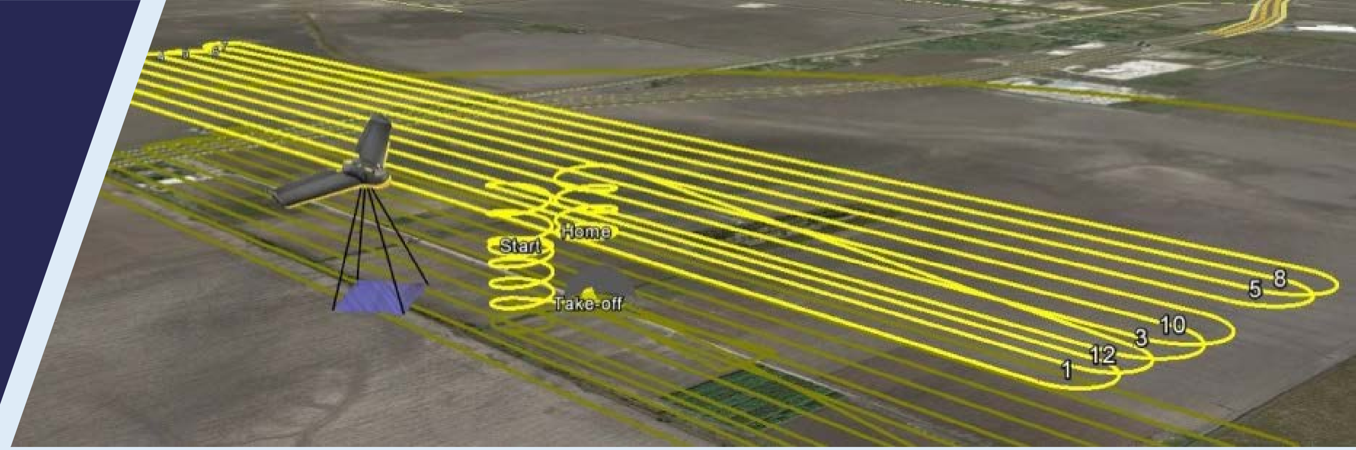

Module 1

Elements of Photogrammetry (7)

Objectives

- **Define** photogrammetry
- **Understand** types of aerial photographs
- **Identify geometry** of a vertical aerial photo
- **Measuring** scale in aerial photos
- **Relief** displacement and elevation in aerial phots

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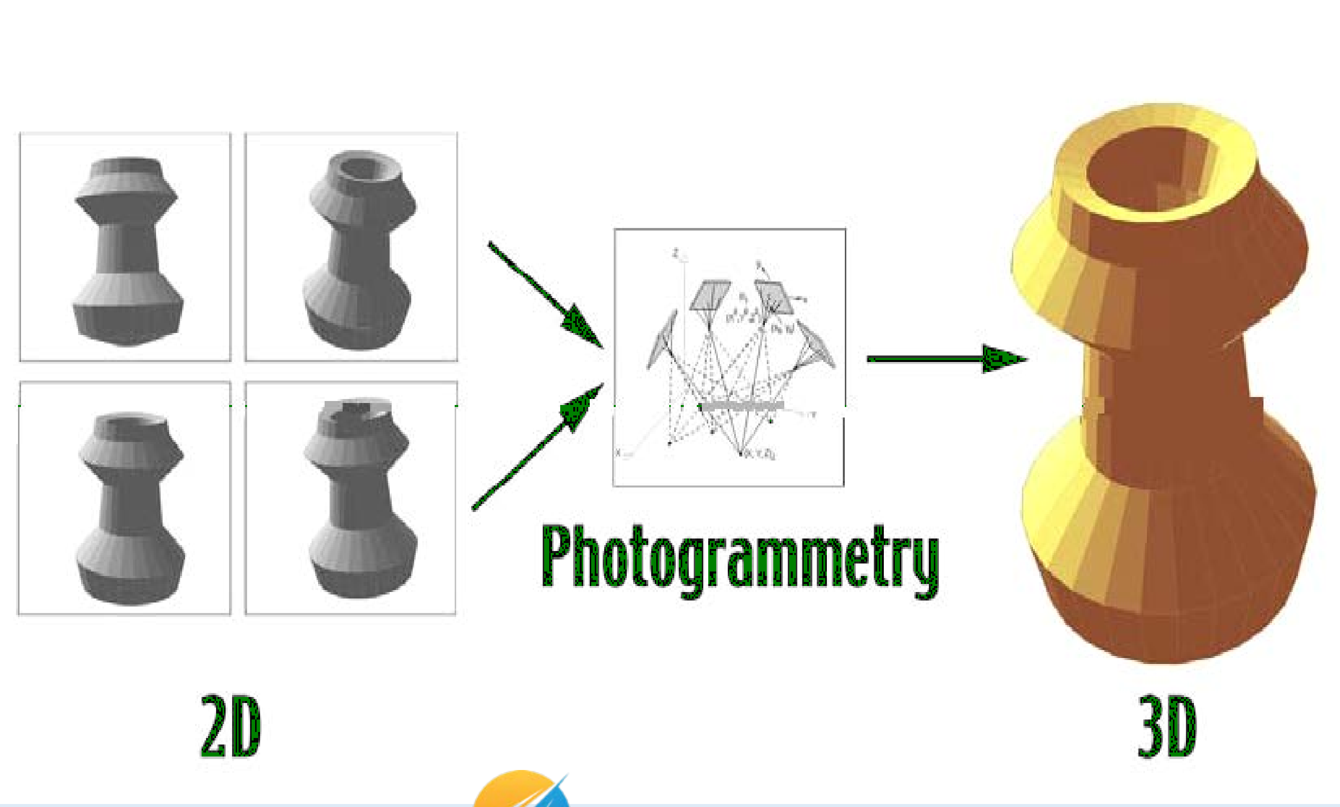
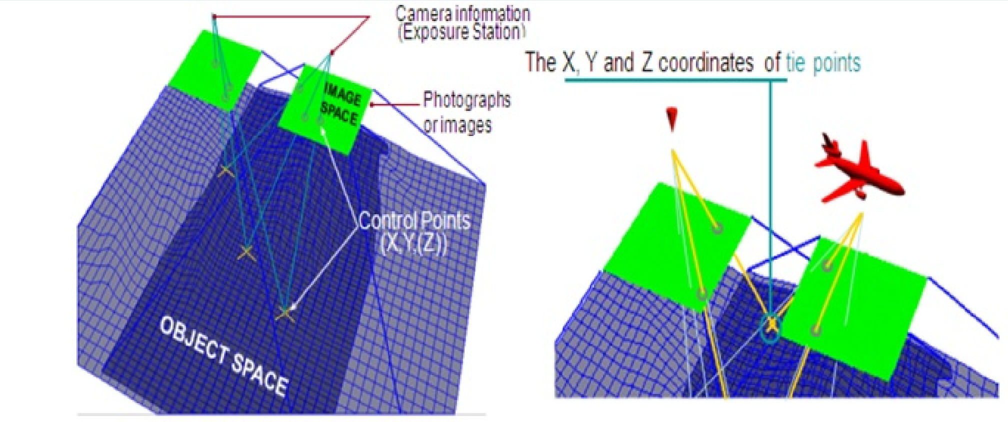
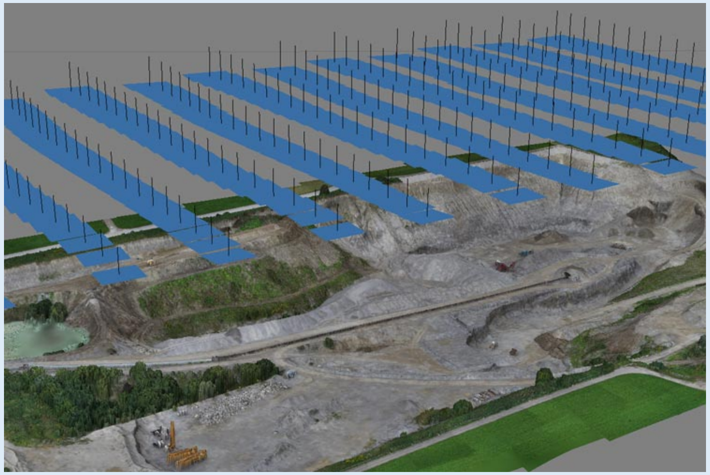
3D Reconstruction

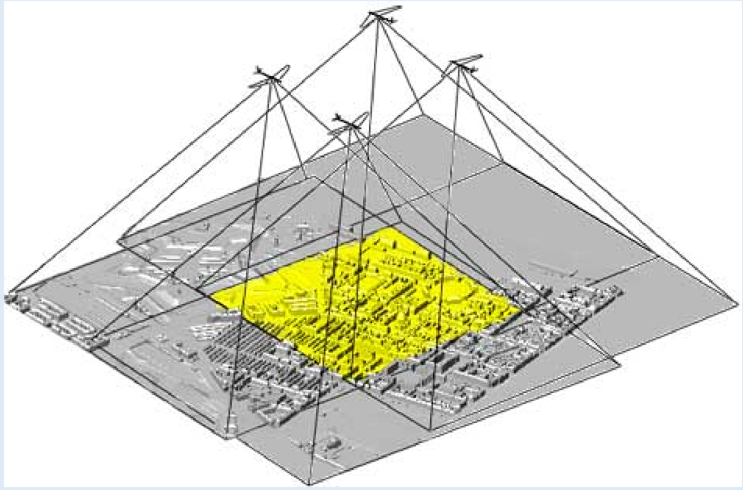
By taking photographs from at least two different locations, so-called "lines of sight" can be developed from each camera to points on the object. These lines of sight (rays) are mathematically intersected to produce 3D coordinates



