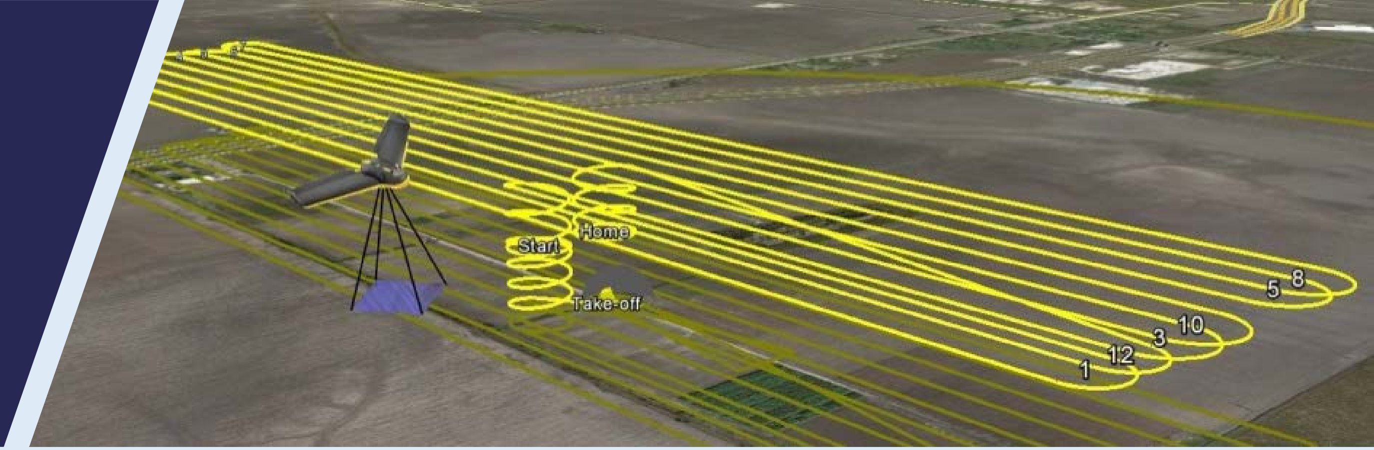


Module 2

Structure from Motion (SfM) (8)

Objectives

- **Define** Structure from Motion photogrammetry
- **Differences** to traditional photogrammetry
- **Understand** basic methodology
- **Learn** stages in SfM processing
- **How** to implement it

SfM versus Traditional Photogrammetry

- Traditional Photogrammetry

  → 2 overlapping images + **metric camera** + camera position / orientation + bundle adjustment = matched points in 3D.

- Structure from Motion (SfM)

  →many overlapping images + **non-metric camera** + feature detection + correspondence + adjustment = matched points in 3D

Non-metric cameras include things like typical consumer-grade hand held digital cameras

Both methods rely on calibrated cameras for accurate measurements but SfM software can calibrate the camera using automated self-calibration methods.

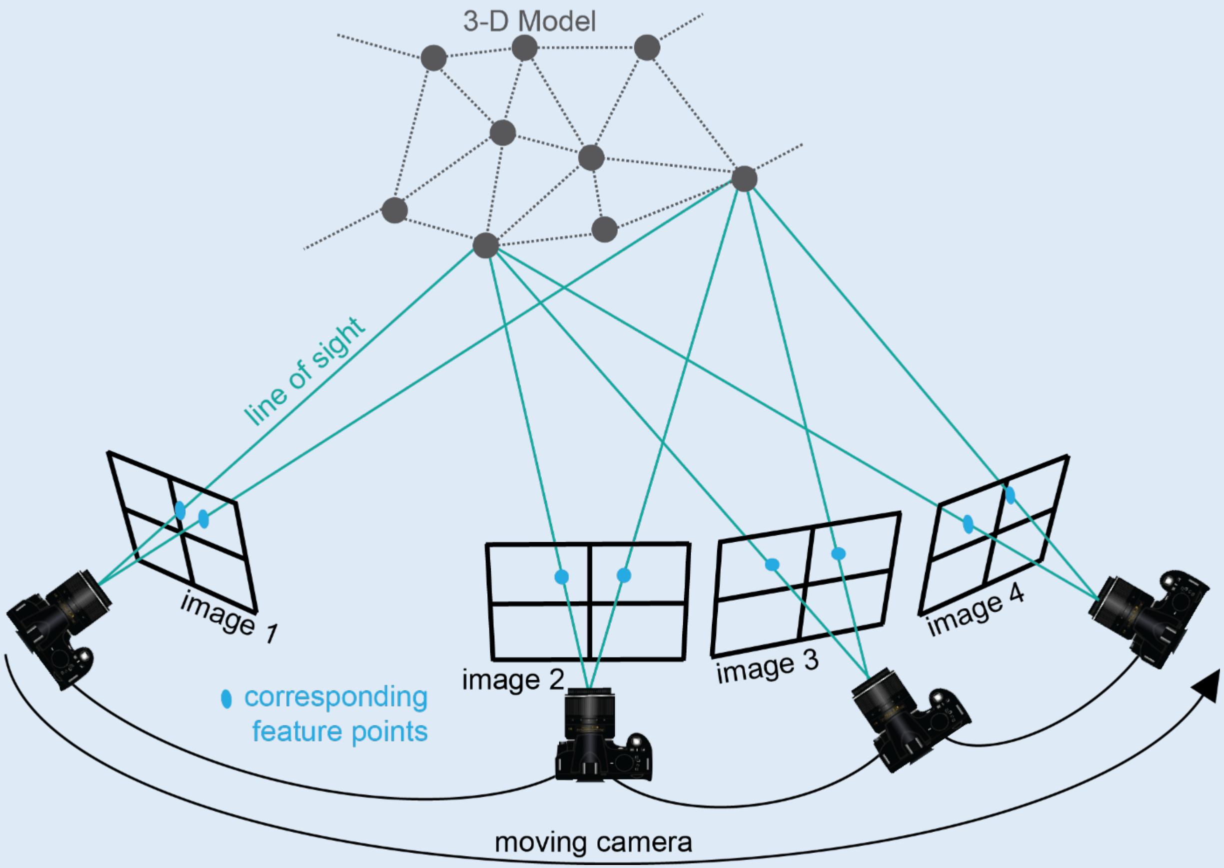
UASTEC

SfM description from UNAVCO

UNAVCO is a non-profit university-governed consortium,
facilitates geoscience research and education using geodesy.

Be sure to read the accompanying reading for this lecture!

Structure-from-motion?



Use the locations of the camera (motion) to interpret the geometry or 3D model (structure) of a scene

Figure Kate Shervais

What do you create?

