Lecture 5

Principles of Aerial Photography, Aerial Photography Scales and Measurements

Stereoscopic Vision

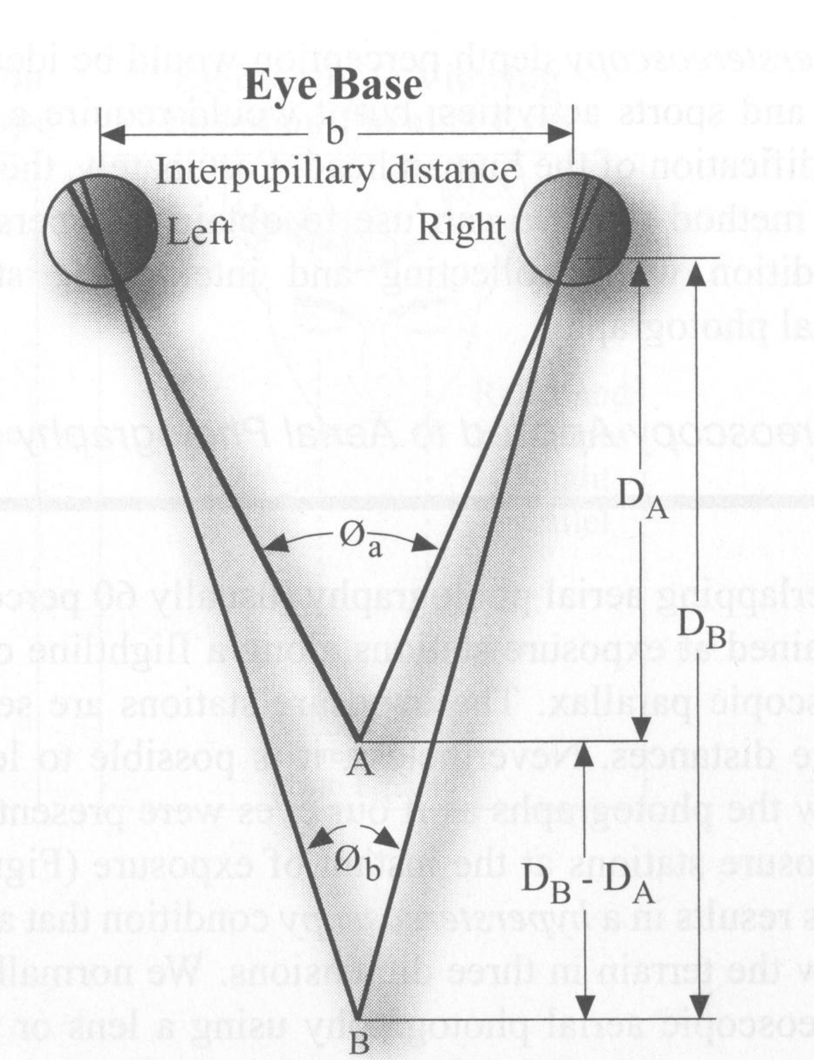
- When focusing with two eyes on an object, a *parallactic* angle is formed.

- The closer the object is to the eyes the wider the parallactic angle is.

- The brain has learned to compare distances D_A and D_B by using respective parallactic angles $Ø_a$ and $Ø_b$ and concludes that B is farther away than A.

- Looking out farther away makes differences in parallactic angles more and more subtle, to the point of them being undistinguishable to an average human adult at around 1000 m.