Ultimately we want to do this from aircraft…

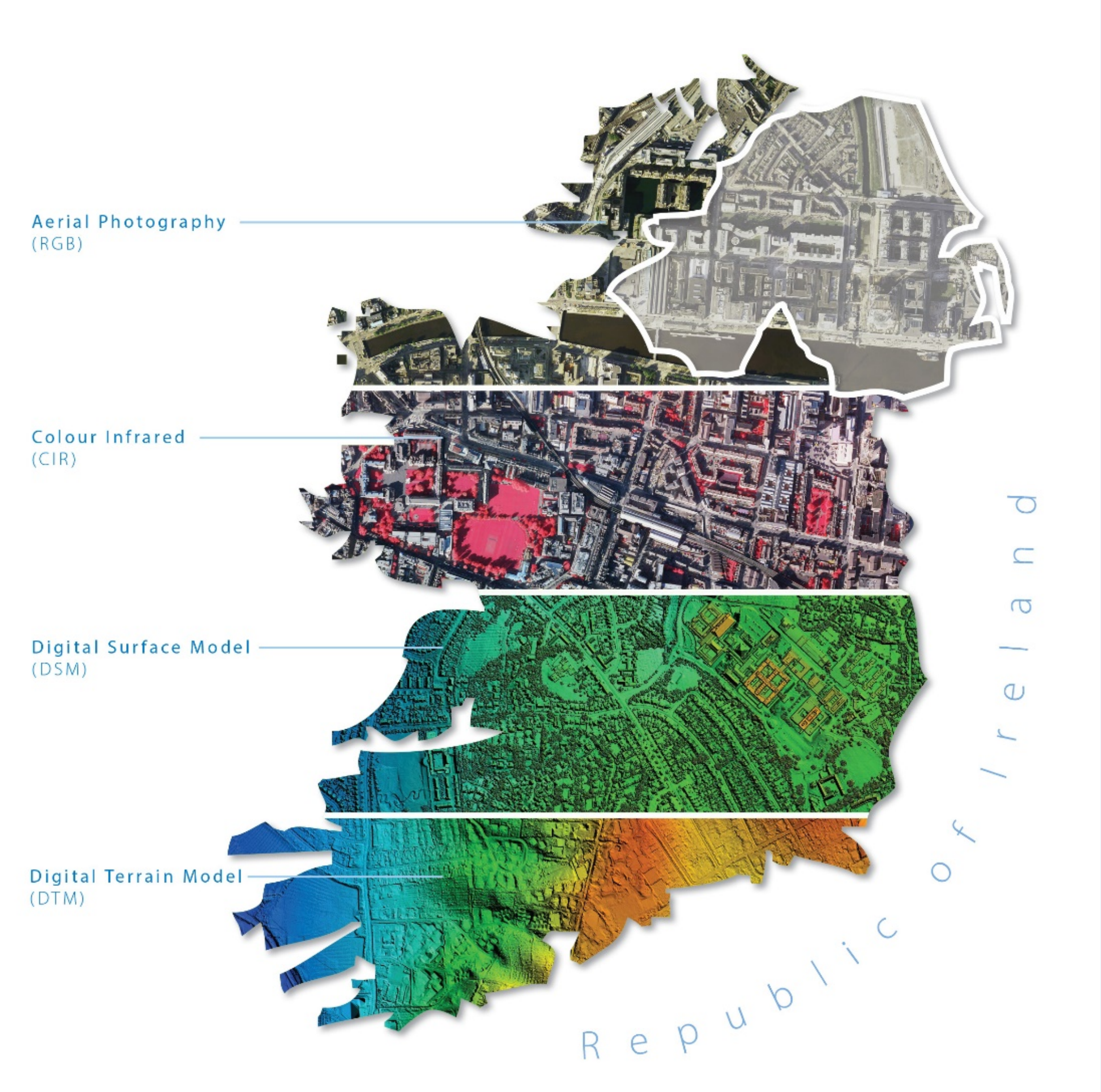






http://www.photogrammetrynews.com/2011/06/introduction-of-aerial-traingulation-in.html

http://www.sharpgis.net/page/True-Orthophoto-Generation



Source: http://www.engineersjournal.ie/wp-content/uploads/2014/11/Aerial-mapping-Ireland.jpg

What is photogrammetry?

- **Metric photogrammetry** – obtaining measurements from photos from which ground positions, elevations, distances, areas, and volumes can be computed and topographic or planimetric maps can be made.
  - Can be done from ground or air

https://www.youtube.com/watch?v=HB67qTbBr78

- **Photo interpretation** – evaluation of existing features in a qualitative manner.

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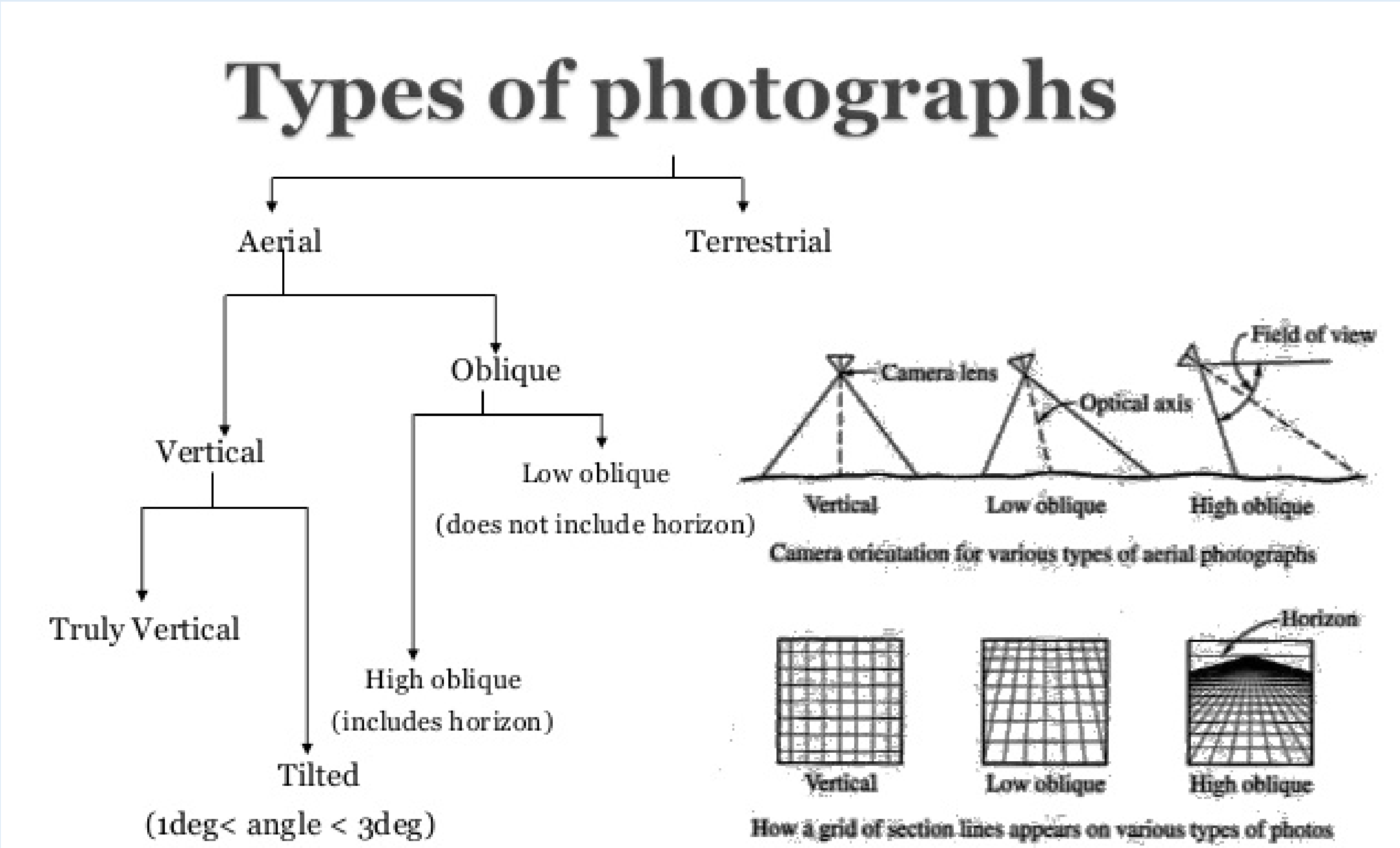

Slide from https://www.slideshare.net/Engineeramir393/photogrammetry-amir

We are concerned with aerial photos

Categories of Aerial Photographs

- Vertical Photograph
  - Camera optical axis < 3° off vertical (minimal tilt)
- Low-Oblique
  - Camera optical axis > 3° off vertical
  - Horizon not in image
- High Oblique
  - Camera optical axis > 3° off vertical
  - Horizon in image

