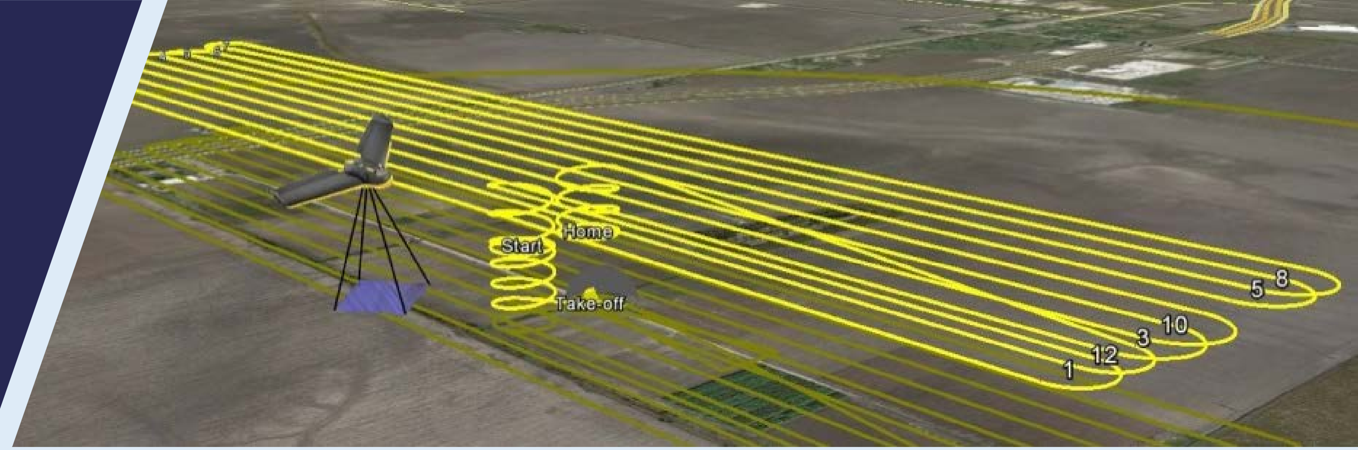

Module 3

UAS Mapping Fundamentals

Objectives

- **Advantages and limitations** of small UAS
- **Understand** flight planning for UAS mapping
- **What is** ground control and when do we need it?
- **Introduce** SfM photogrammetry software
- **Summarize** UAS-SfM data processing workflow
- **Identify** key geospatial data products produced

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UAS

adaptive tools for aerial surveying

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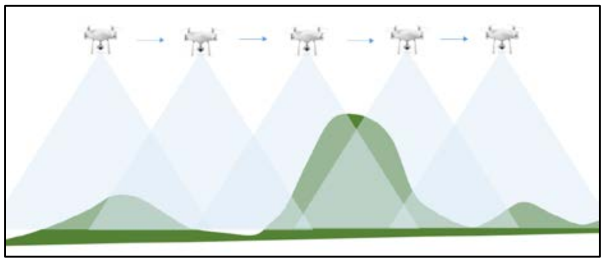
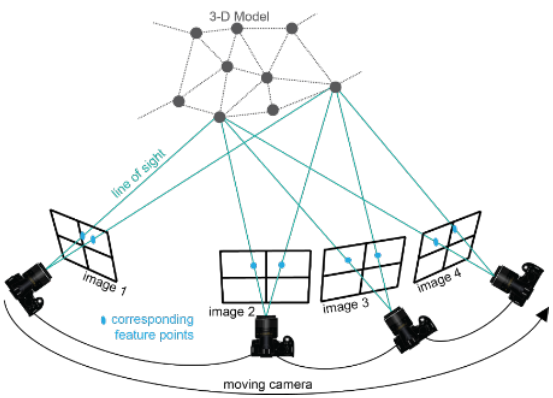
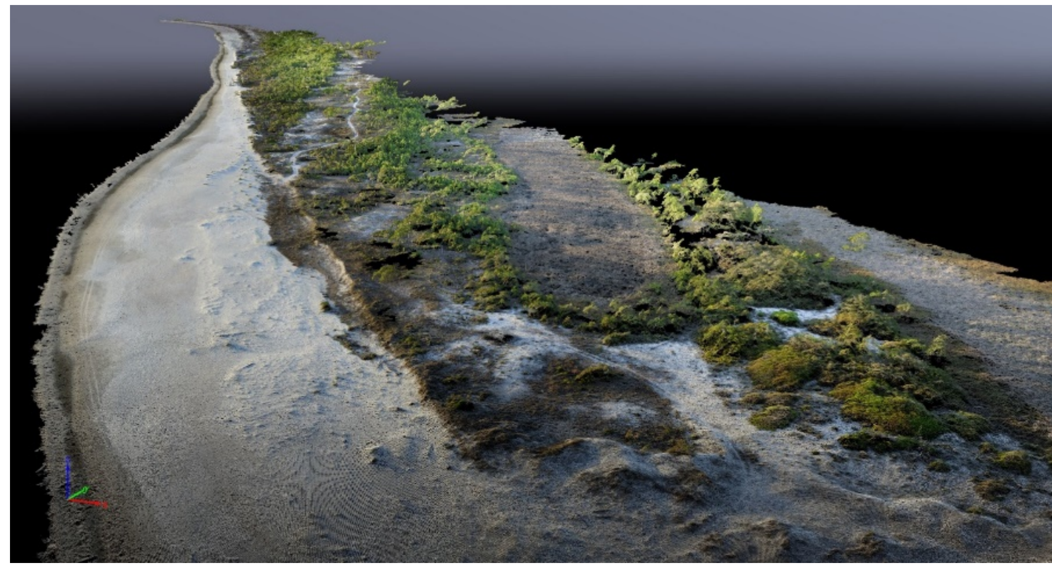
UAS
aerial mapping







*imagery is processed using **structure-from-motion (SfM)** photogrammetry*

Advantages of sUAS for Mapping

- Rapid deployment
- High temporal repeatability
- Flexibile acquisition
- Can be less costly and safer (no pilot onboard)
- Hyperspatial imagery resolution (meters to mm)