- The eye base would need to stretch out to a meter or hundreds of meters, creating *hyperstereoscopy.*



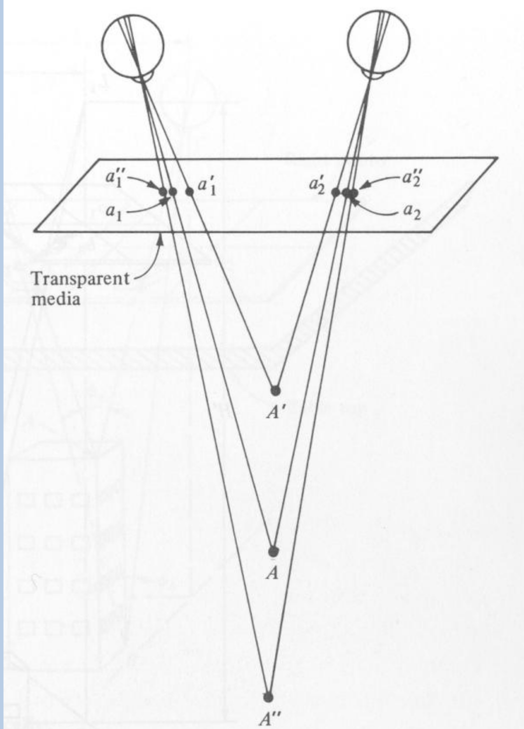
Source: Jensen (2007).

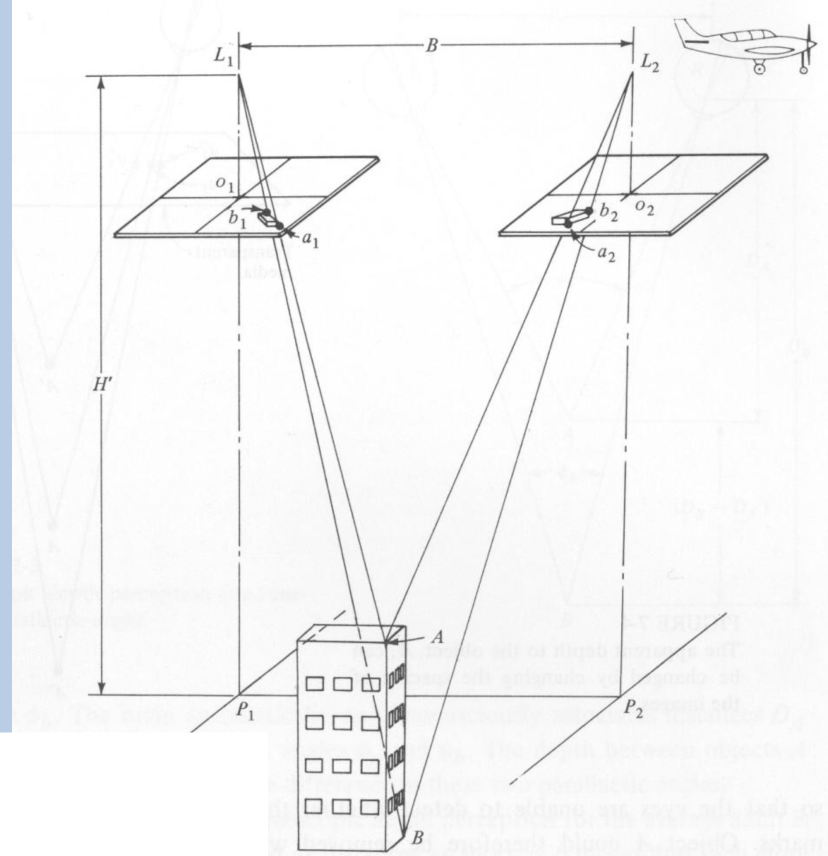
- Obviously, biologically this is impossible, but can be substituted by using a model, i.e. stereo (aerial) photos.