~500 points/m^2 colored point cloud along a ~1 km section of the 2010 El Mayor-Cucapah earthquake rupture generated from ~500 photographs captured in 2 hours from a helium blimp

Figure Ed Nissen

What can we compare sfm to?

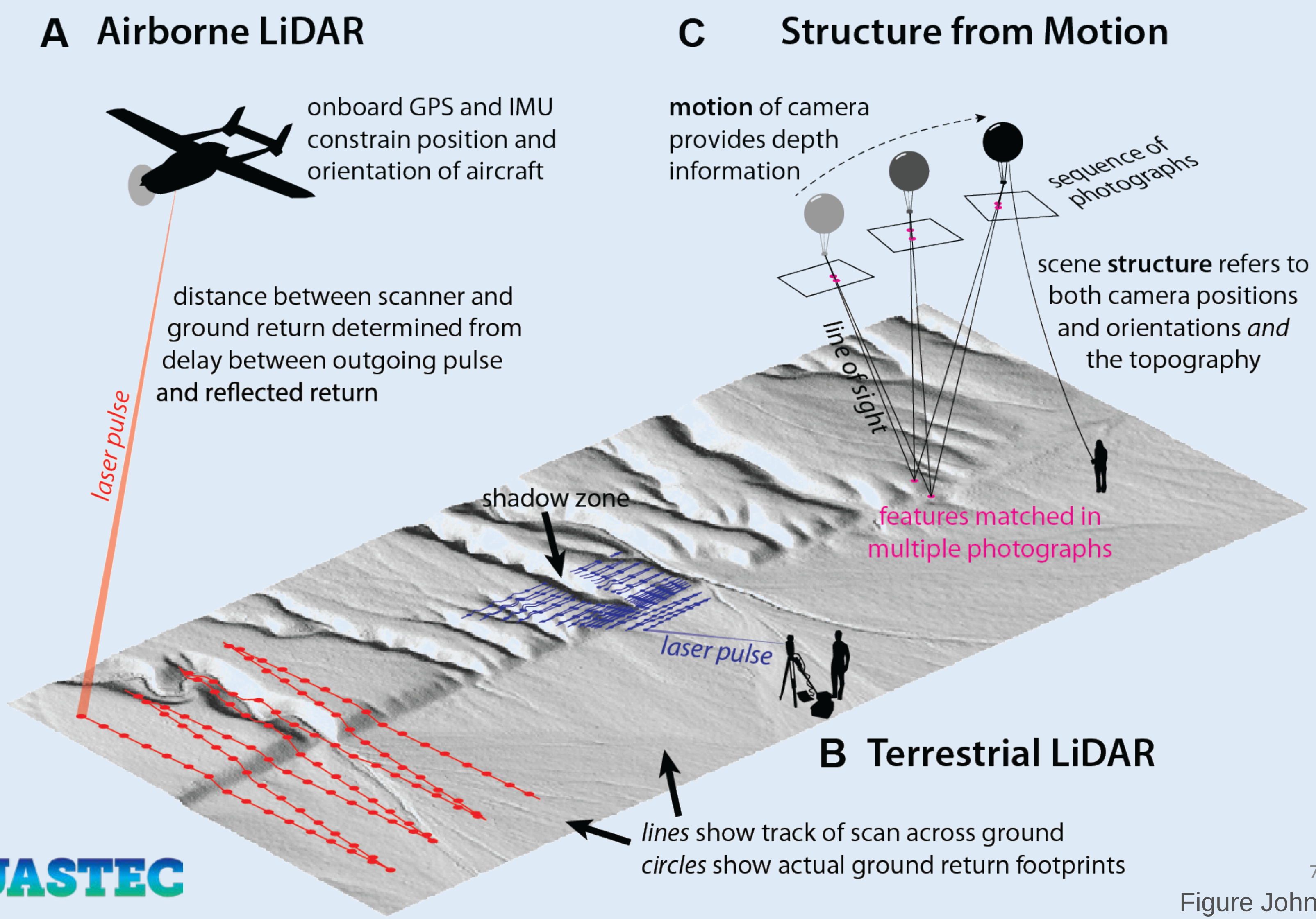
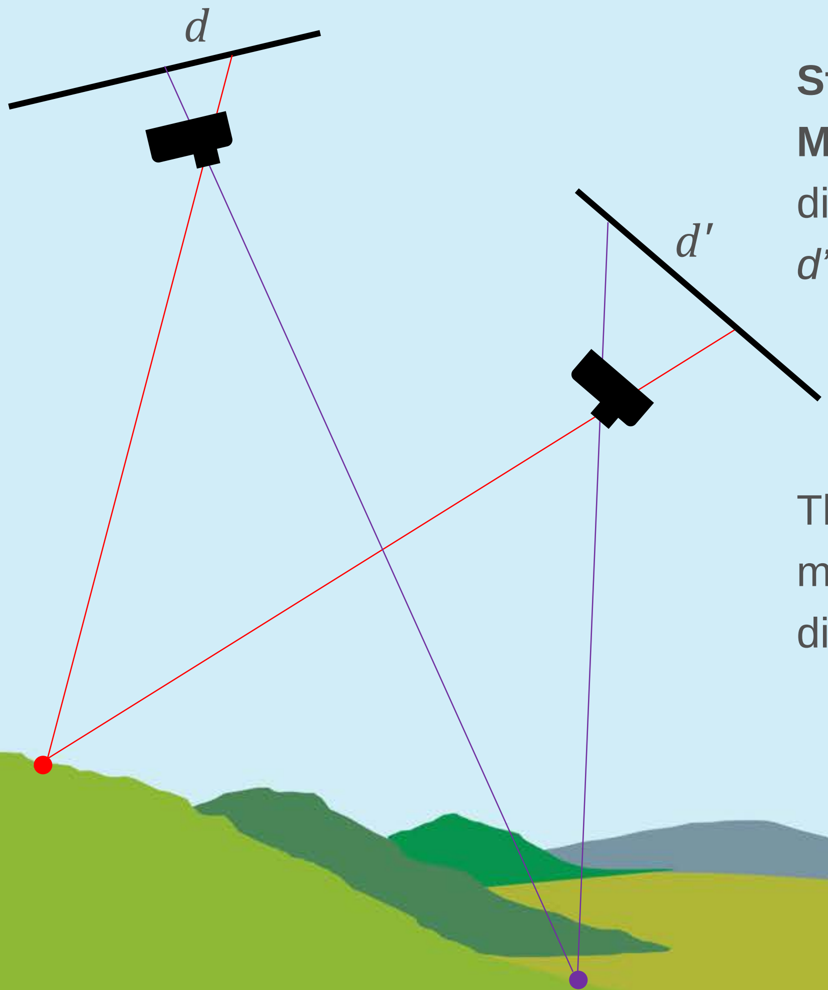