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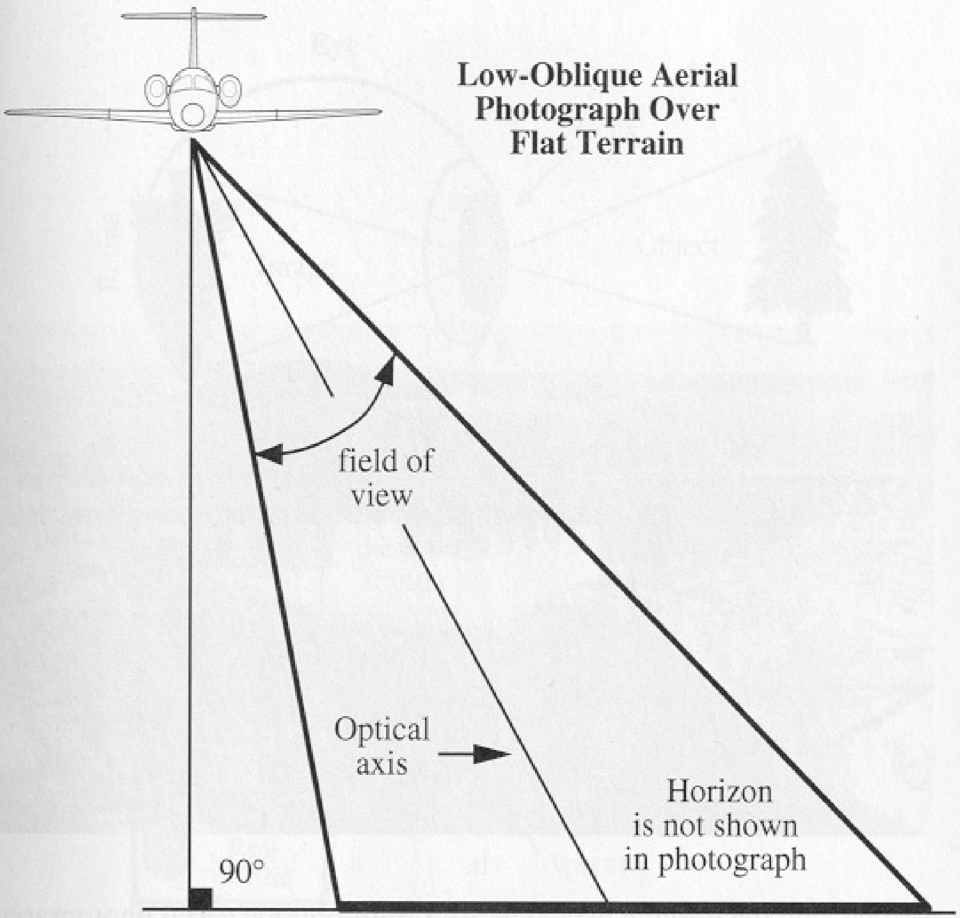
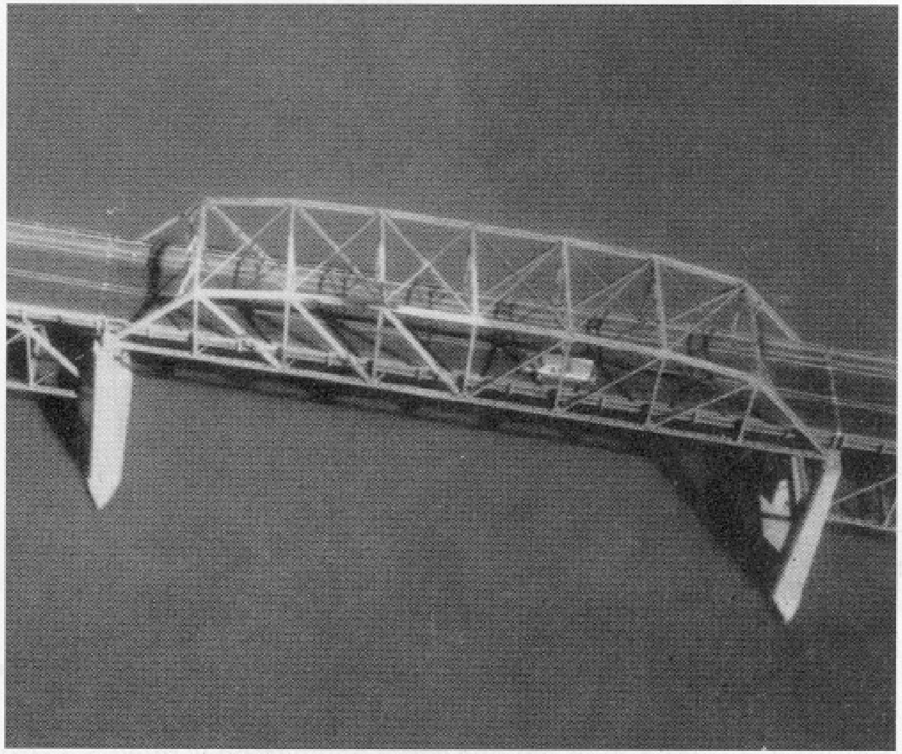
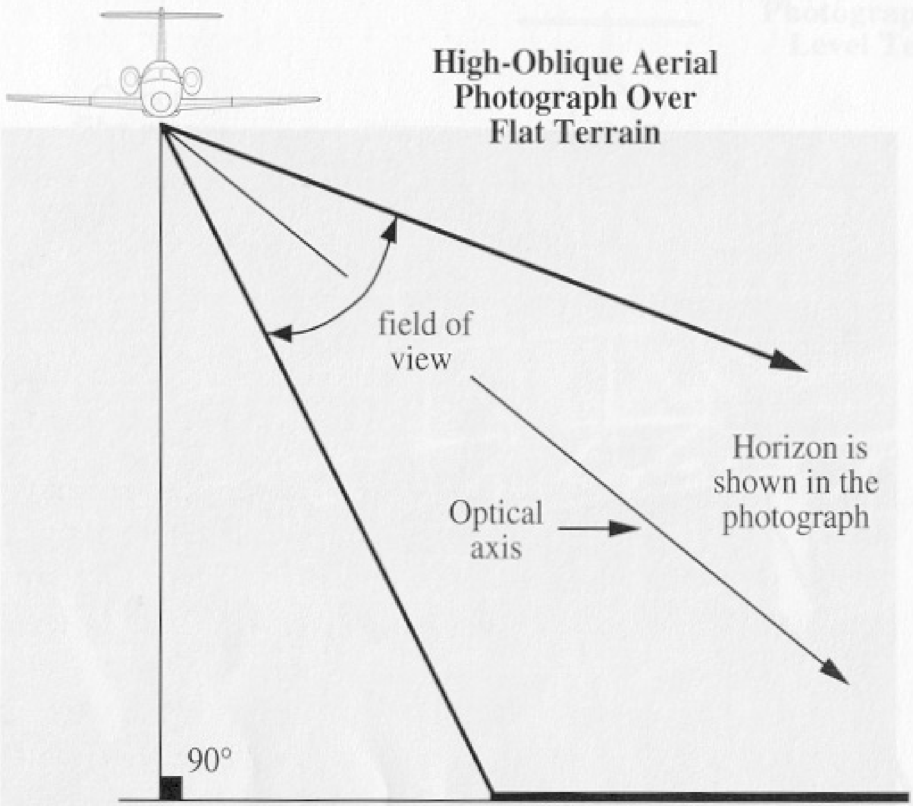
Low-Oblique Aerial Photograph Over Flat Terrain





High-Oblique Aerial Photograph Over Flat Terrain



a.

b.