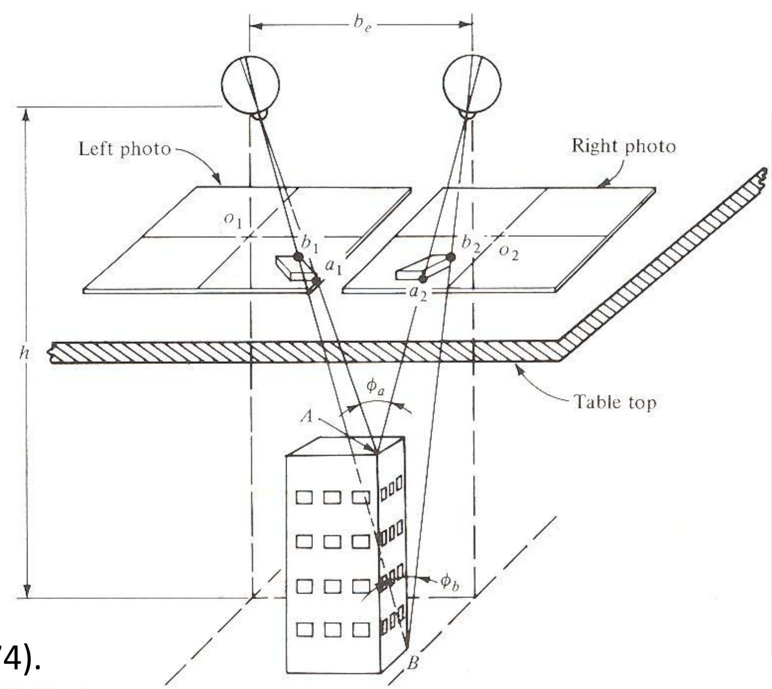
• When viewing stereo photos in stereo, parallactic angles are formed between the eyes and the points on the viewed images of objects.

• Stereo photos act as a transparent media introduced between the eyes and the observed objects.

• The brain observes the multitude of points on the two stereo photos and forms a three dimensional *stereomodel*.