Limitations: *Payload weight, endurance, spatial coverage, regulations*

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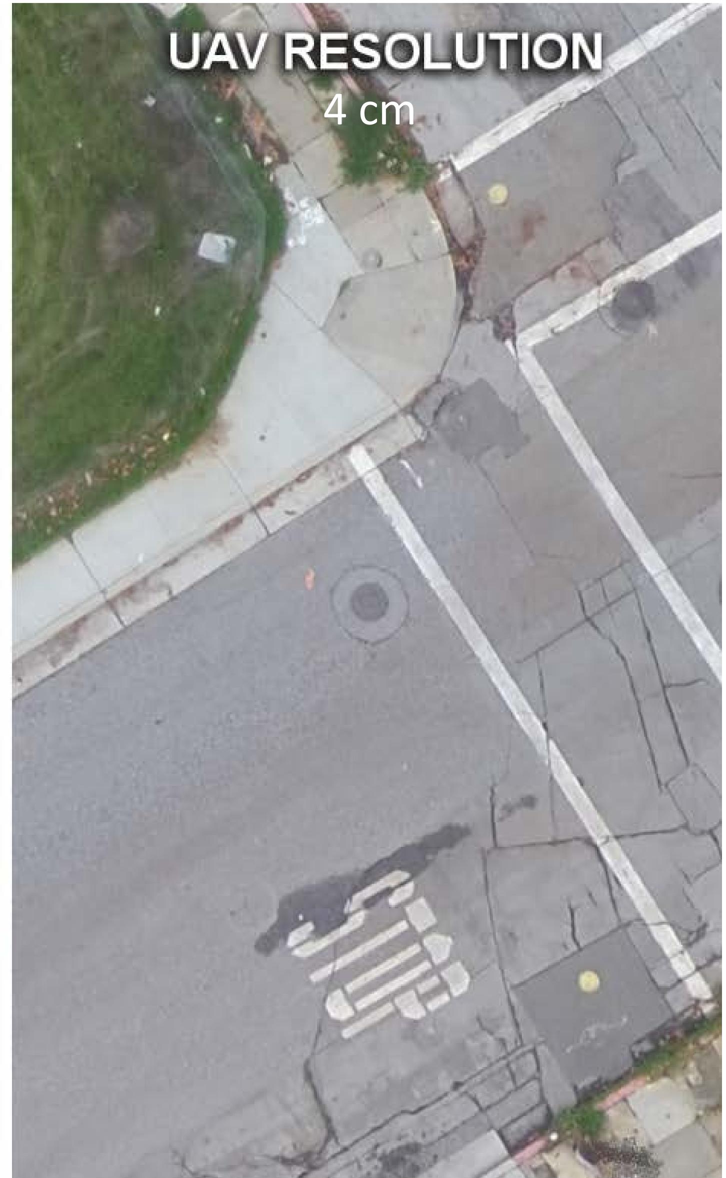
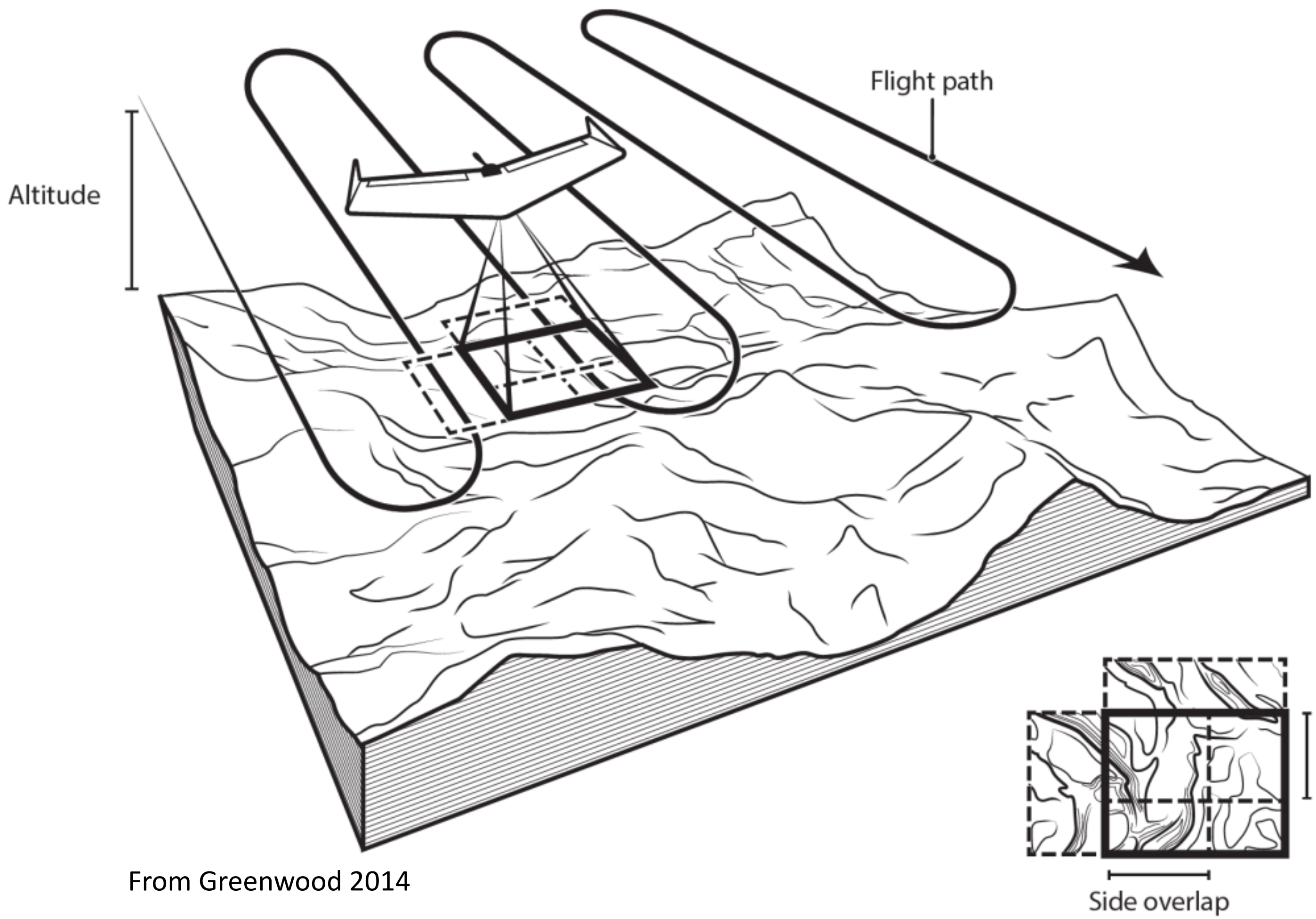