Figure Johnson 2014

Matching features



Step 1

Match corresponding features and measure distances between them on the camera image plane *d, d'*

The Scale-Invariant Feature Transform is key to matching corresponding features despite varying distances

Figure Ed Nissen

Scale-invariant feature transform (SIFT)

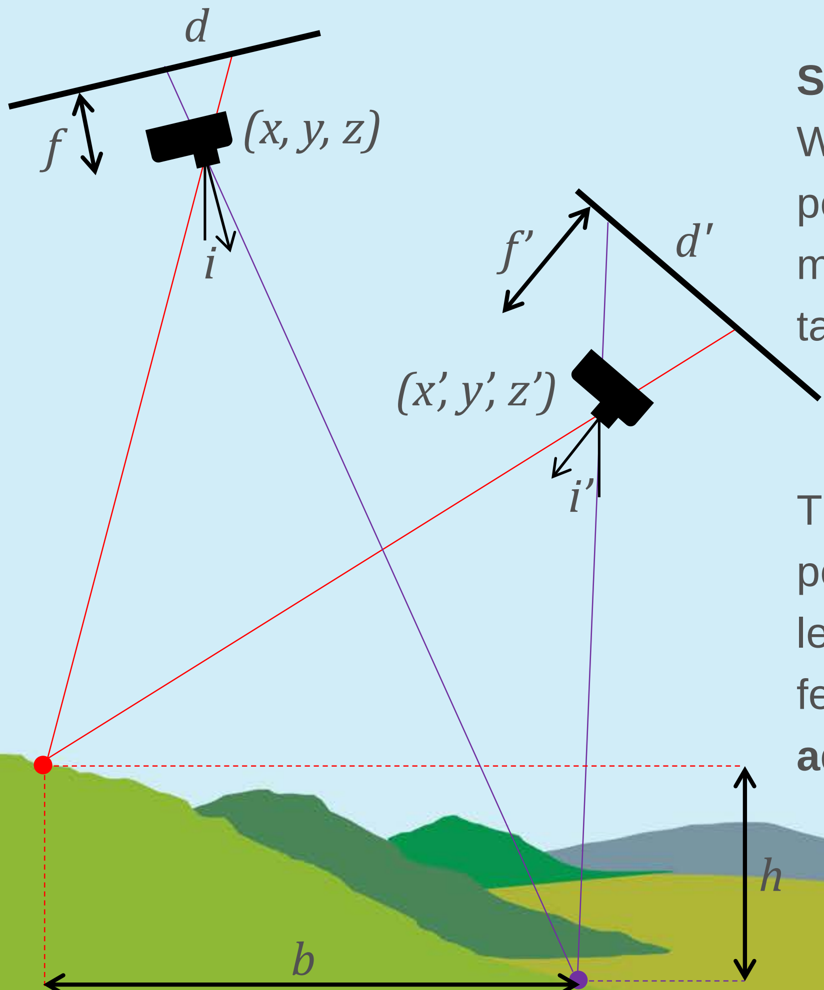
Figure Ed Nissen

Scale-invariant feature transform (sift)

- Finds matching features in multiple photographs
- Scale, perspective, and illumination of the feature in the photograph do not affect algorithm
- Used as the input for calculating camera locations

Figure Ed Nissen

Find camera locations



Step 2

When we have the matching locations of multiple points on two or more photos, there is usually just one mathematical solution for where the photos were taken.

Therefore, we can calculate individual camera positions *(x, y, z), (x', y', z'),* orientations *i*, *i'*, focal lengths *f*, *f'*, and relative positions of corresponding features *b, h,* in a single step known as **"bundle adjustment."**

analytical self-calibration of camera

Figure Ed Nissen

Multi-view stereo / Densification

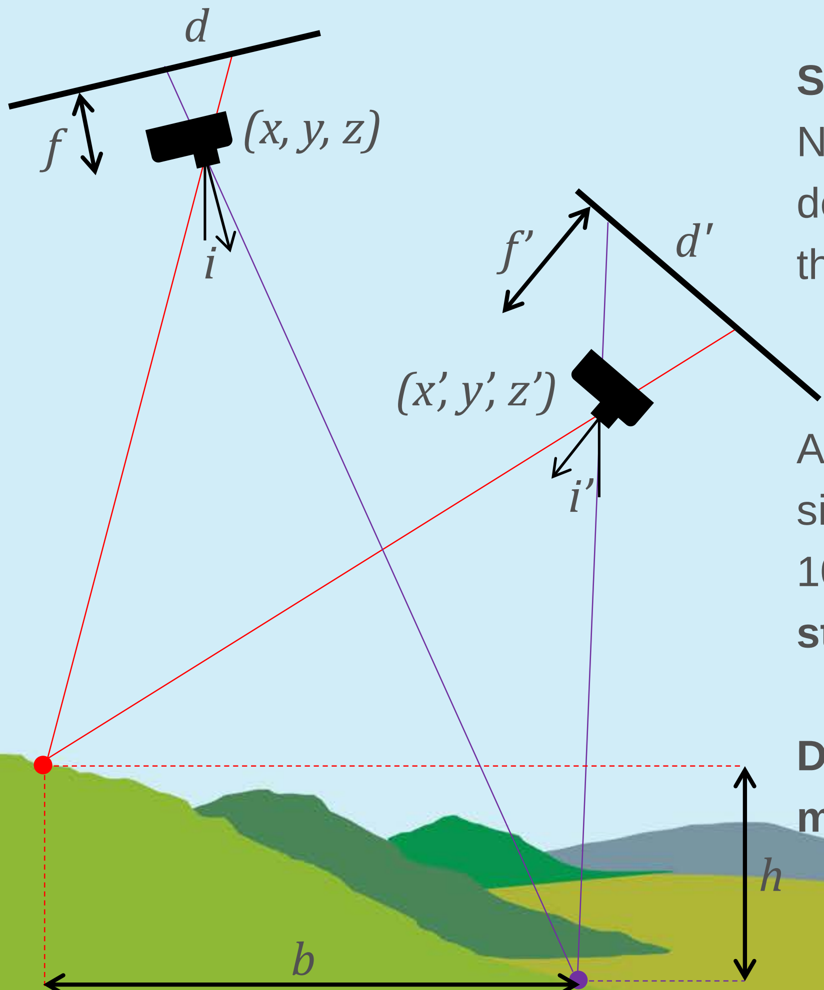


Figure Ed Nissen

Step 3

Next, a dense point cloud and 3D surface are determined using the known camera parameters and the sparse point cloud as input.