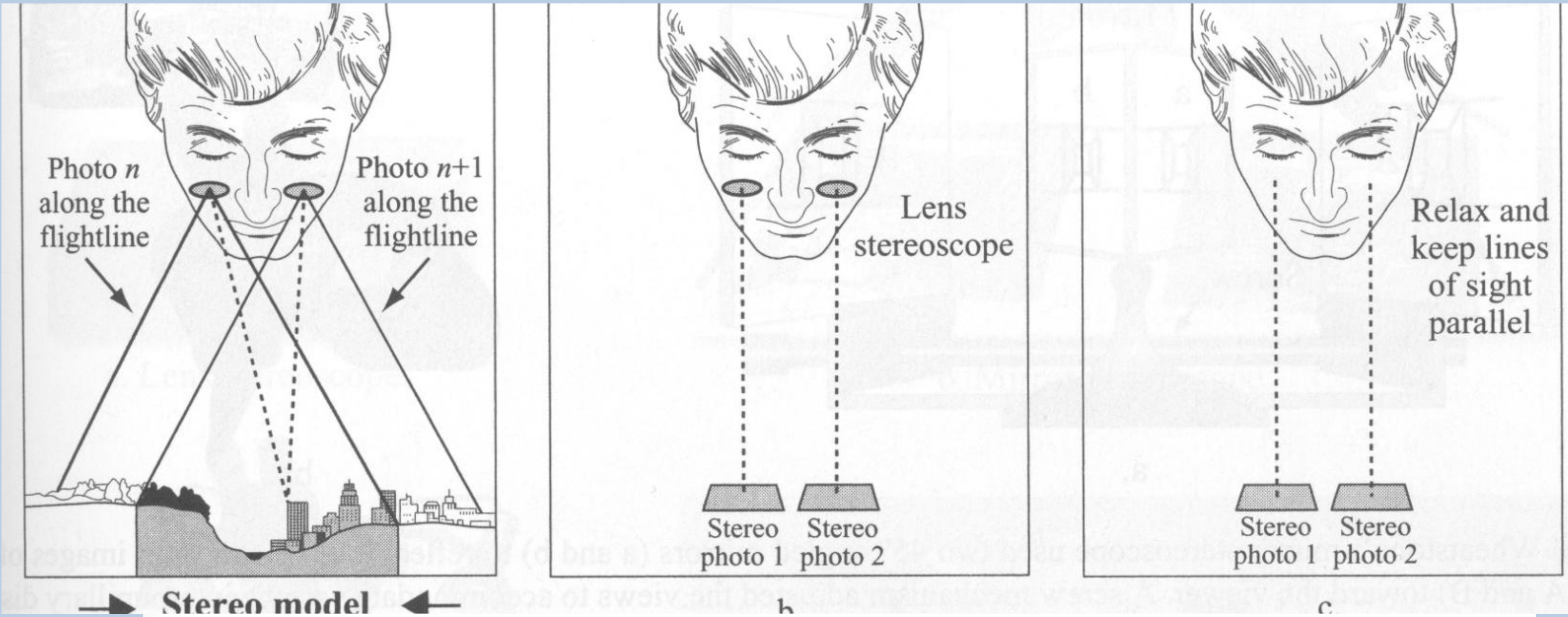


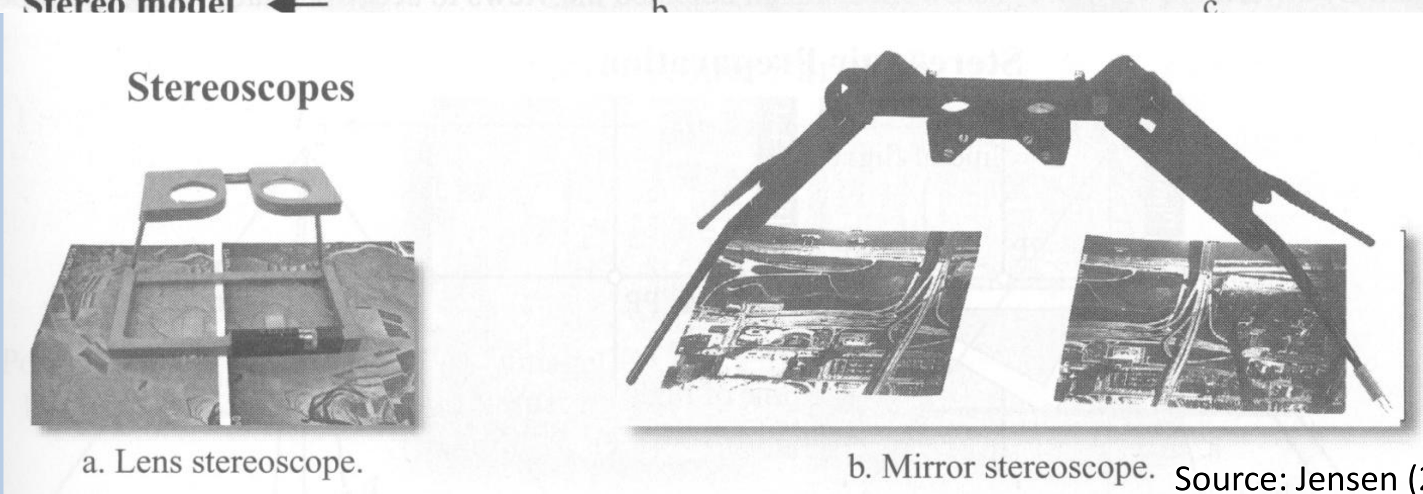


Source: Wolf (1974).

• A pair of two stereo photos is called a *stereopair.*
• A stereopair implies that the two photos can be viewed in stereo, meaning that they, partially or completely, show the same area – there is an overlap in the area shown.

• Once a stereopair is created what is left is to place the stereo photos/images in a proper position and force the left eye to look at the left photo/image only and the right eye to look at the right photo/image only.
• This visual separation is achieved through different means.