Source: WestCoastPlacer

Mission Planning

Define Overlap



flight direction

From Greenwood 2014

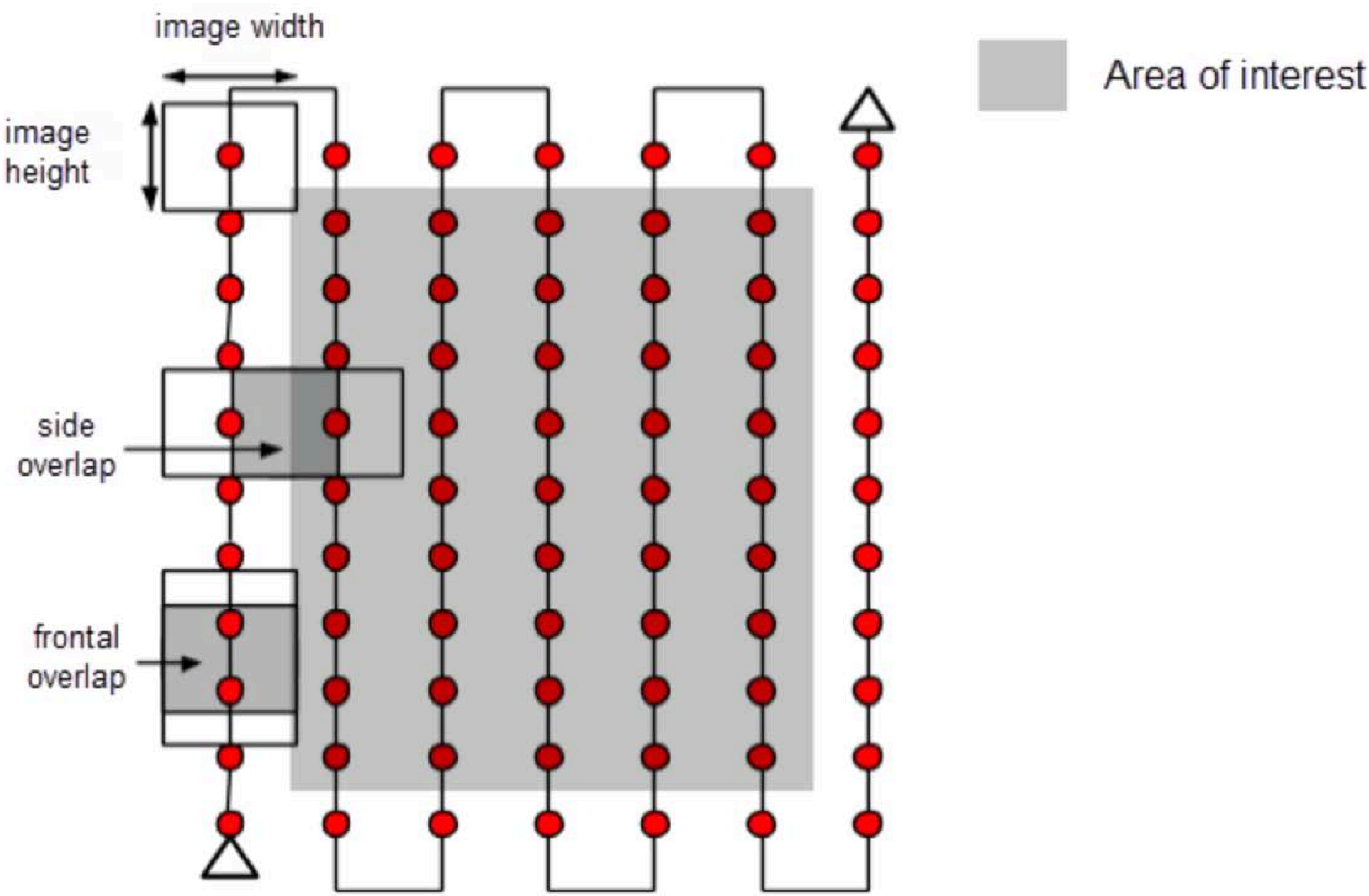


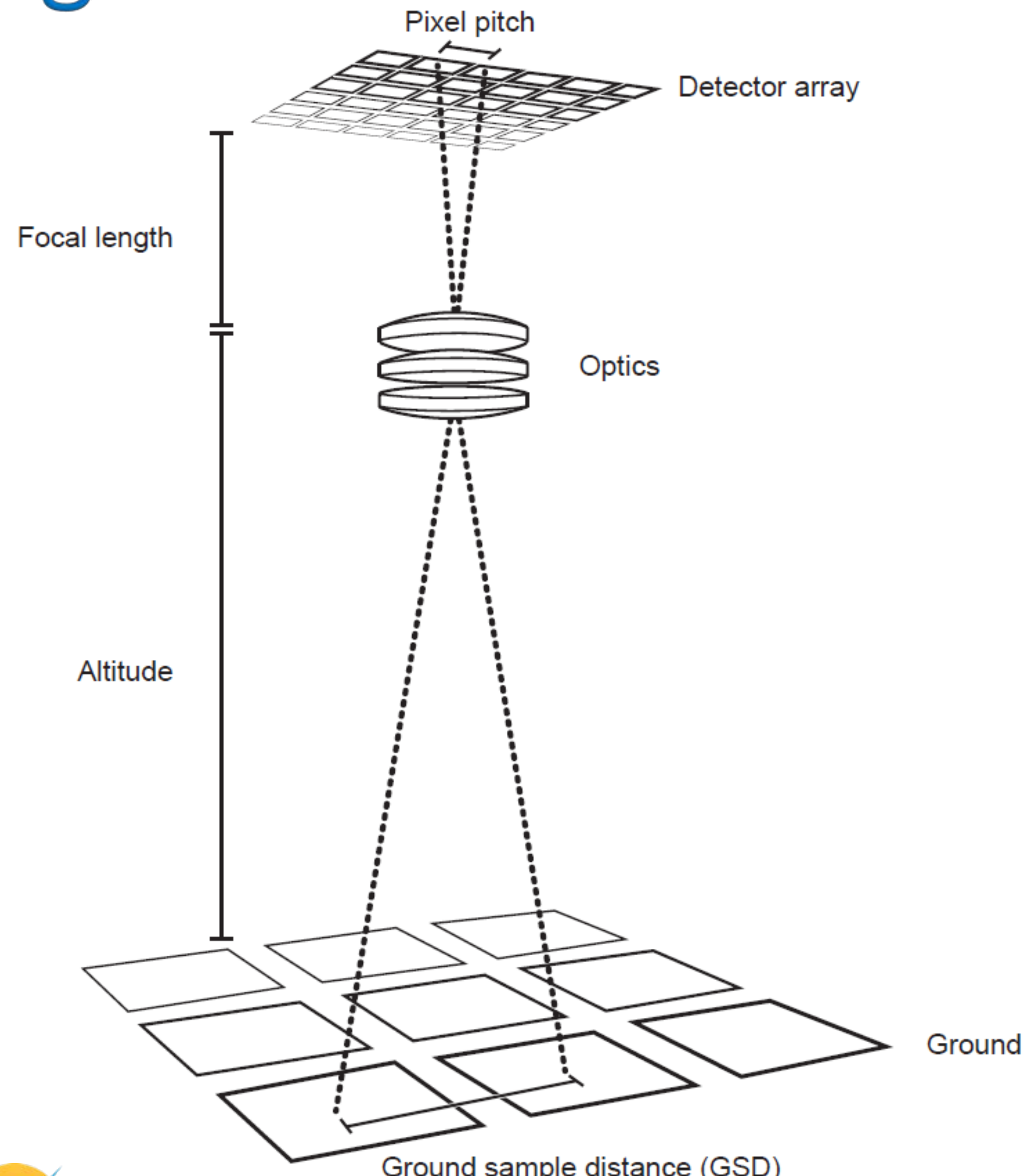
Figure 1. Ideal Image Acquisition Plan - General case.

image source: Pix4D

How much overlap?