Vertical Aerial Photograph Over Level Terrain

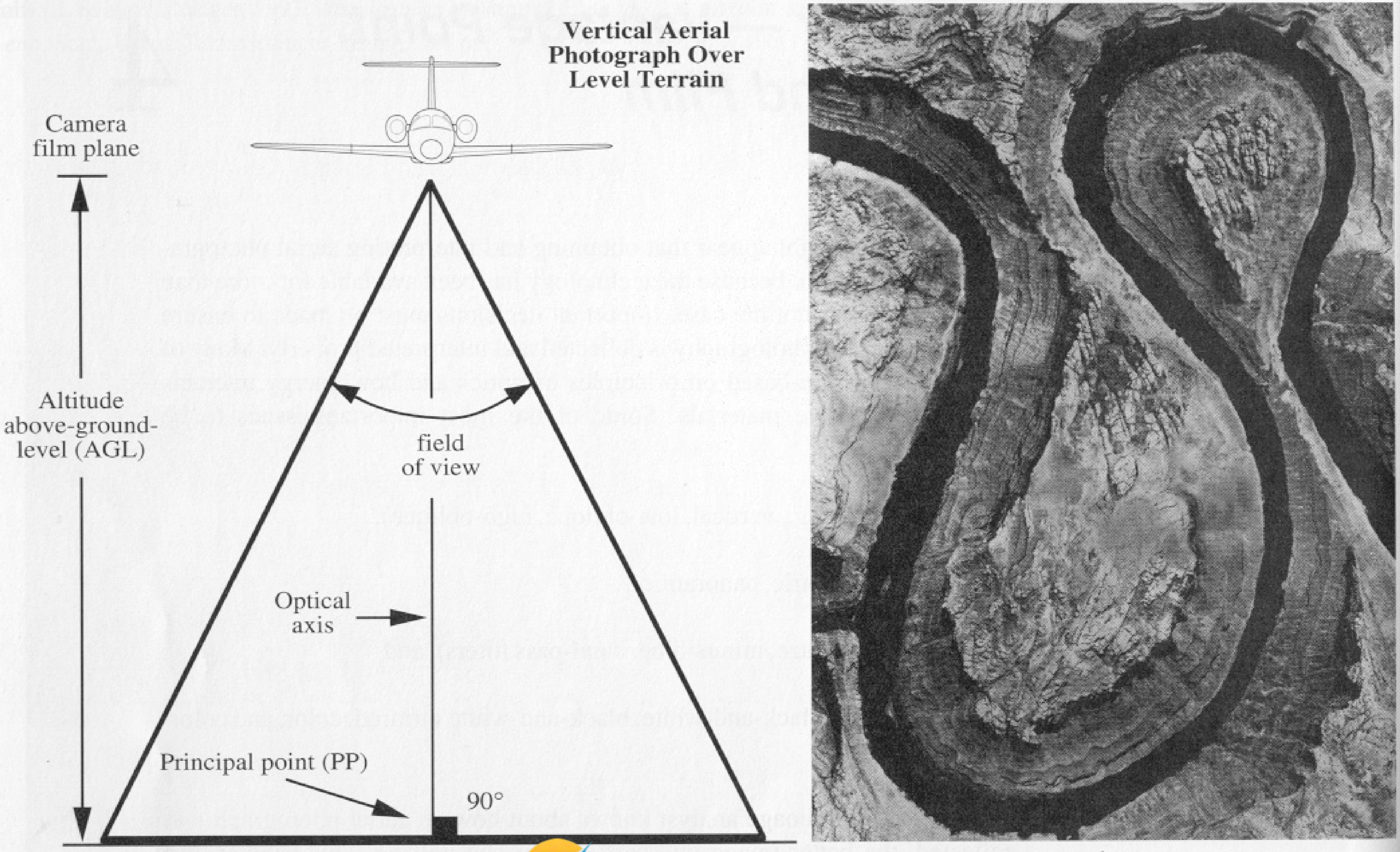


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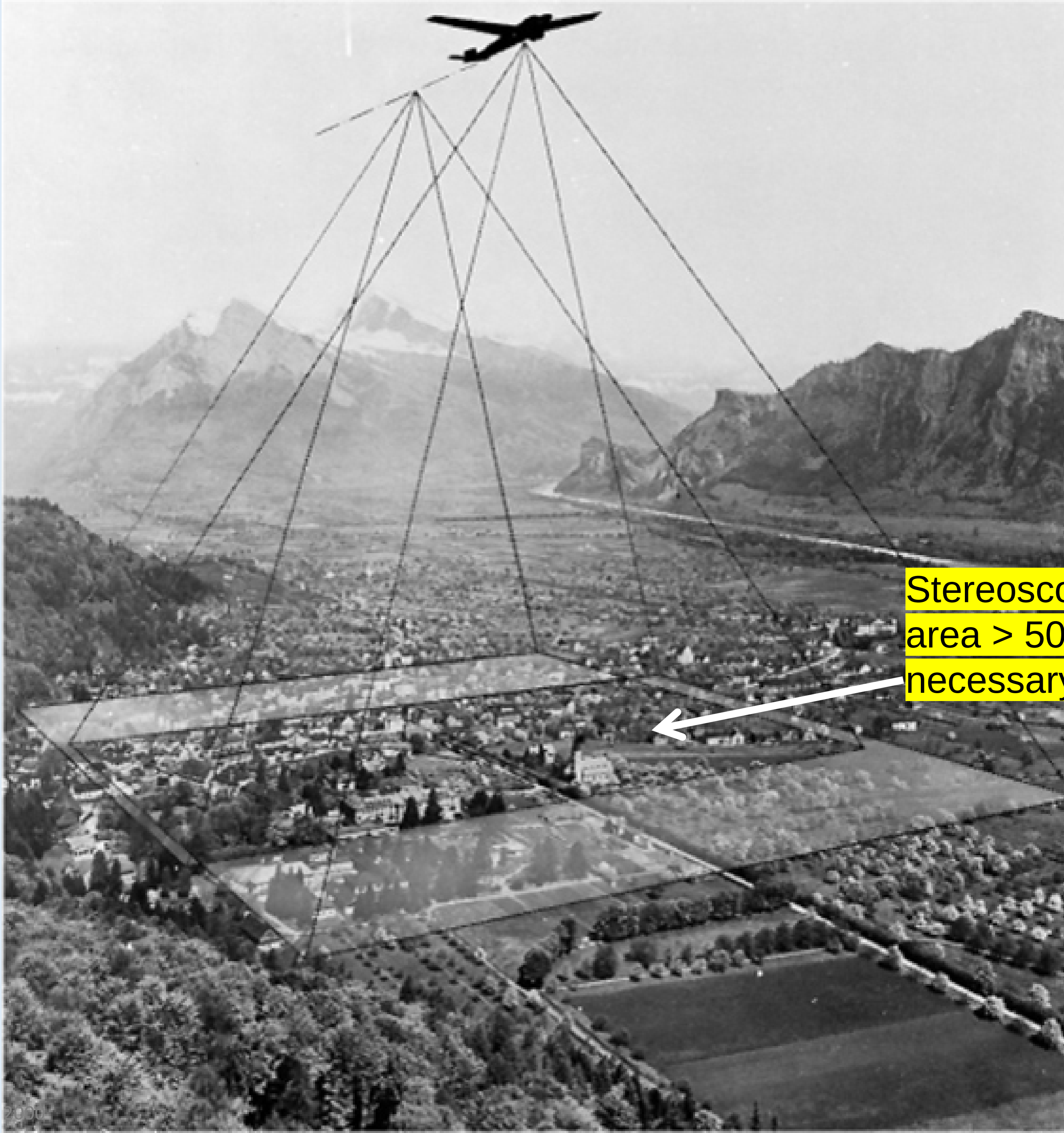
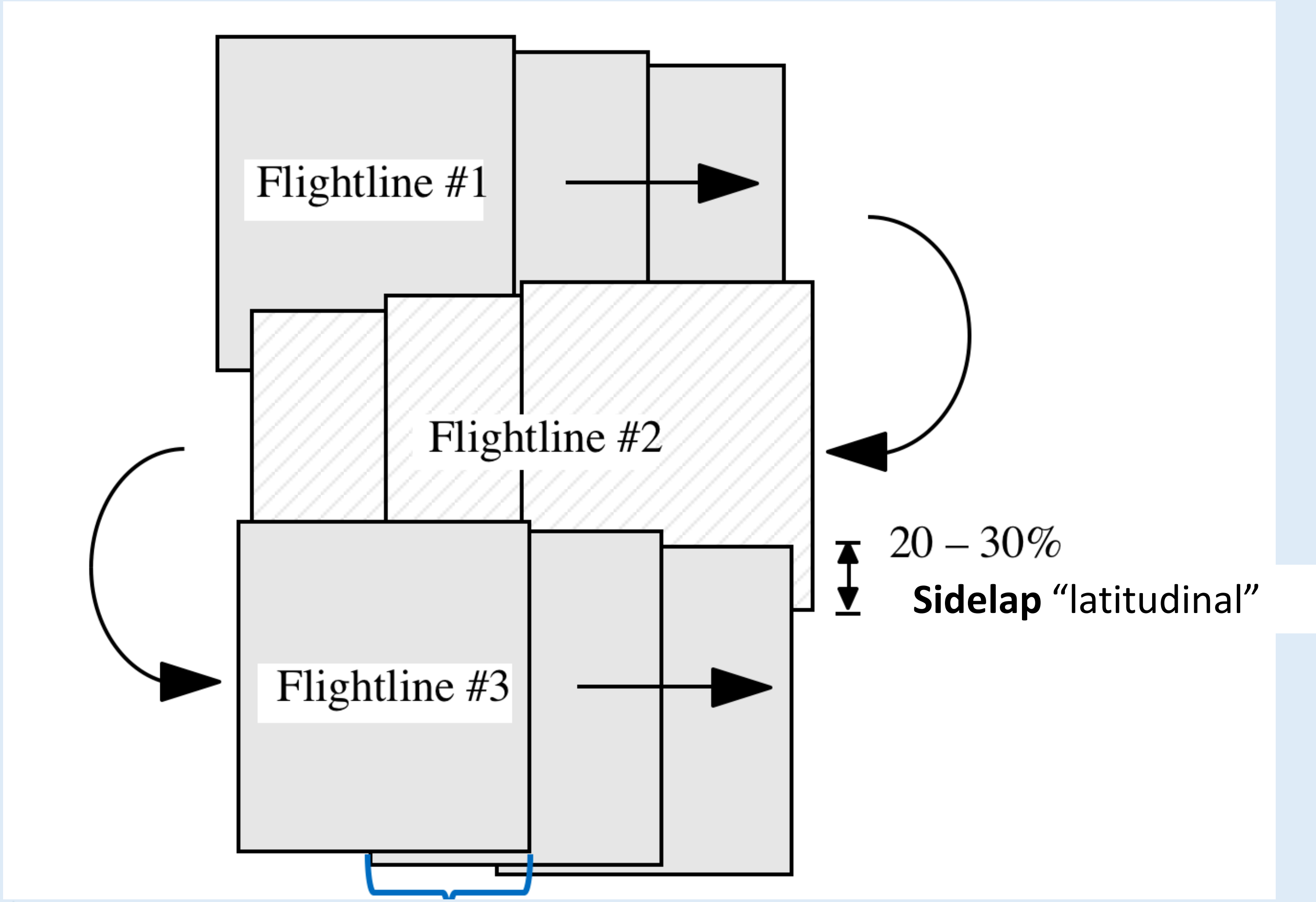
Figure 10