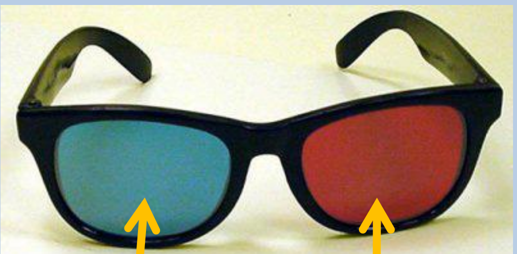


Source: Jensen (2007).

a.k.a. pocket sterescope

Anaglyph Glasses

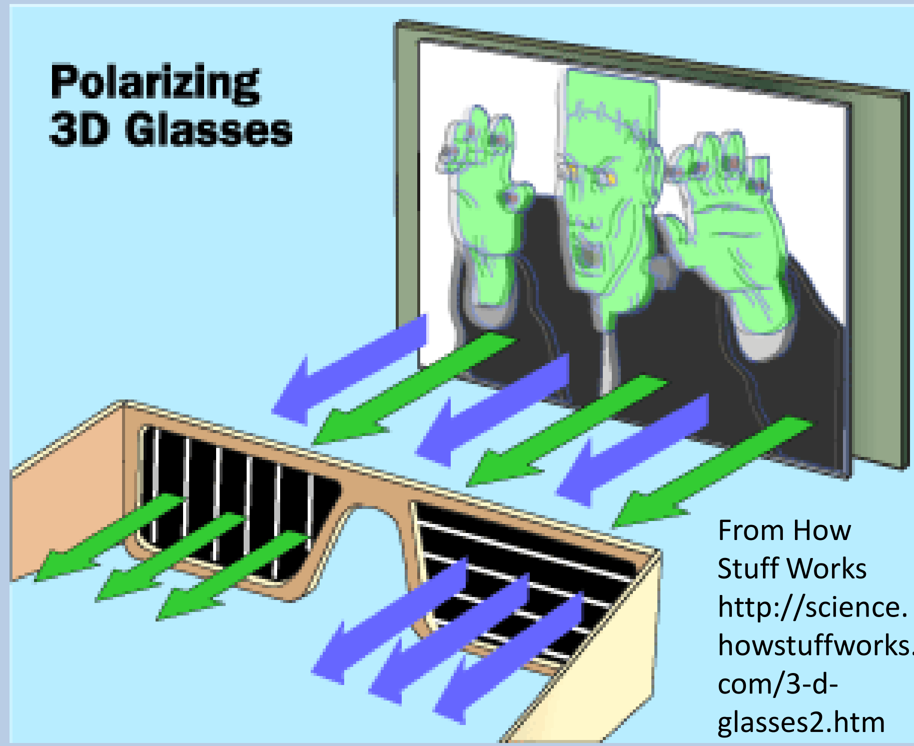
Anaglyph glasses



cyan red

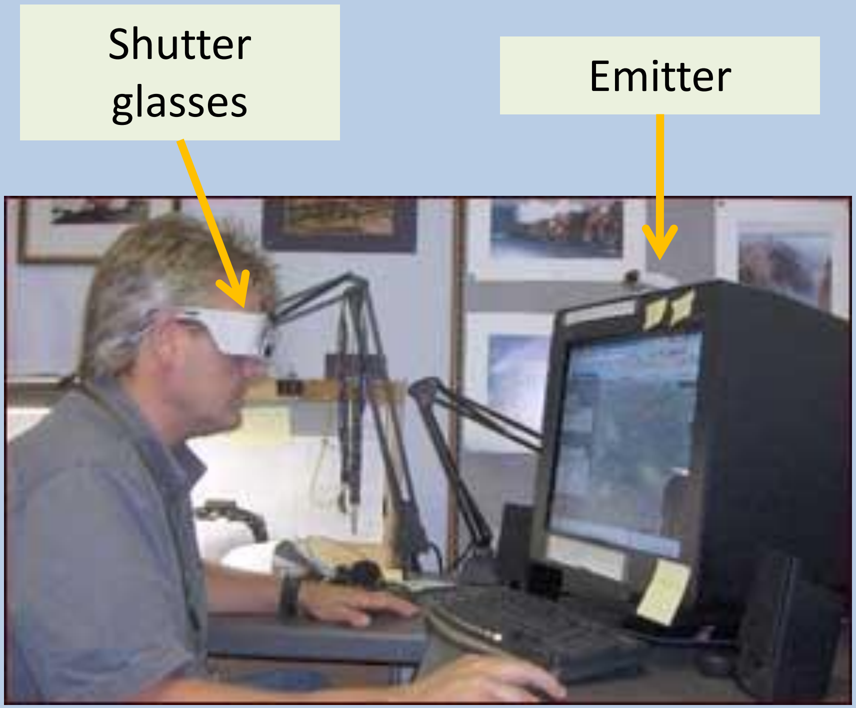
• The left image (from the viewer's perspective) is displayed in red and the right in cyan. The left eye, red, filter on the glasses, absorbs cyan and lets through red and the right eye, cyan, filter, absorbs red and lets through only cyan.