- Amount of overlap depends on objectives and terrain.
- Increase overlap, increase flight time
- From Pix4D
  - 75% frontal and 60% side overlap in general cases.
  - 85% frontal and 70% side overlap for forests, dense vegetation and fields.
  - 85% frontal overlap for single track corridor mapping. Use 60% side overlap if the corridor is acquired using two flight lines.

Mission Planning
Define Resolution



Image's Ground Sample Distance:
Depends on flying height above ground, focal length of camera, and pixel pitch (size of pixel in camera)

From Greenwood 2014

Put simply:

GSD = (pixel size x height above ground level) / focal length

An S100 lens, zoomed out, has a focal length of 5.2 mm (26 mm zoomed in). So if we wanted, say, to be able to resolve 1 cm-sized features on the ground using a zoomed-out S100, we would have to fly at

1 cm x 5.2 mm / 0.0019 mm = 27.3 m = 89.7 feet

Zooming the lens all the way in would allow comparable resolution images from an altitude five times as high.

From Greenwood 2014

Example Problem

- S110 NIR camera on eBee
  - Sensor size 7.44 x 5.58 mm
  - 1.86 um pixel pitch
  - 4000 x 3000 pixel array

- **What is the pixel pitch?**

7.44 mm / 4038 ~= 0.0018 mm

5.58 mm/3038 ~= 0.0018 mm

- **What is GSD at 100 m AGL for 5.2 mm *f* ?**

GSD = (pixel pitch * H')/f
GSD = (0.0018 mm * 100 m) / 5.2mm ~= 3.53 cm

Mission Control Software

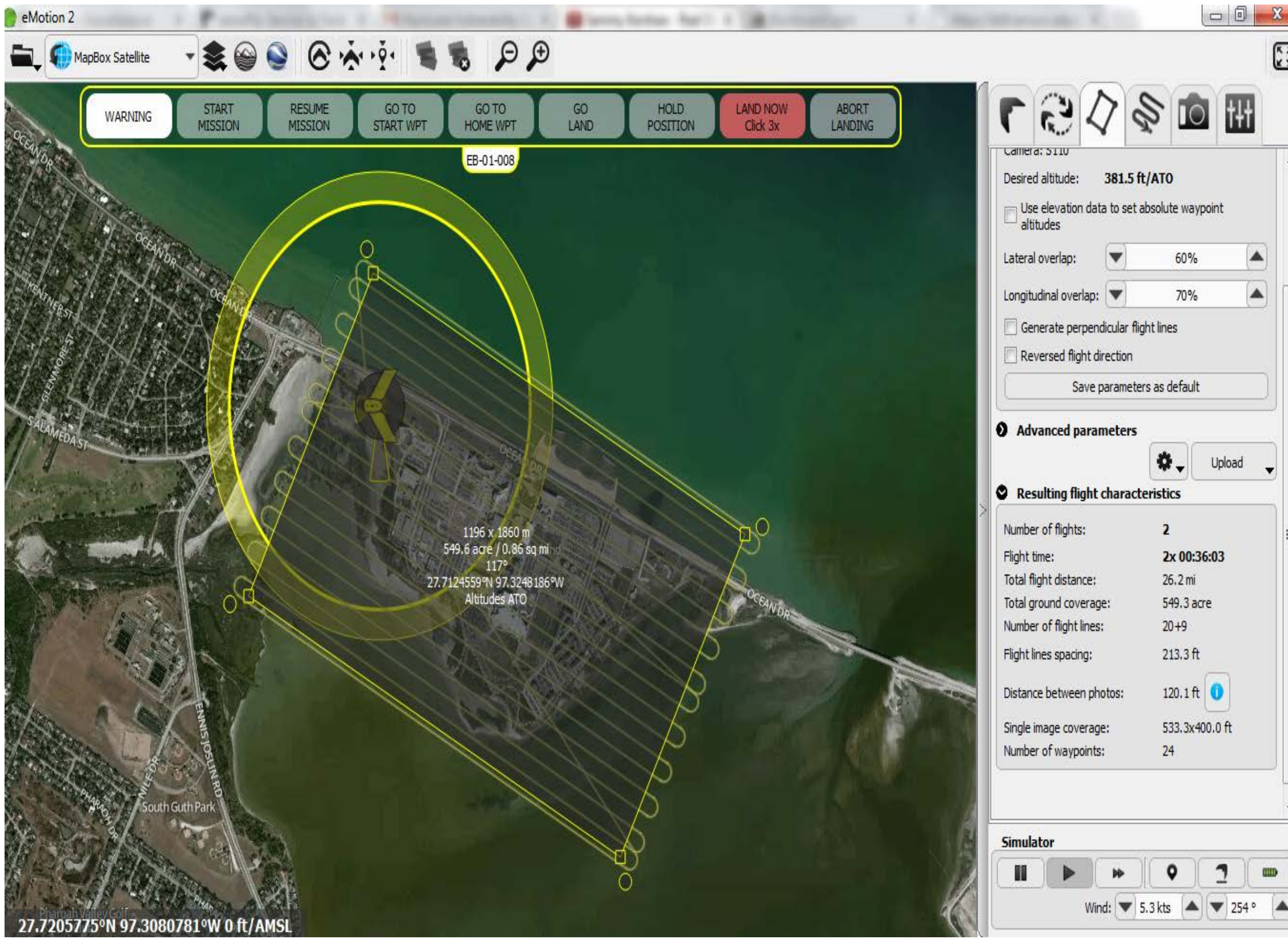
Example eMotion

<u>Mission Planning</u>

- Create area to be mapped
- Set flying height
- Define overlap / flight direction

<u>Command-and control</u>

- Real-time tracking
- GPS location
- Aeronautical information

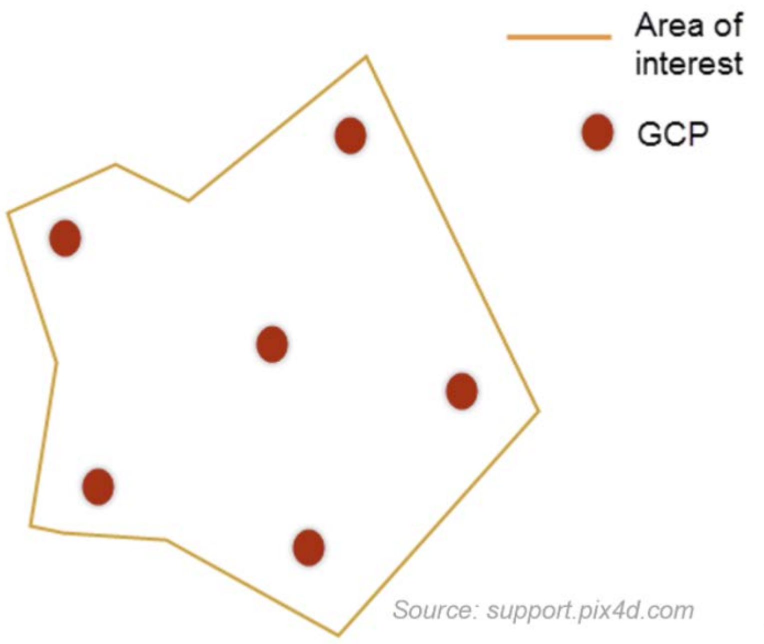


Ground Control Points (GCPs)