Stereoscopic overlap area > 50% is often necessary

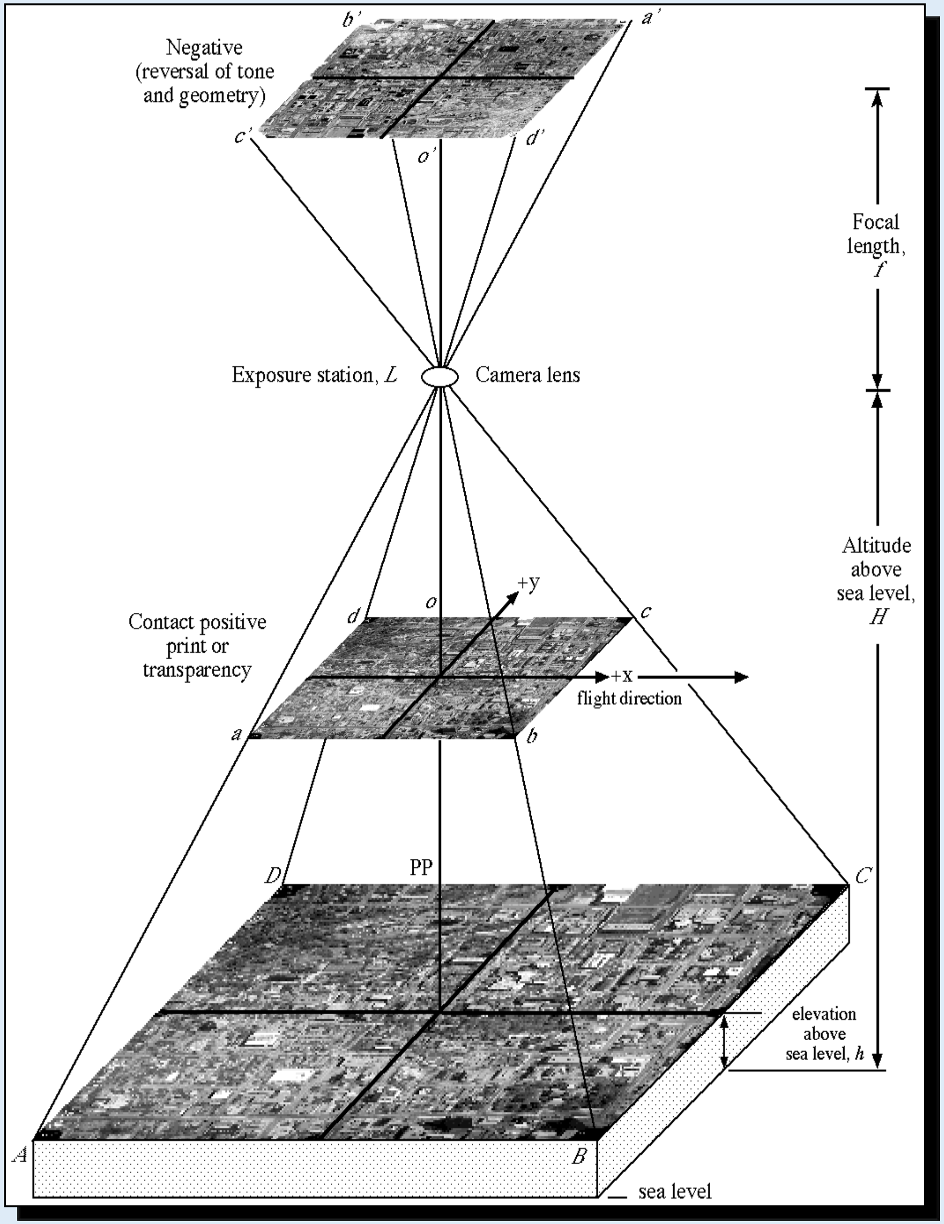
Image source: Jensen, 2000

Block of traditional aerial photos



Endlap “longitudinal”

Geometry of vertical aerial photo



O = principal point
What is it? intersection of optical axis and film plane

PP = ground principal point; point where optical axis intersects the terrain

Image source: Jensen, 2000

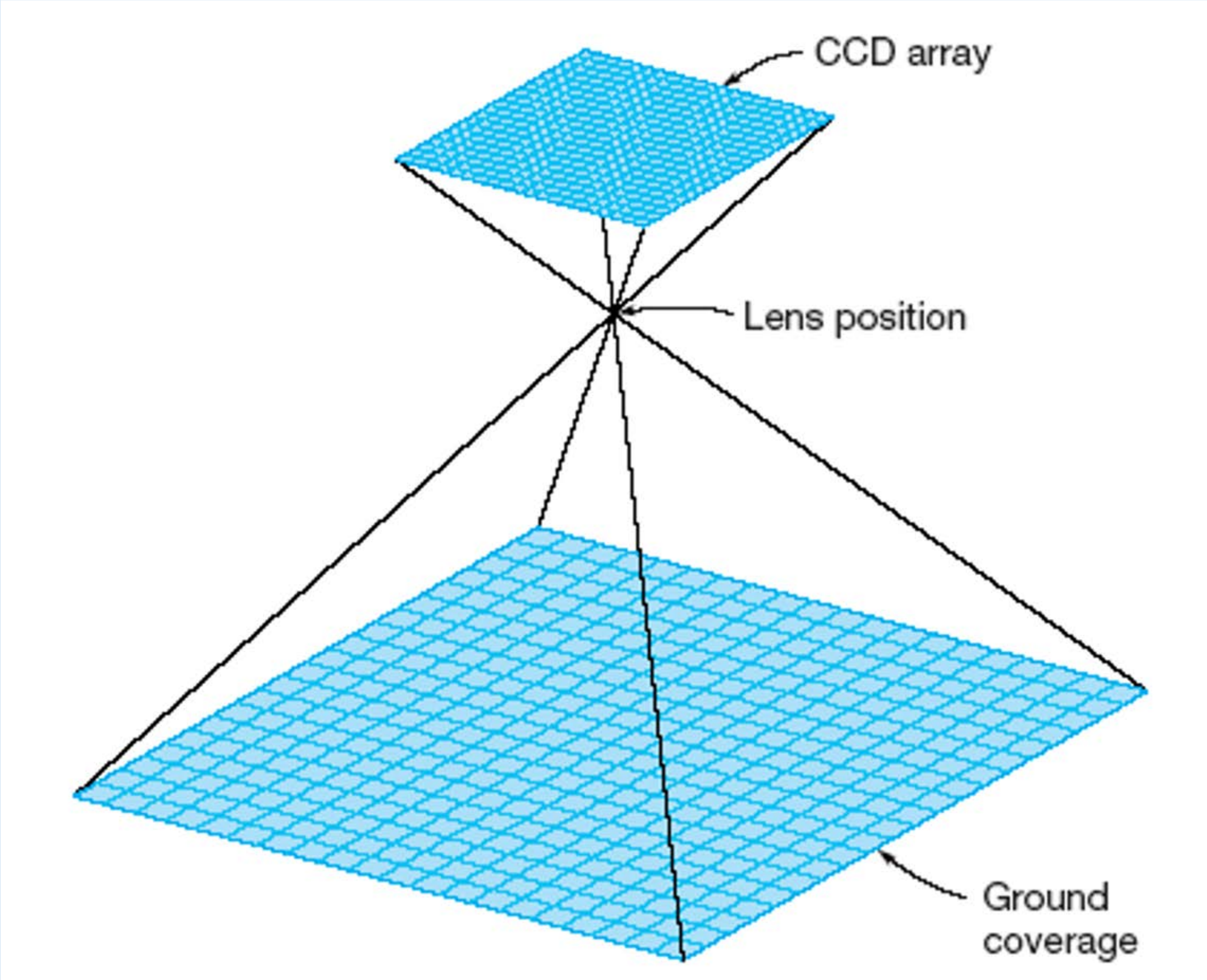
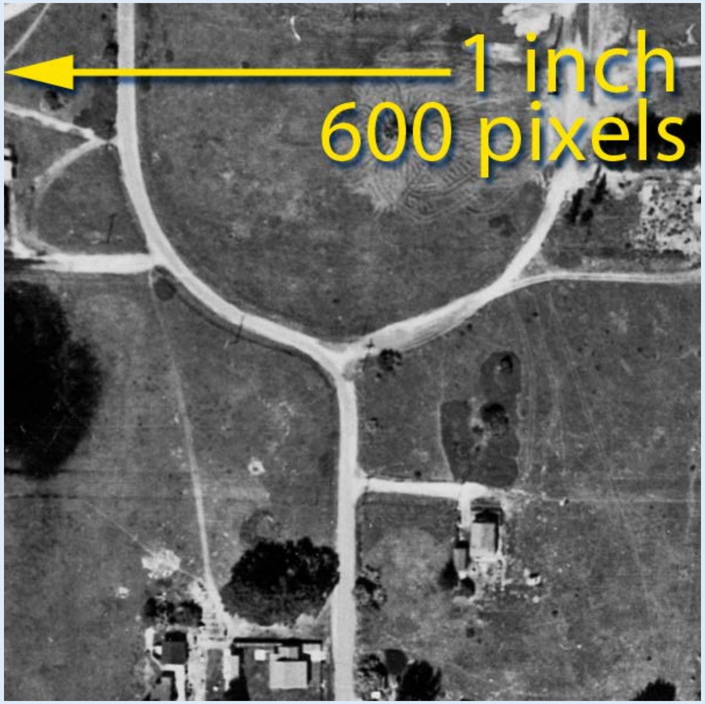