Polarized Glasses



From How Stuff Works http://science.howstuffworks.com/3-d-glasses2.htm

Computer Generated Stereo Display With Shutter Glasses



Picture from http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/199556.html

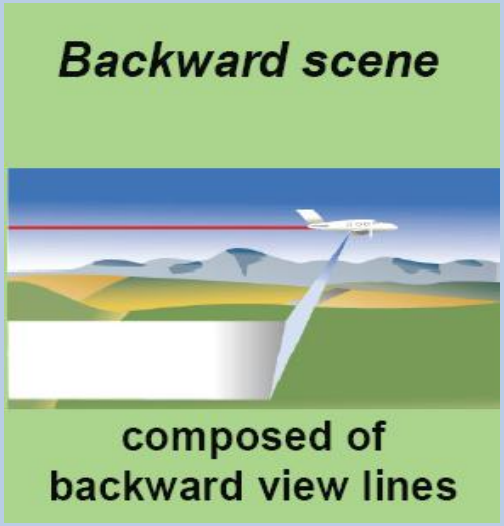
- The computer, through the graphics card, shows the left and the right image on the screen and alternatively turns them on and off ~60 times/sec (Hz) each.

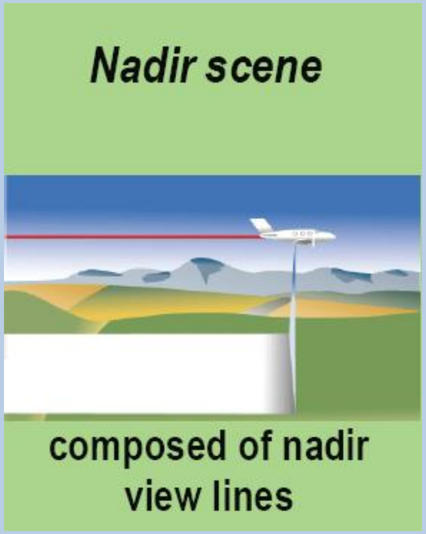
- The emitter is connected to the computer graphic card and syncs through infrared the shutter glasses with the image displays - the left eyepiece on the glasses opens up when the left image is displayed and closes when the right image is displayed; the opposite applies to the right eyepiece.

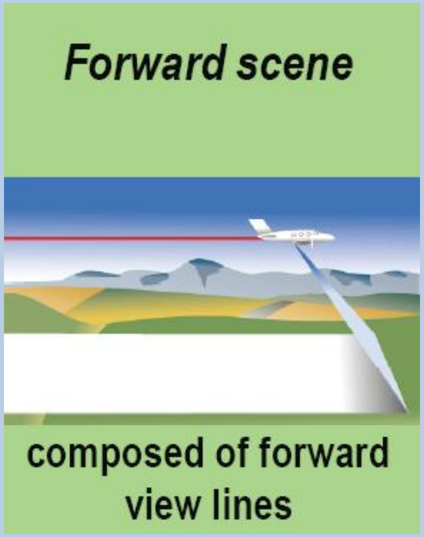
Creation of Stereo Images with ADS40

• ADS40 is a camera with a linear scanner, which means that it creates a seamless image strip.