- What is ground control?
  - Physical points on ground whose coordinate positions are known (x,y) and/or elevations (z)
- Measurements of photos are tied to “real-world” coordinates on ground through ground control (GC)
- Photogrammetric measurements only as reliable as the GC they are based on
- Control points must be easily identifiable
  - Identifiable features in scene or ground control targets

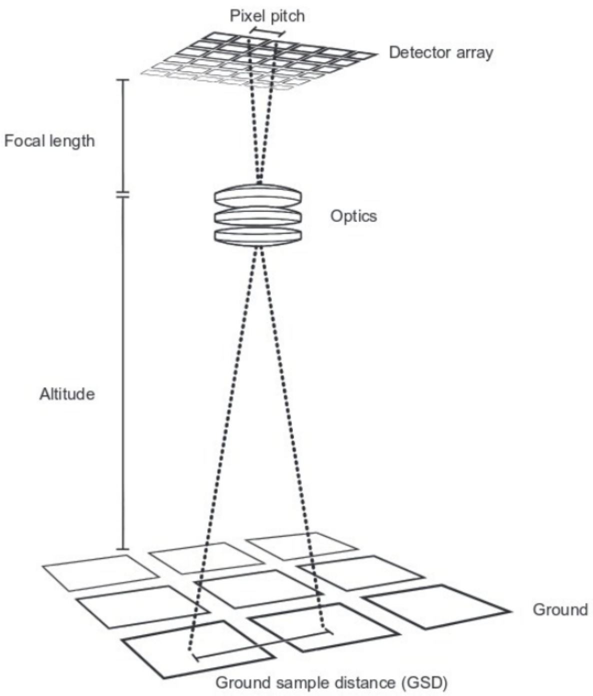
GCP Network

- distribute as evenly as possible
- boundary should be enclosed
- # depends on size of area
- 5 to10 unless steep terrain or large area
- Good to include extras for check points
- Rules of thumb:
    - < 1000 ft separation
    - Do not place the GCPs exactly at the edges of the area



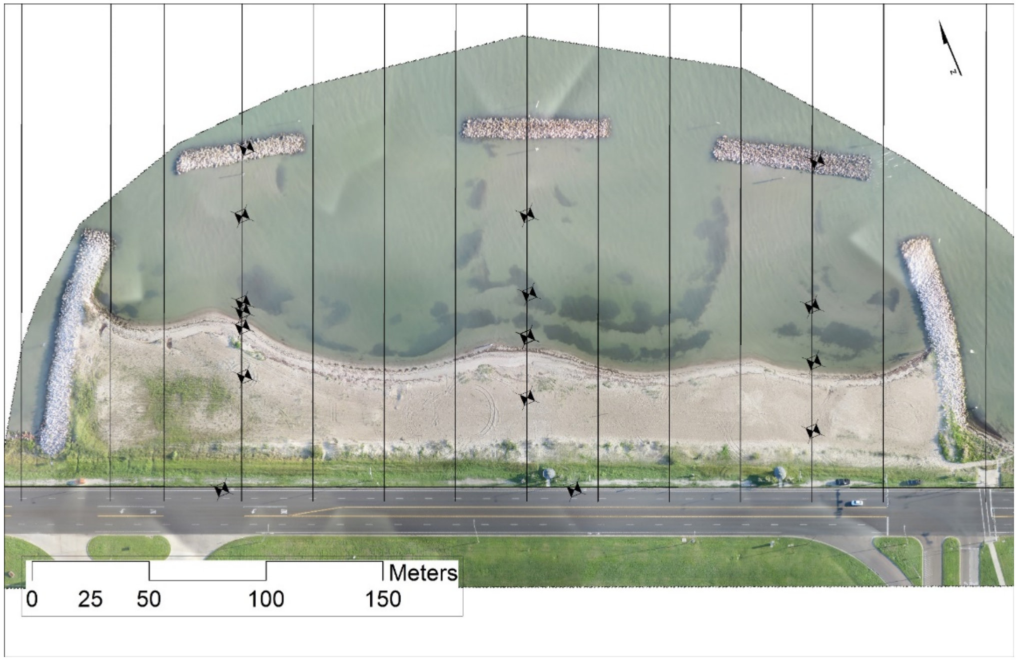
GCP Accuracy

Factors for defining GCP acuracy:



- Accuracy needed for the final results
- Ground Sampling Distance* of the images:
  - GCP target size: 5-10 x GSD
  - GCP accuracy: at least 0.1 GSD
- * distance between two consecutive pixel centers measured on the ground

Example: Ground Control Targets



Use Objects in Image Post-Flight

RTK GPS used to manually survey coordinates on these identifiable features

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Alternative to GCP

RTK GPS

eBee RTK

- Use base station or broadcast correction to differentially correct GPS on drone
- Improves geotagging accuracy of imagery (e.g 15 ft down to < 1 ft)
- Onboard RTK GPS receiver cost coming down

Remember

- Absolute accuracy of UAS data products depends on accuracy of your control and/or geotagging
- Even if you do have onboard RTK GPS for high accuracy geotagging, you should always acquire check points to validate accuracy

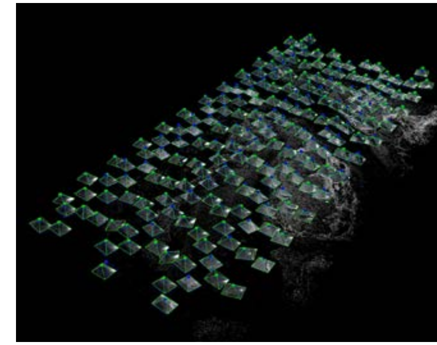
SfM Software for UAS Mapping

Pix4D and Agisoft PhotoScan are well known commercial SfM photogrammetry software for UAS (drone) image processing. **User-friendly, powerful, flexible,** and offer **good documentation** and customer support. But **can be relatively expensive**.

OpenDroneMap project is a suite of open source tools for UAS-SfM processing. **Open source software** removes expense, but the user should be prepared to have **less software support** and **less control** over the processing.

Many other commercial software are available beyond these mentioned here.