All pixels in all images are used so the dense model is similar in resolution to the raw photographs (typically 100s–1000s point/m^2). This step is called "**multi-view stereo matching" (MVS) or densification.**

Different algorithms including semi-global matching

georectification

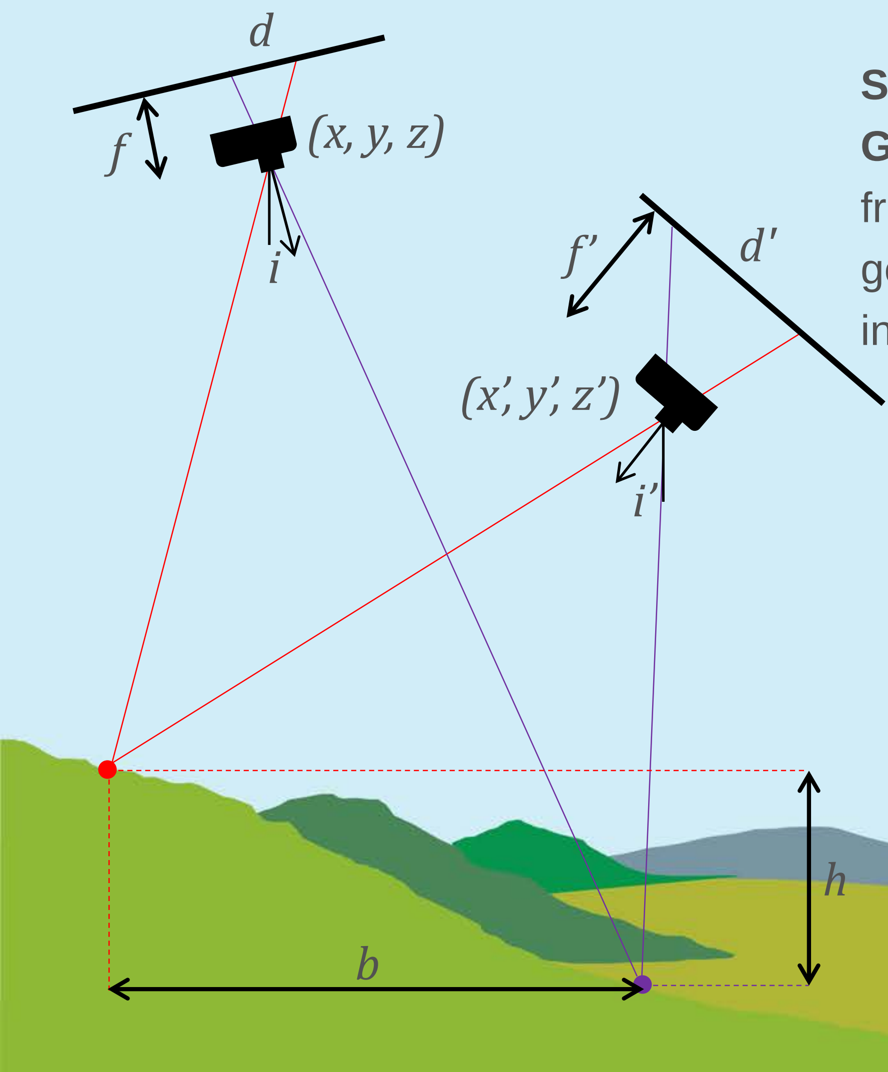
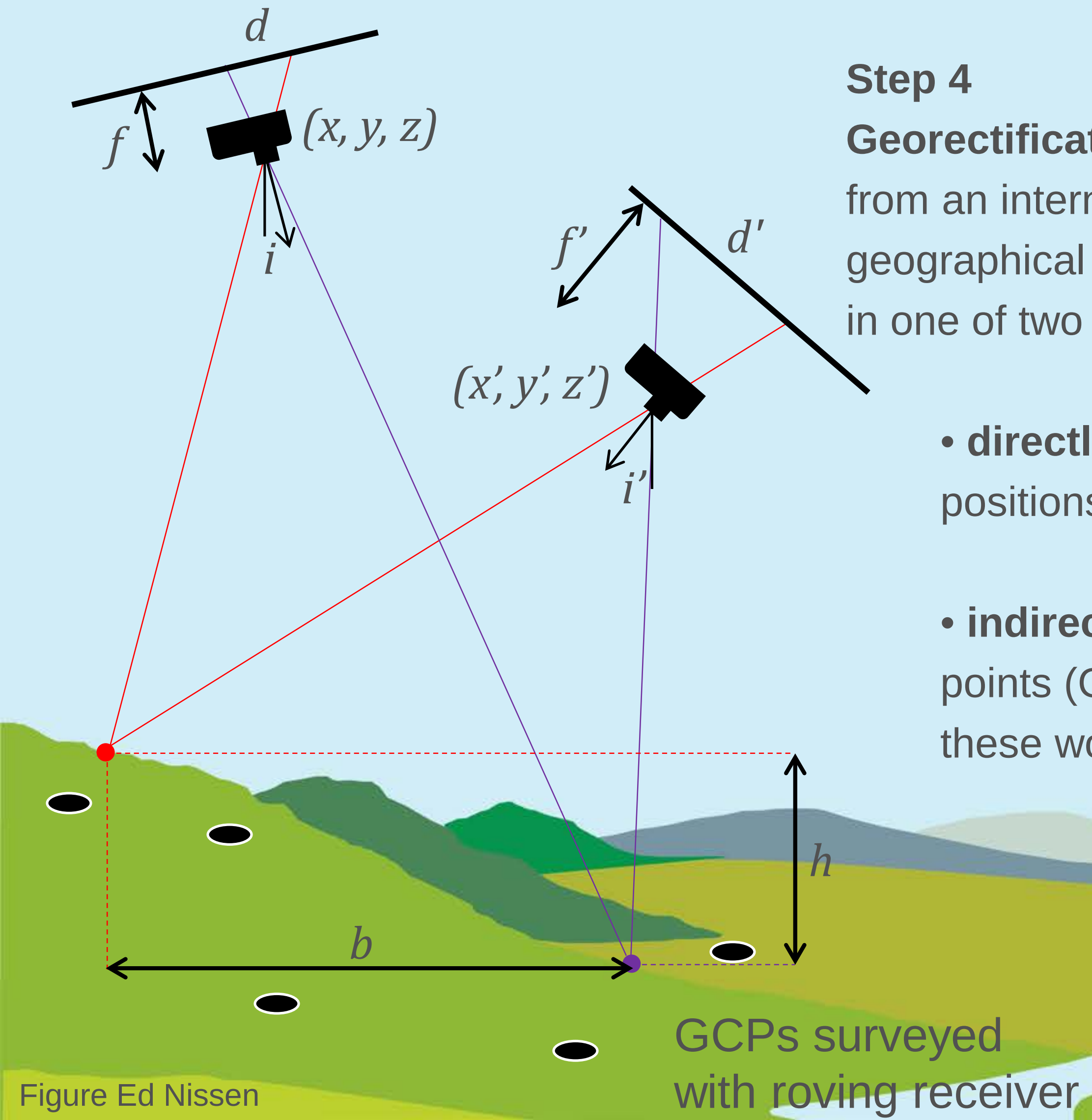


