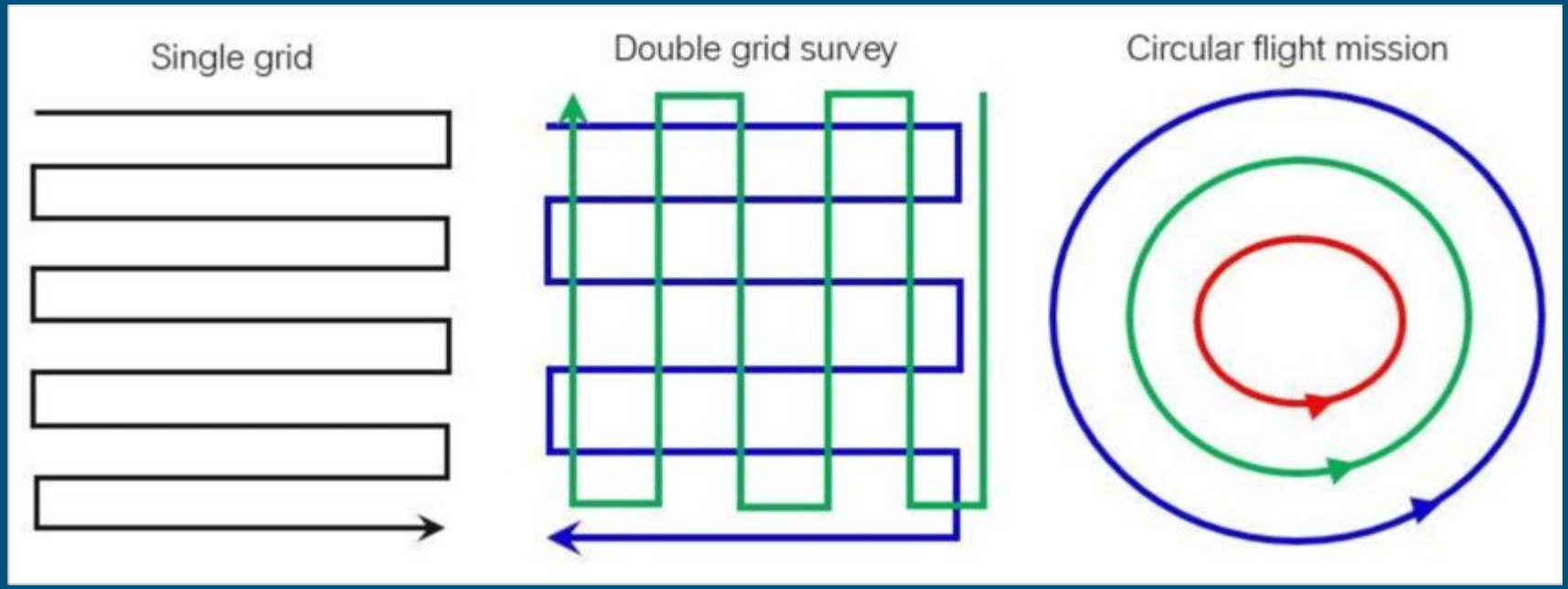
Is it safe/legal to fly here?
https://faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad

Planning - how will I capture my necessary data?

- How many flights/battery changes will I need? (planning software should say)
- Do I need to break my flight plan into separate chunks for safety or logistics?
  - Can't fly over roads
  - Can't fly where you can't see the drone
  - Needs more batteries than you have
- Are there big elevation changes that alter my GSD? (then break into multiple flights from separate locations)
- If I need to map a surface and capture a building in detail, is it better to fly each separately and combine the models later? If you want to combine orbital flight images and nadir images, try to keep them at similar GSD quality/less than 2x difference between them.
- Litchi is a cheap app that allows for very specific pathing/camera angles/shooting locations.

It's better to repeat a flight or spend time adjusting for field conditions than it is to lose your drone or cause problems that break something/hurt someone/bring the FAA.

Planning - Different flight paths



Simple orthophoto - 3D mapping - Vertical faces/tall objects
(perpendicular not required)

Planning - Trade-offs in data collection

Balance safety and collection requirements by adjusting the height and speed of flight plans.

	Pros	Cons
Flying low and slow	Clearer images More detail	Needs more batteries, safety planning Processing time increases
Flying high and fast	Fewer battery changes More efficient in large areas Easier to process	Less detailed Risk of blurred images 399’ (or lower!) safety limit

Planning - the environment

- Weather - Will it be rainy? Windy?
- Illumination - cloudy around noon is best, avoid large/hard shadows
- People and objects - Will cars be parked on top of things you want to see? Will you need to avoid people on the ground?
    - Transitory objects like cars driving or people walking may appear as ghosts or not be visible at all.
    - Large stationary objects like cars or piles of building materials will appear in your model, but smaller objects like fences or utility poles can disappear or show up erratically unless you specifically plan flights to capture them

Flying for data collection

- Charge all the things
- Keep it safe and legal
- Expect issues and setbacks. Be flexible, but pedantically careful.
- Try to collect all your data at the same time (e.g. don’t get photos of one side of you house on Tuesday and the other on Wednesday)
- Always check the weather forecast
- Always bring sunglasses and a hat with brim
- Try to bring a buddy if you’re in public (you have to fly the drone, not talk to randos)

Processing - software

- OpenDroneMap: free, comes in noob to hacker, widely known/documented, Docker image(s) available, can be fiddly & the .exe installer option costs money
- Reality Capture: Epic made it free, very fast, polished with decent tutorials

- Other open source software: MicMac, Meshroom/AliceVision, COLMAP, Regard3D
- Commercial software: Pix4Dmatic, Agisoft Metashape, AutoDesk ReCap Pro, 3DF Zephyr

Processing the data - Loading & Registration

- Create a project and load in your photos. The program uses EXIF data for first pass placement/orientation of imagery.
- If your software asks about a coordinate system, it's GPS latitude/longitude, aka WGS84
- Process all the images for initial alignment or registration, where the computer compares the relationships of the 'infinite triangles' geometry with the GPS location tagged into photos. This could take 10 minutes or 24 hours, depending on resolution/quantity of images, chosen software, available RAM, and quality of matchpoints within overlaps.

GCPs

Professionals use Ground Control Points (GCPs) to increase accuracy. They take high-precision GPS measurements of clearly visible objects, load those coordinates in after initial alignment, then hand-mark those locations in photos for the software to use in modeling.

You can get some of this same improvement by adding manual tie points to images (but not adding coordinates). Zoom in very close, and only mark things that are clearly visible, where the computer can accurately define the pixel object. Don’t mark smeary blobs, even if you feel you can judge the location of the tie point accurately.

Note about accuracy

Without actual GCPs, you may see your software give your accuracy/error residuals as perfect or RMSE/standard deviations of 0.00. This is because it only has the image coordinate tags to compare against. So the software evaluating the location accuracy pulls the image coordinates, looks for the GCP coordinates to compare & doesn’t find them, and computes the difference from initial coordinates to adjusted coordinates as 0.