Structure from Motion (SfM) Workflow



Feature detection

Feature correspondence

3D camera pose reconstruction

Sparse 3D point cloud

Dense 3D matching

Dense "textured" 3D point cloud

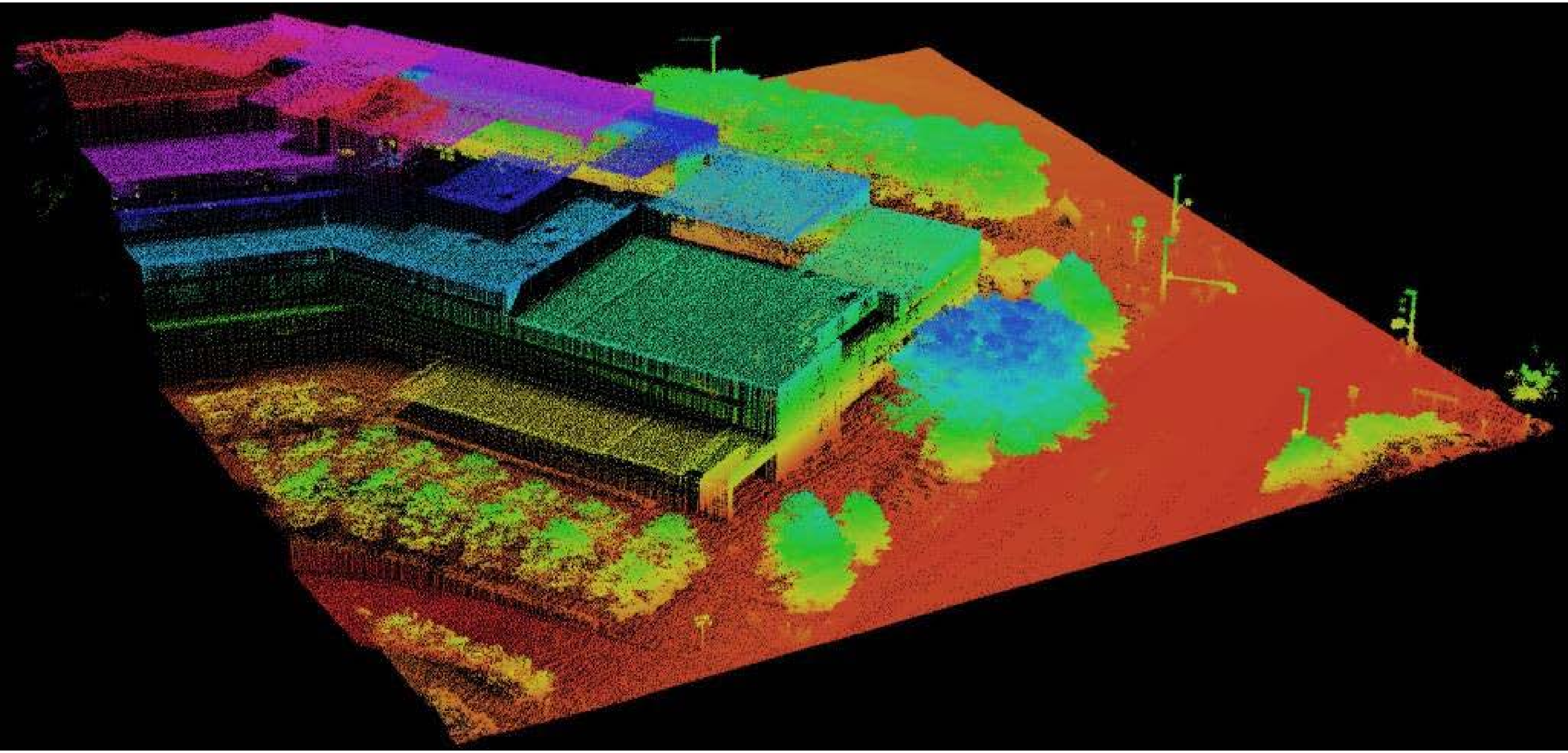
Dense 3D point cloud → Digital Surface Model → Orthorectified Image Mosaic

Remember

- Different software vary in how the SfM processing workflow is implemented.
- SfM software offer many parameters for tuning results but can be “black box” in many aspects.
- Therefore, understanding the main stages and fundamentals of SfM photogrammetry is important

Geospatial Data Products

3D Point Cloud



Surveyed Coordinates (colored by height)

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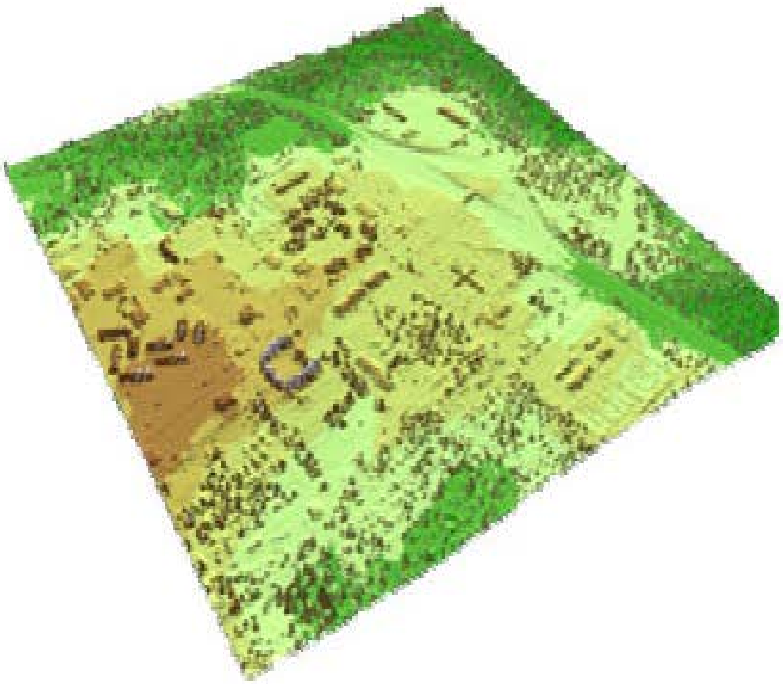
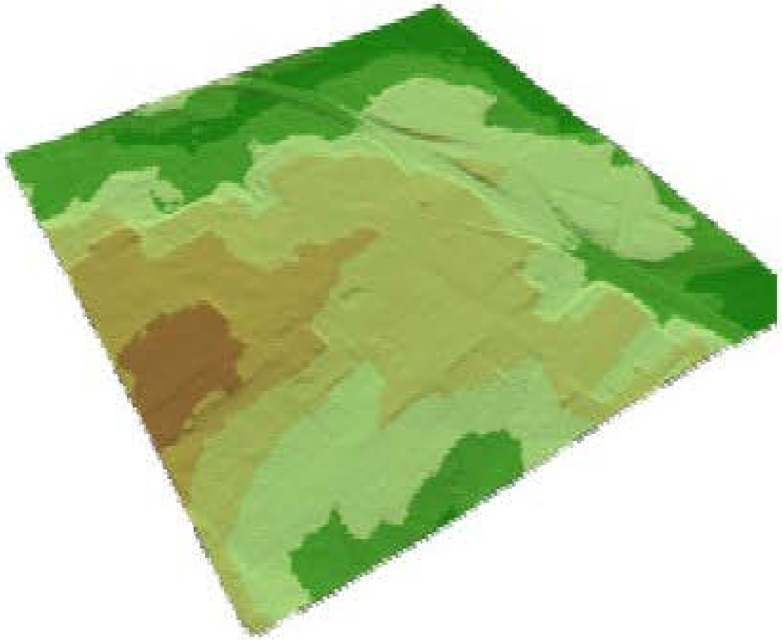
Image from Mitasova, NSCU