Figure Ed Nissen

Step 4

Georectification means converting the point cloud from an internal, arbitrary coordinate system into a geographical coordinate system. This can be achieved in one of two ways:

georectification



Step 4

Georectification means converting the point cloud from an internal, arbitrary coordinate system into a geographical coordinate system. This can be achieved in one of two ways:

- **directly,** with knowledge of the camera positions and focal lengths
- **indirectly,** by incorporating a few ground control points (GCPs) with known coordinates. Typically these would be surveyed using differential GPS.

Figure Ed Nissen

products

Optional Step 5

Generate derivative products:

- Digital Surface Model
- Orthomosaic for texture mapping

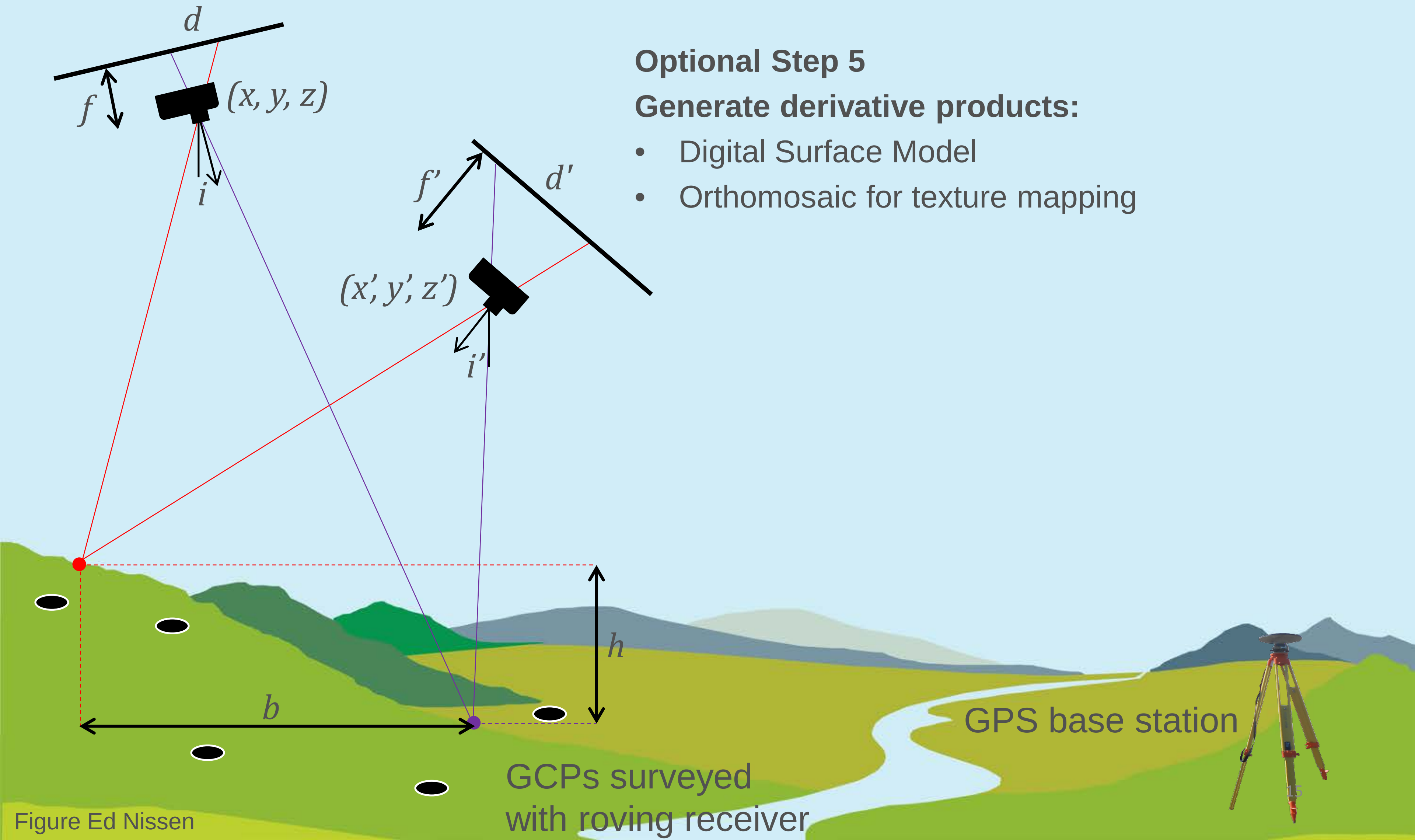


Figure Ed Nissen

Photo density map