CCD array
Lens position
Ground
coverage

Photo Scale (S)

$$S = \text{photo scale} = \frac{\text{photo distance}}{\text{ground distance}} = \frac{d}{D}$$



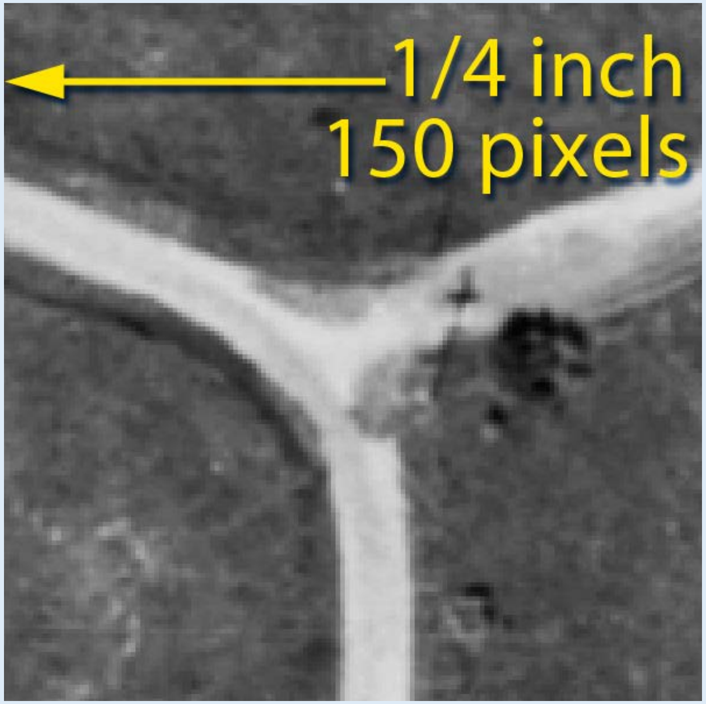


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Image source: UCSB library web link

Example

$$S = \text{photo scale} = \frac{\text{photo distance}}{\text{ground distance}} = \frac{d}{D}$$

Assume that two road intersections shown on a photograph can be located on a 1:25,000 scale topographic map. The measured distance between the intersections is 47.2 mm on the map and 94.3 mm on the photograph. (*a*) What is the scale of the photograph? (*b*) At that scale, what is the length of a fence line that measures 42.9 mm on the photograph?

Solution

(a) The ground distance between the intersections is determined from the map scale as

$$0.0472 \text{ m} \times \frac{25{,}000}{1} = 1180 \text{ m}$$

By direct ratio, the photo scale is

$$S = \frac{0.0943 \text{ m}}{1180 \text{ m}} = \frac{1}{12{,}513} \text{ or } 1:12{,}500$$

from Lillesand, et al, 2007

Scale Relation to Focal Length and Flying Height

$$\text{Scale} = \frac{\text{camera focal length}}{\text{flying height above terrain}} = \frac{f}{H'}$$

H' = flying height above datum (H) – terrain height (h)

$$S = \frac{f}{H - h}$$

**Most important thing to observe is that photo scale is a function of terrain elevation h. Hence, only photographs over flat level terrain have uniform scale; else varying elevations cause continuous variations in a photo's scale*

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Example

$$S = \frac{f}{H - h}$$

Assume that a vertical photograph was taken at a flying height of 5000 m above sea level using a camera with a 152-mm-focal-length lens. (*a*) Determine the photo scale at points *A* and *B*, which lie at elevations of 1200 and 1960 m. (*b*) What ground distance corresponds to a 20.1-mm photo distance measured at each of these elevations?

Solution?

(*a*)

$$S_A = \frac{f}{H - h_A} = \frac{0.152 \text{ m}}{5000 \text{ m} - 1200 \text{ m}} = \frac{1}{25{,}000} \quad \text{or } 1{:}25{,}000$$

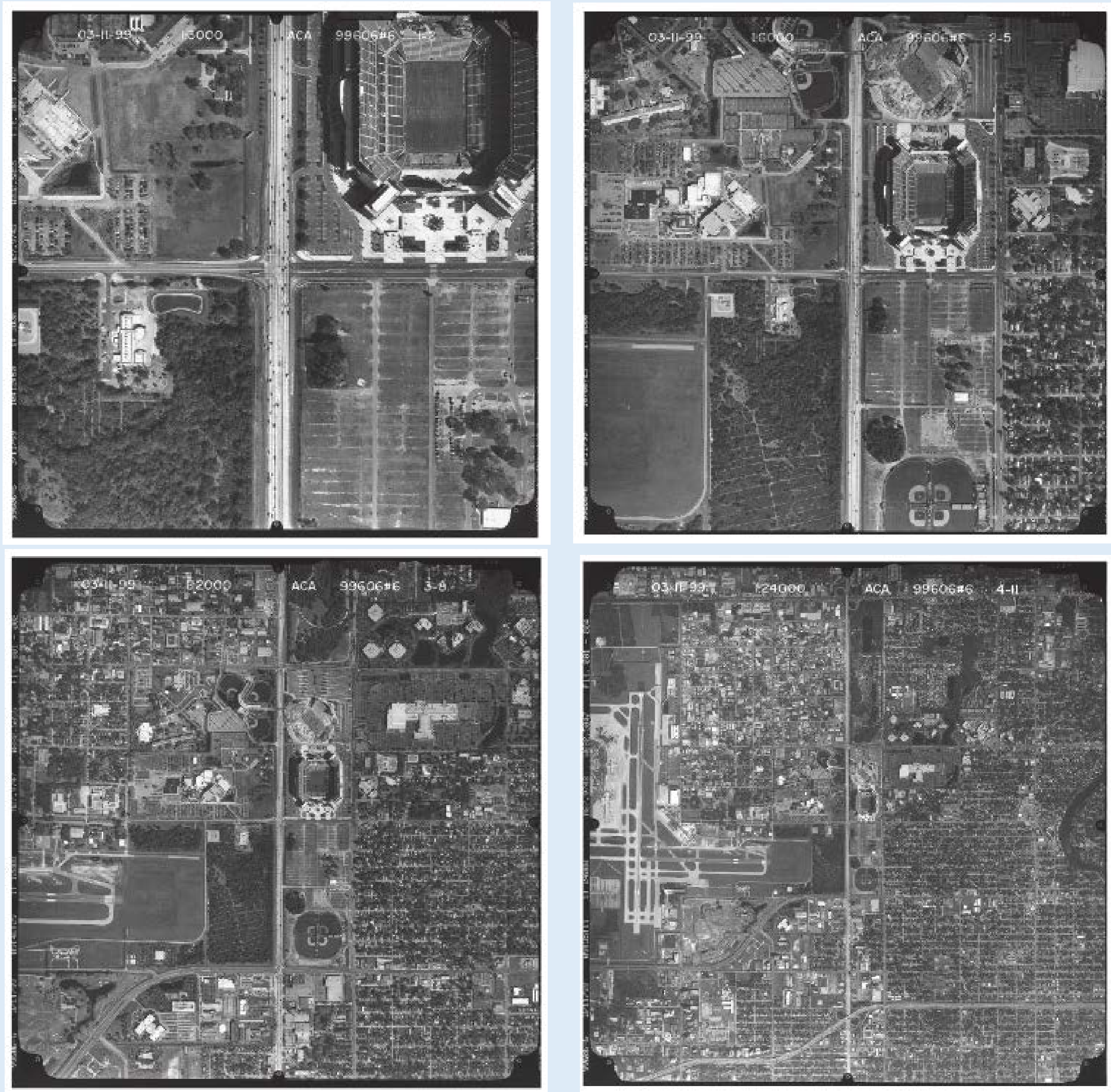
$$S_B = \frac{f}{H - h_B} = \frac{0.152 \text{ m}}{5000 \text{ m} - 1960 \text{ m}} = \frac{1}{20{,}000} \quad \text{or } 1{:}20{,}000$$