Topographic Products



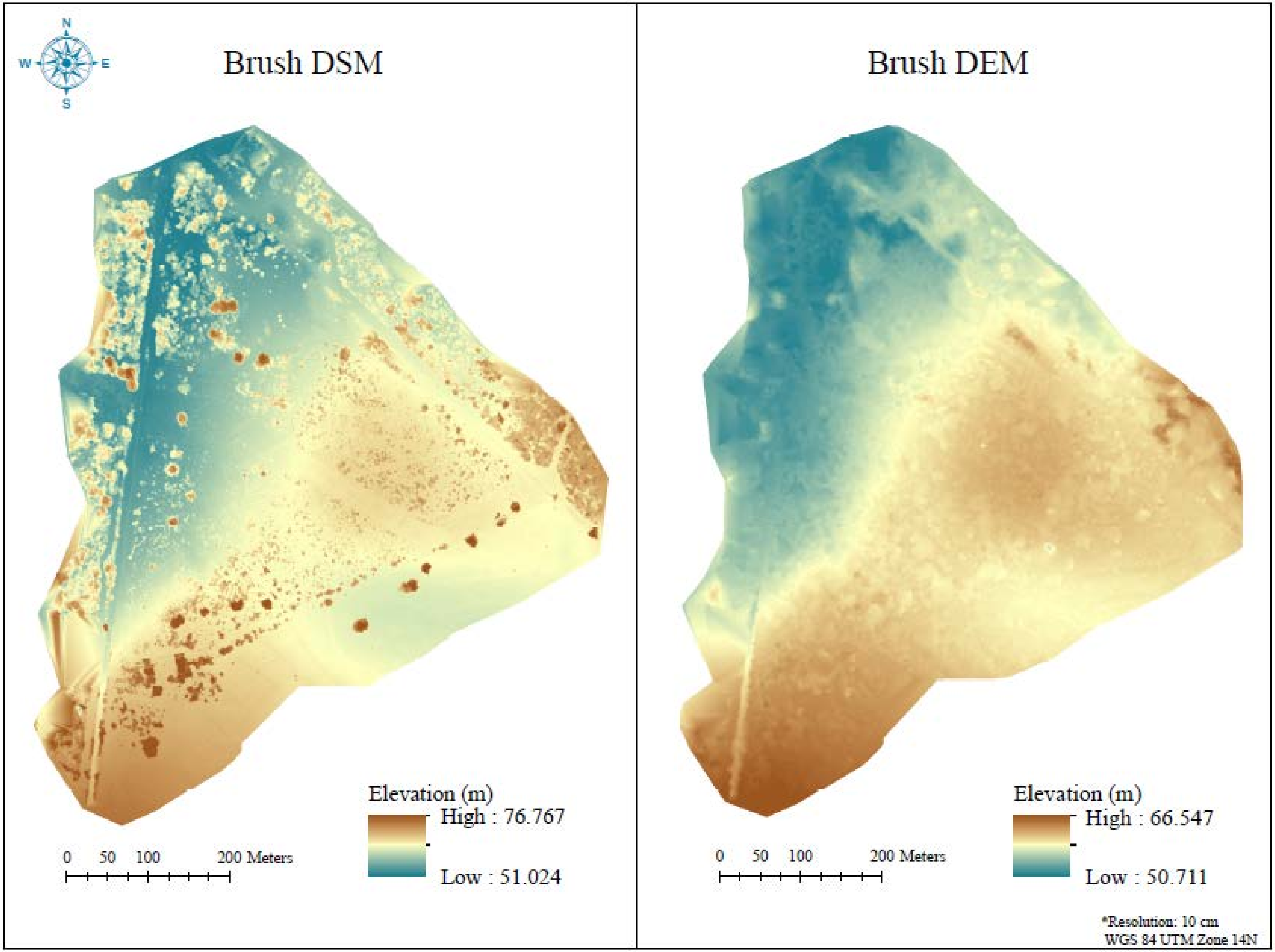
Digital Surface Model (DSM)



Digital Elevation Model (DEM)

From Greenwood 2014

Example from AgriLife: Beeville, TX



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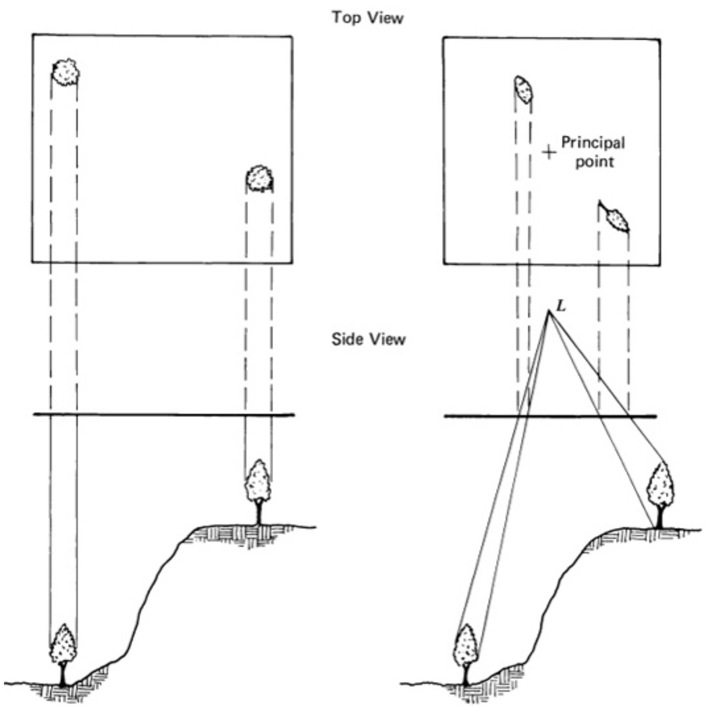
What is an orthophoto?

Image that is corrected (through the process of orthorectification) from the effect of terrain relief or sensor tilt to convert it to a unified scale map.