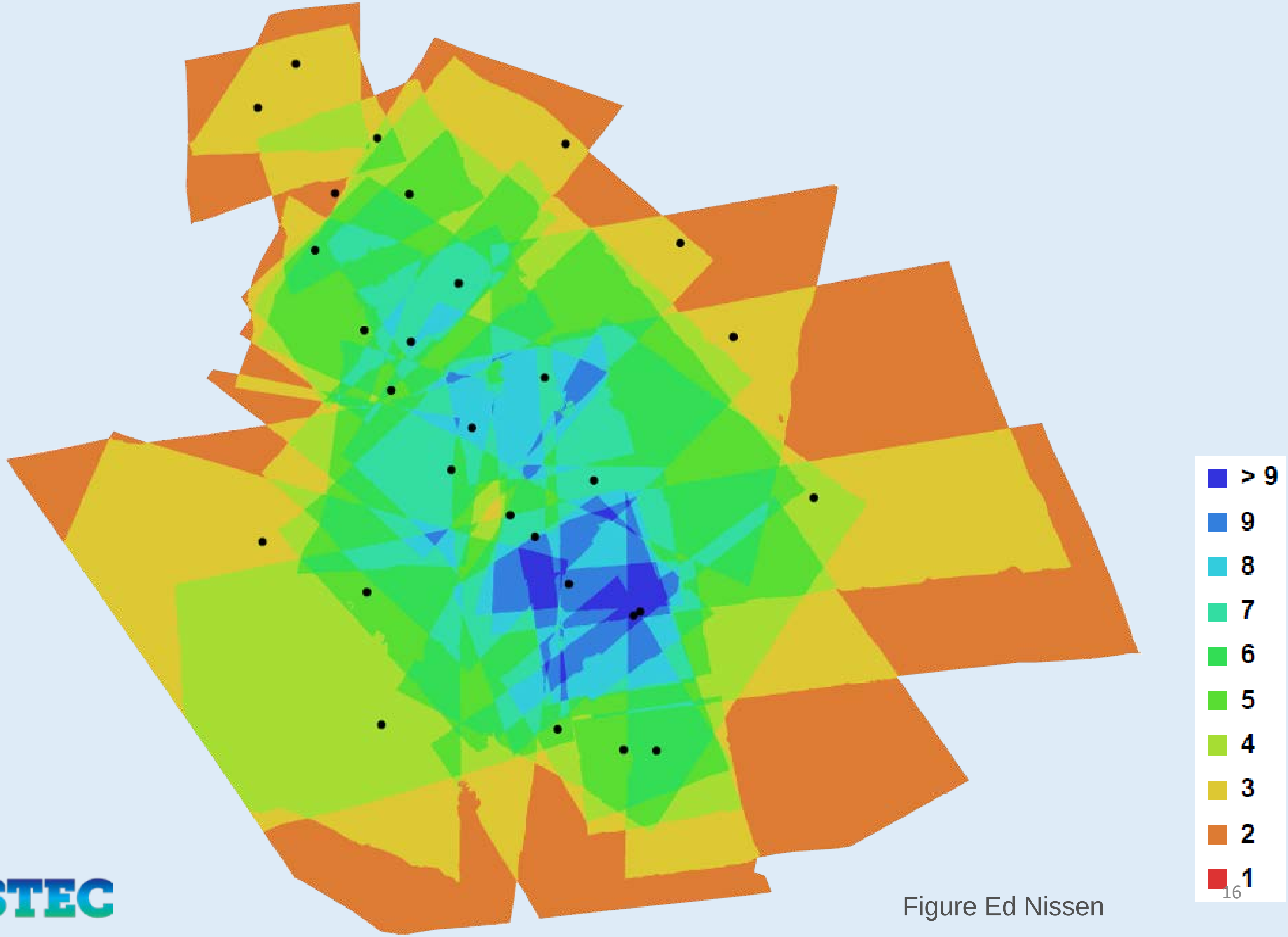


Figure Ed Nissen

orthomosaic

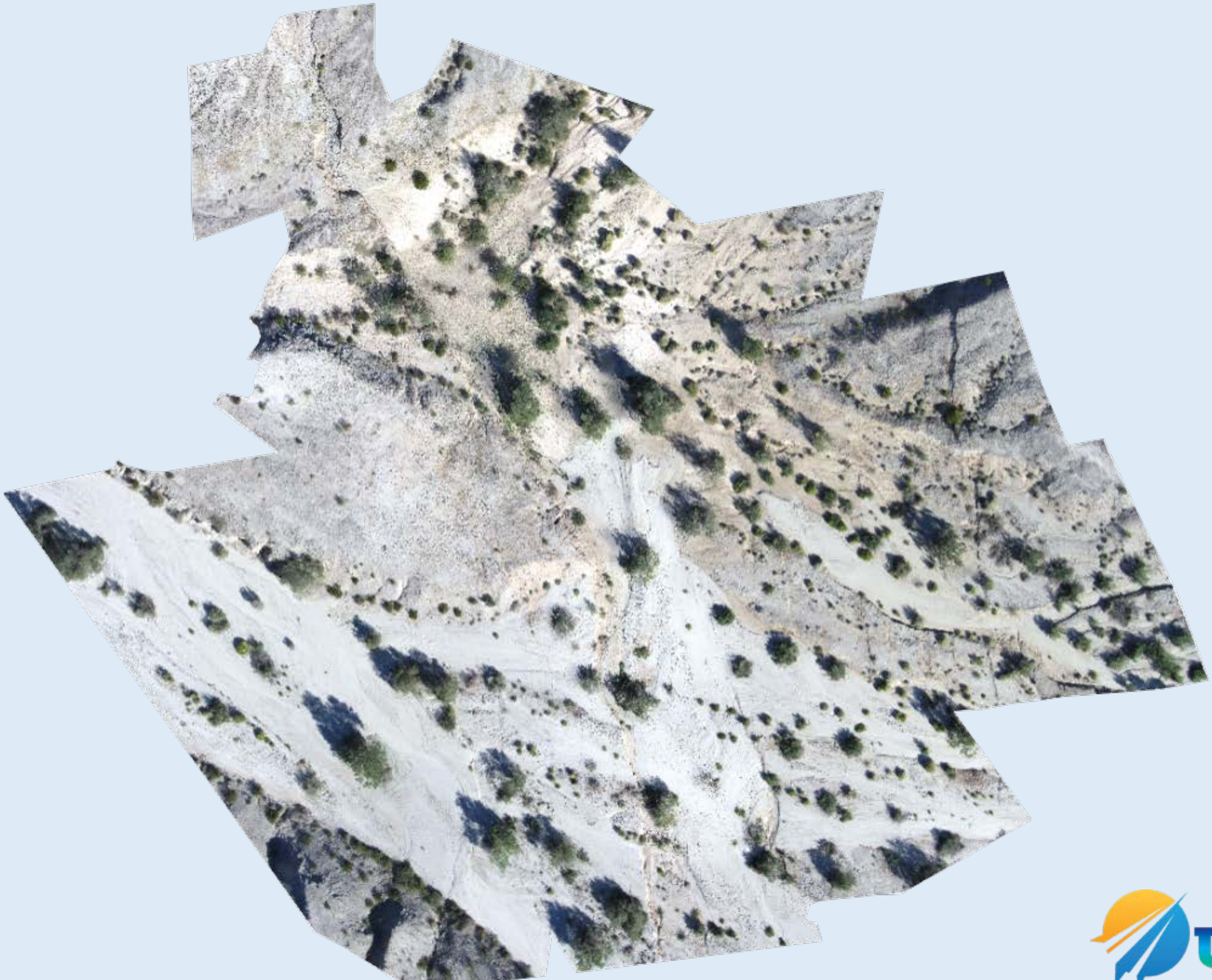


Figure Ed Nissen

Shaded digital elevation model

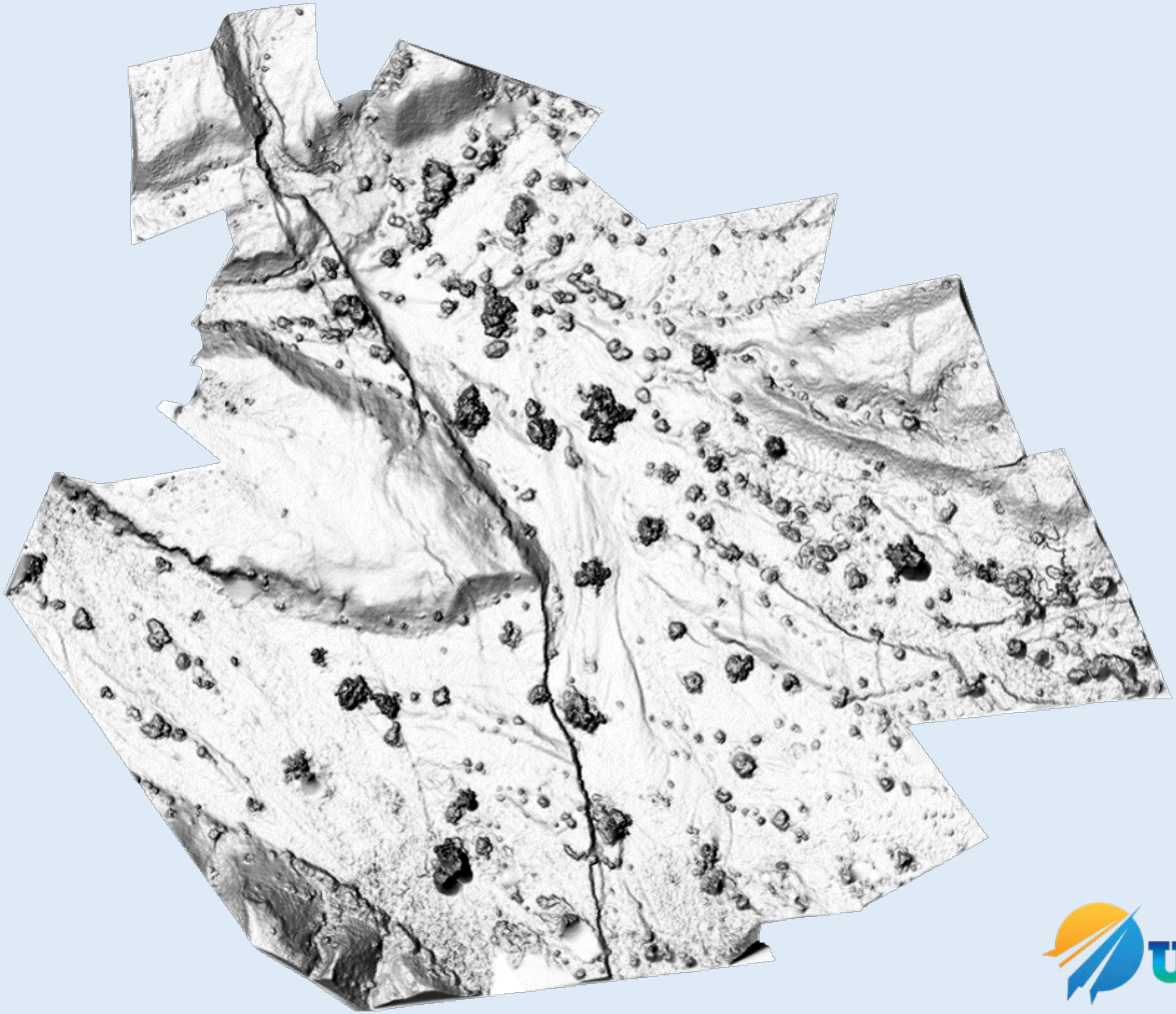


Figure Ed Nissen

platforms

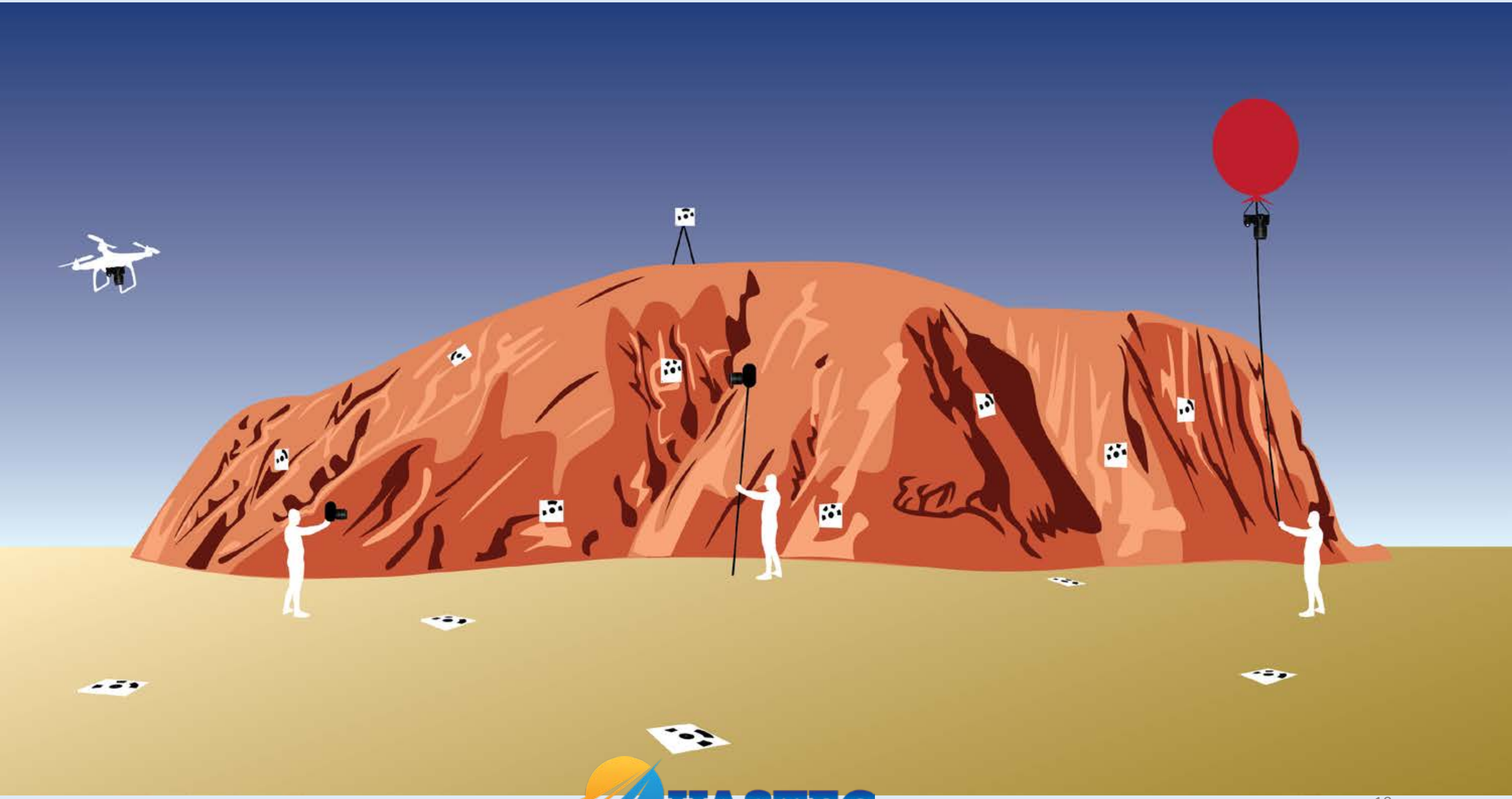


Figure Kate Shervais

Platforms – pole

Figure Kate Shervais

Platforms – kite

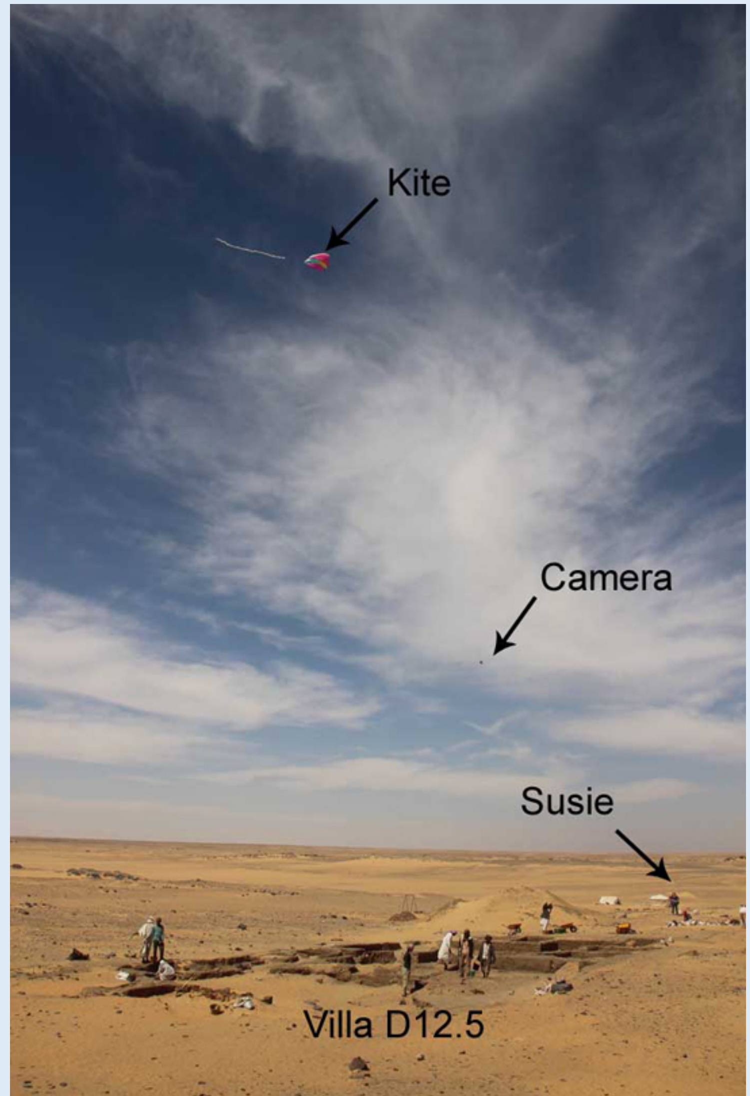


Figure Neal Spencer

Platforms - balloon