(*b*) The ground distance corresponding to a 20.1-mm photo distance is

$$D_A = \frac{d}{S_A} = 0.0201 \text{ m} \div \frac{1}{25{,}000} = 502.5 \text{ m} \quad \text{or} \quad 502 \text{ m}$$

$$D_B = \frac{d}{S_B} = 0.0201 \text{ m} \div \frac{1}{20{,}000} = 402 \text{ m}$$

from Lillesand, et al, 2007



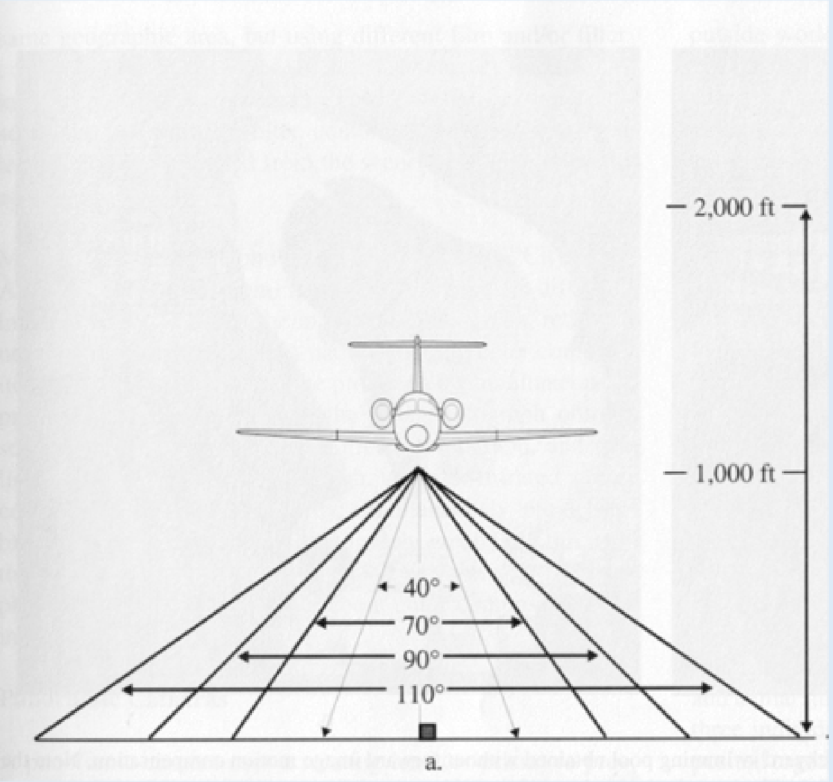
Impacts of decreasing scale (higher flying height)

Relationship between aircraft altitude and ground coverage – two ways to change FOV

a) Changing the focal length of the camera lens will alter the angular coverage of the system

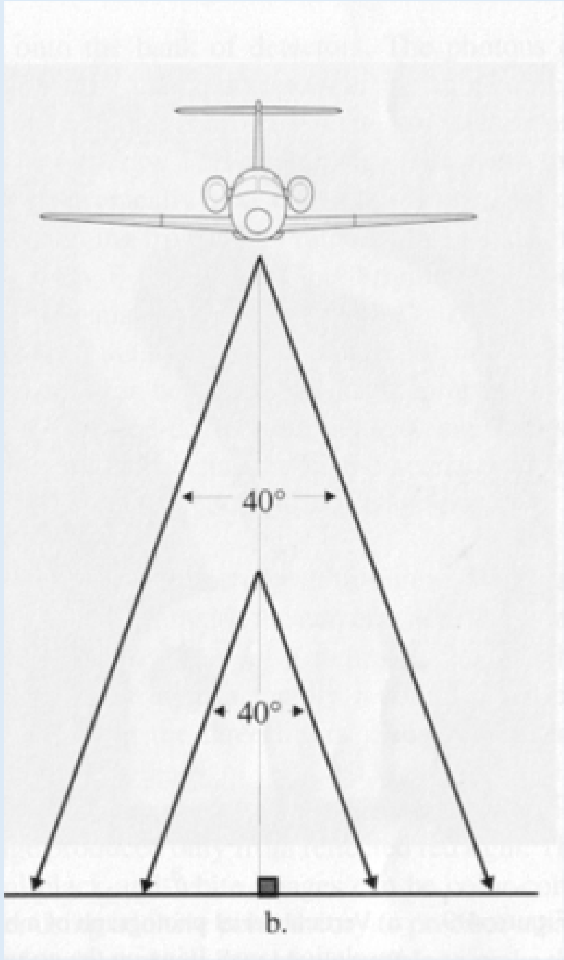
increase focal length→decrease angular coverage

b) As the angular cover increases (focal length decreases), the FOV increases



Relationship between aircraft altitude and ground coverage – two ways to change FOV

Changing the aircraft altitude will alter the ground coverage of the system



f =152.4 mm
H’ = 18,300m
S=1:210000

Image source: Jensen, 2000

$f = 152.4$ mm
$H' = 915$ m
$S = 1:10500$

Image source:
Jensen, 2000

Measurements from non-corrected Aerial Photo

- Due to scale variations from terrain height and tilt of aircraft, area measurements can be inaccurate
- However, simple scales over low varying relief terrain can be used to measure area
- Points on a GIS map are projected to their true relative planimetric (horizontal) positions
  - **Orthographic projection**
- Points on a photo taken over varying terrain are displaced from their true "map positions"
  - **Perspective projection**

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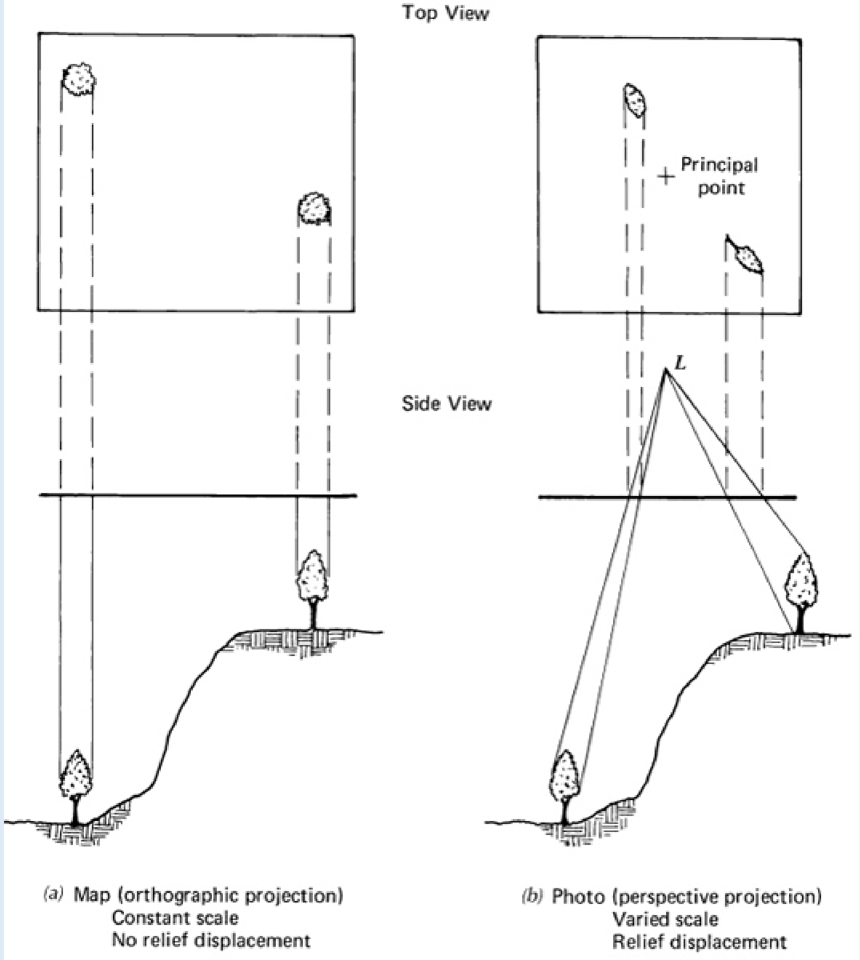
Orthographic vs. Perspective Projection



What effect does this have on objects in photo?

Relief Displacement

- **vertical features lean away from center of photo**

Columbia, SC
Original scale = 1:6,000
Focal length = 6” (152.82 mm)
March 30, 1993

Image source: Jensen, 2000

Minimal displacement of towers because they are located close to photo’s principal point

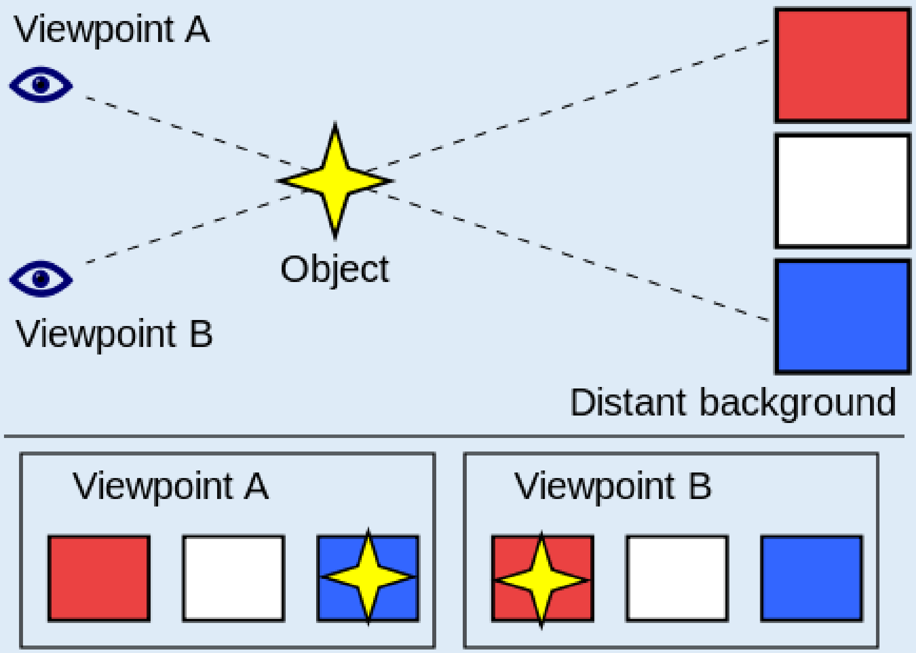
Lots of displacement of towers due to radial nature of relief displacement; ***it increases with increase in radial distance from principal point of a photo***

Correcting for Relief Displacement

- Terrain (not just objects) also shows relief displacement due to height variation
- Quantification of relief displacement can be used to correct image positions of terrain points in a photo
- Through photogrammetric process, photos cane be "**orthorectified**" such that features are shown at their true planimetric position.
  - More about this later!