(a) Map (orthographic projection)
Constant scale
No relief displacement

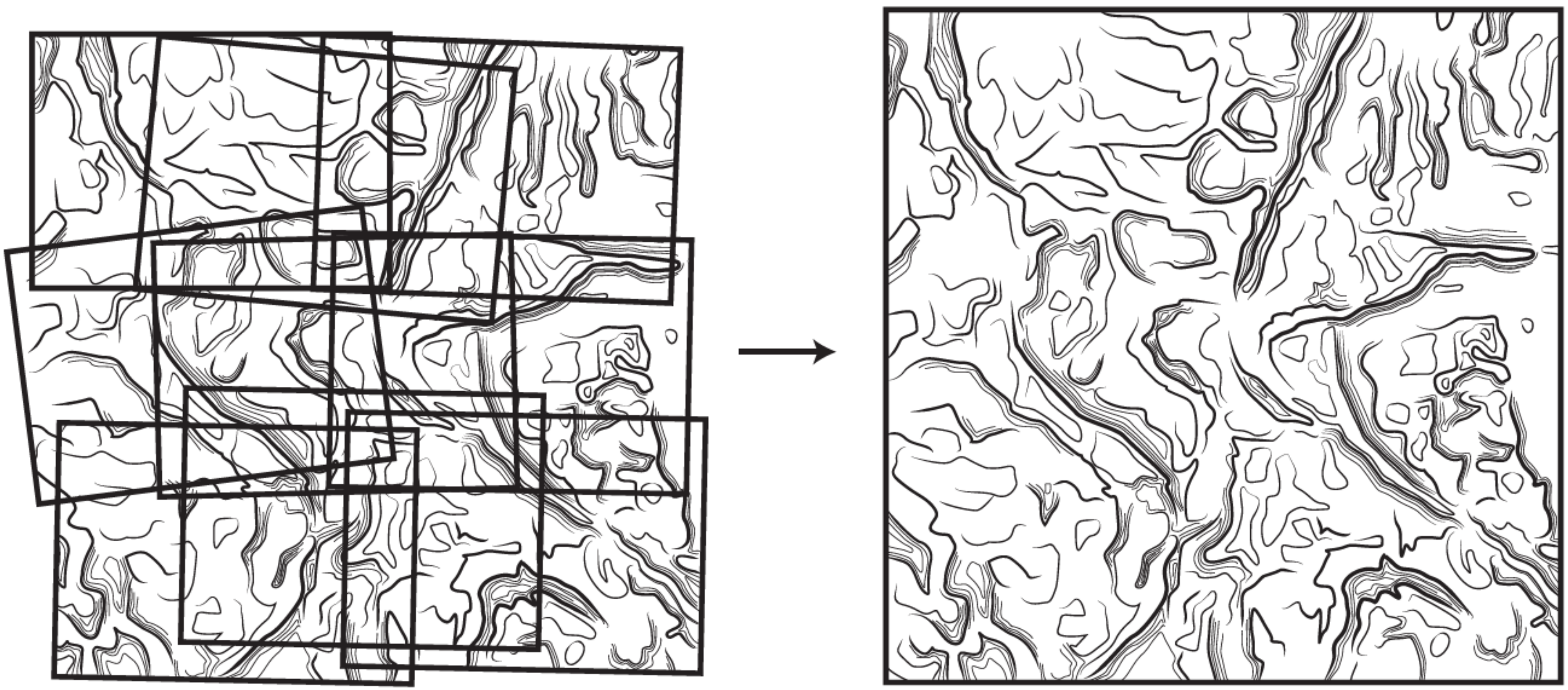
(b) Photo (perspective projection)
Varied scale
Relief displacement

Resulting Image (orthophoto)

- It is now a **“Photo-Map”**
- Image is aligned with ground coordinates (e.g. north-south streets will be aligned)
- Each pixel will have nominal ground coordinates
- Scale variation, relief, tilt removed
- Can accurately measure distances, areas…
- Can be used for “heads-up” digitizing in a GIS

Orthomosaic

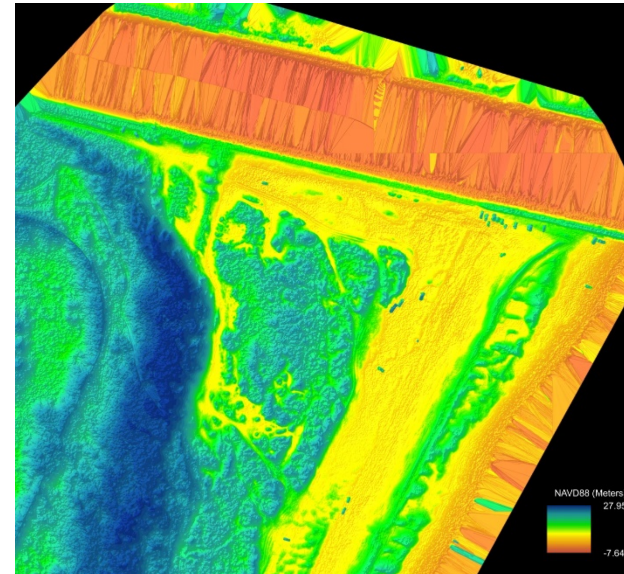
- Merging together a block of single ortho-photos to create a large seamless, orthorectified image

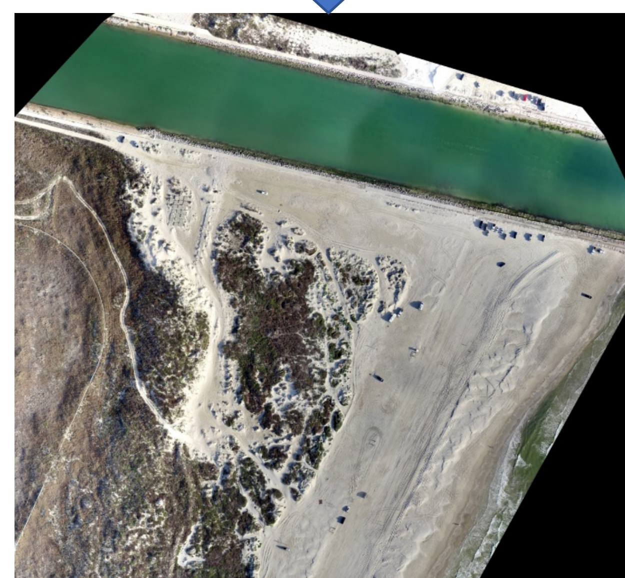


Processing software combines many photographs into a single orthomosiac image,

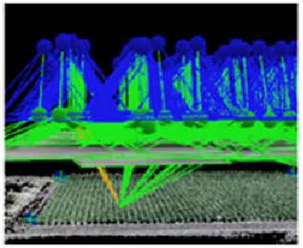
Example

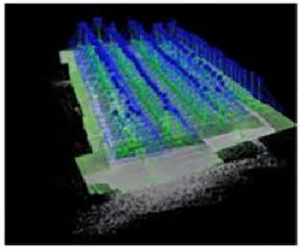
North Padre Island, TX

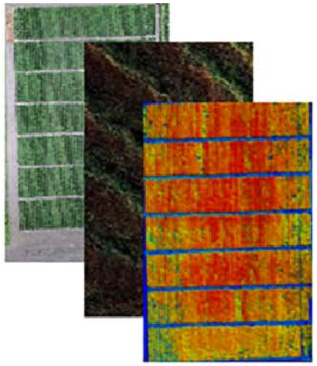




Example of UAS-SfM Ag. Processing Workflow







RGB Images → Key Point Detection & Image Matching → Bundle Block Adjustment → Product Generation

3D Point Cloud

↓

Digital Surface Model

↓

3-Band Reflectance Map

3D Point Cloud

↓

Digital Surface Model

↓

3-Band Reflectance Map

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