Figure Kate Shervais

UNAVCO

Platforms – uas

UASTEC

Figure Mike Bunds

Remember

- Accurate measurements from photogrammetry always requires **calibrated cameras**
  - calibrated as precisely as possible for that given camera model
- SfM software can calibrate the camera using automated **self-calibration** methods as part of the processing workflow

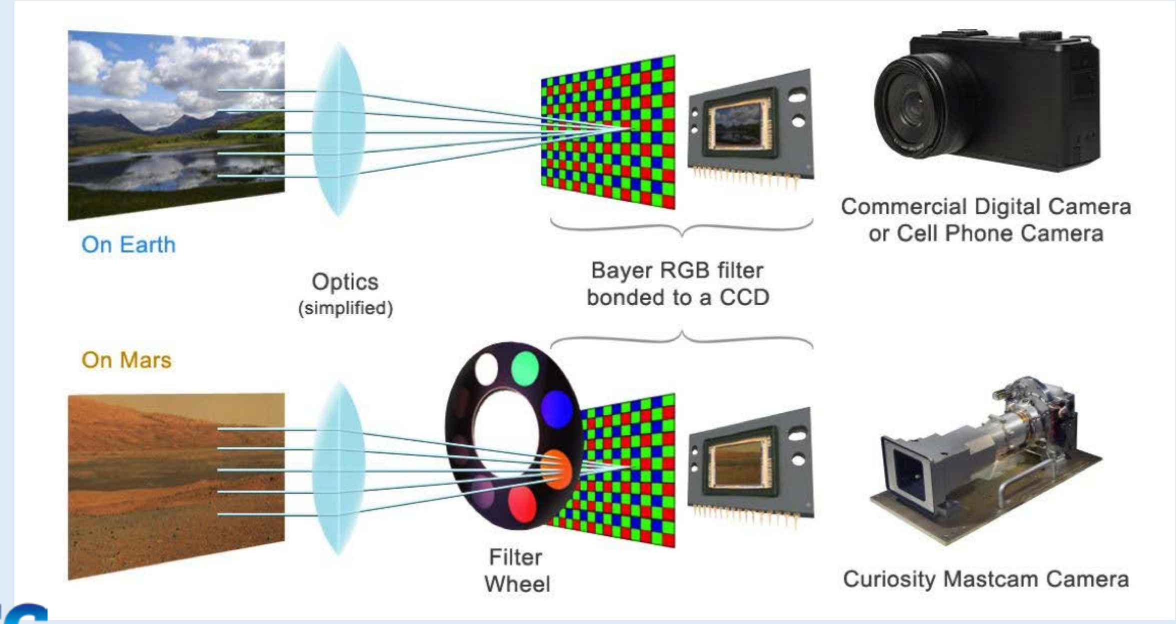


Image source: NASA Jet Propulsion Lab