What is Parallax?

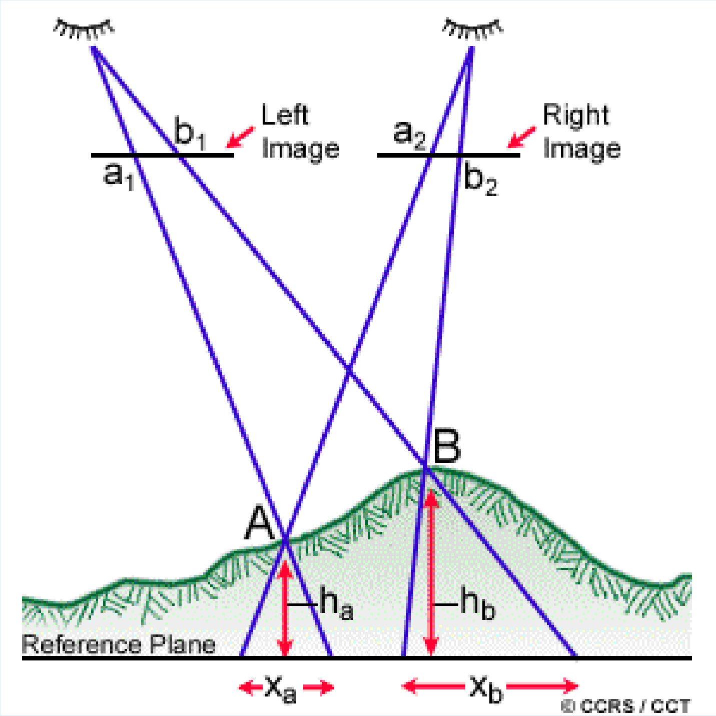
- apparent change in relative positions of stationary objects caused by a change in viewing position



When viewed from "Viewpoint A", the object appears to be in front of the blue square. From "Viewpoint B", the object *appears* to have moved in front of the red square.

Importance of parallax in photogrammetry?

- Parallax at any point is directly related to elevation of that point.
- Parallax is greater for higher points than low points
- **Stereoscopic parallax** is caused by taking photographs of the same object but from different points of observation.



Graphic from http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/stereosc/chap4/

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Stereo-photogrammetry

- Most photogrammetric operations use stereo-pairs or many pairs of overlapping photos (***multi-view stereo-photogrammetry***)
- Principles of parallax and relief displacement are exploited to measure distances and elevations on ground from pairs of photos
- Similar to how our eyes work!

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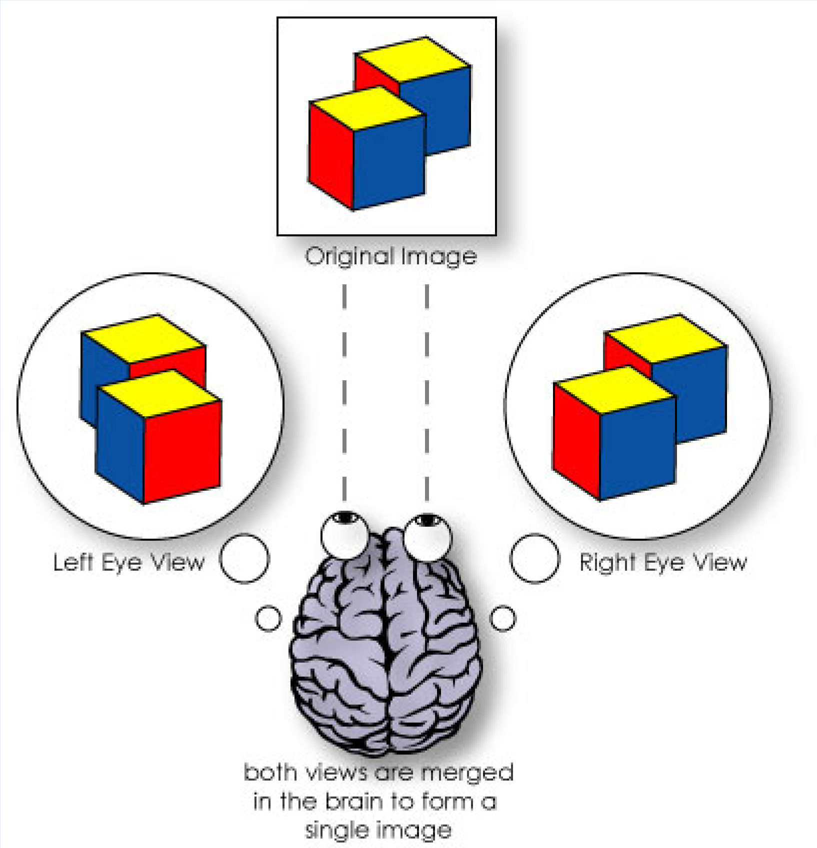
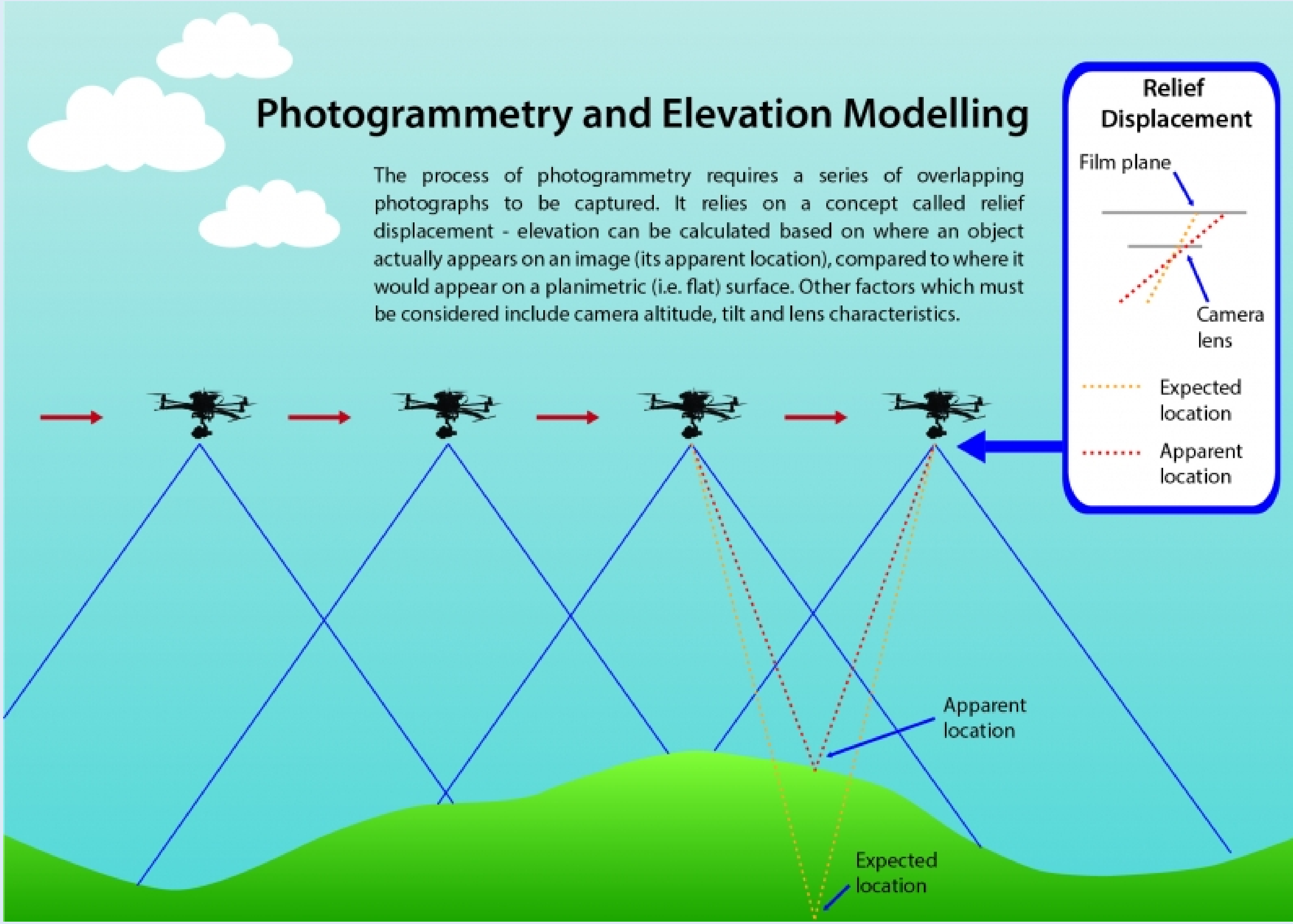

Original Image
Left Eye View
Right Eye View
both views are merged
in the brain to form a
single image



Source: http://www.remoteaerialsurveys.co.uk/photogrammetry