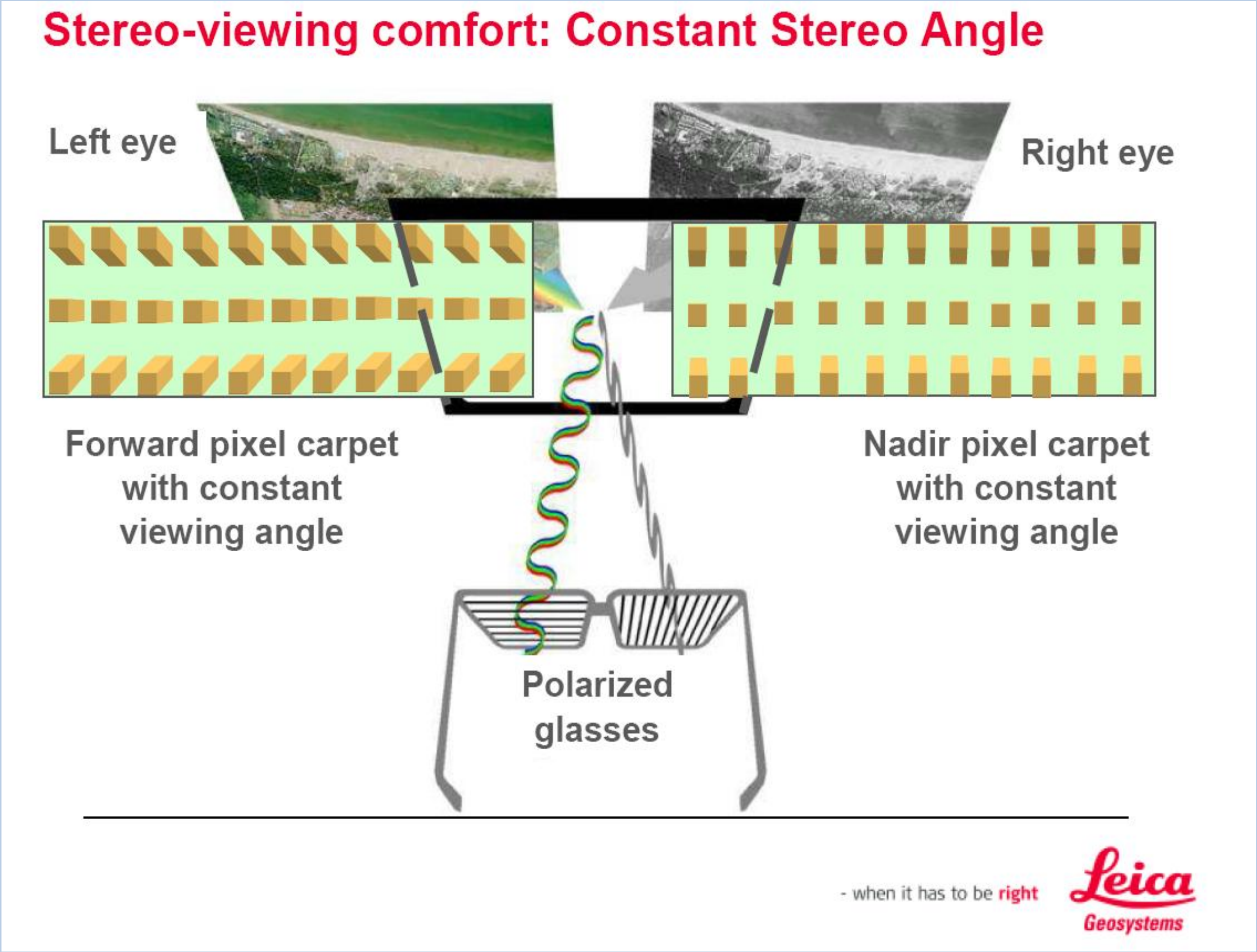
• Images are taken from three different angles, backward, nadir, and forward.







Stereo Viewing of a Seamless Image Strip by ADS40

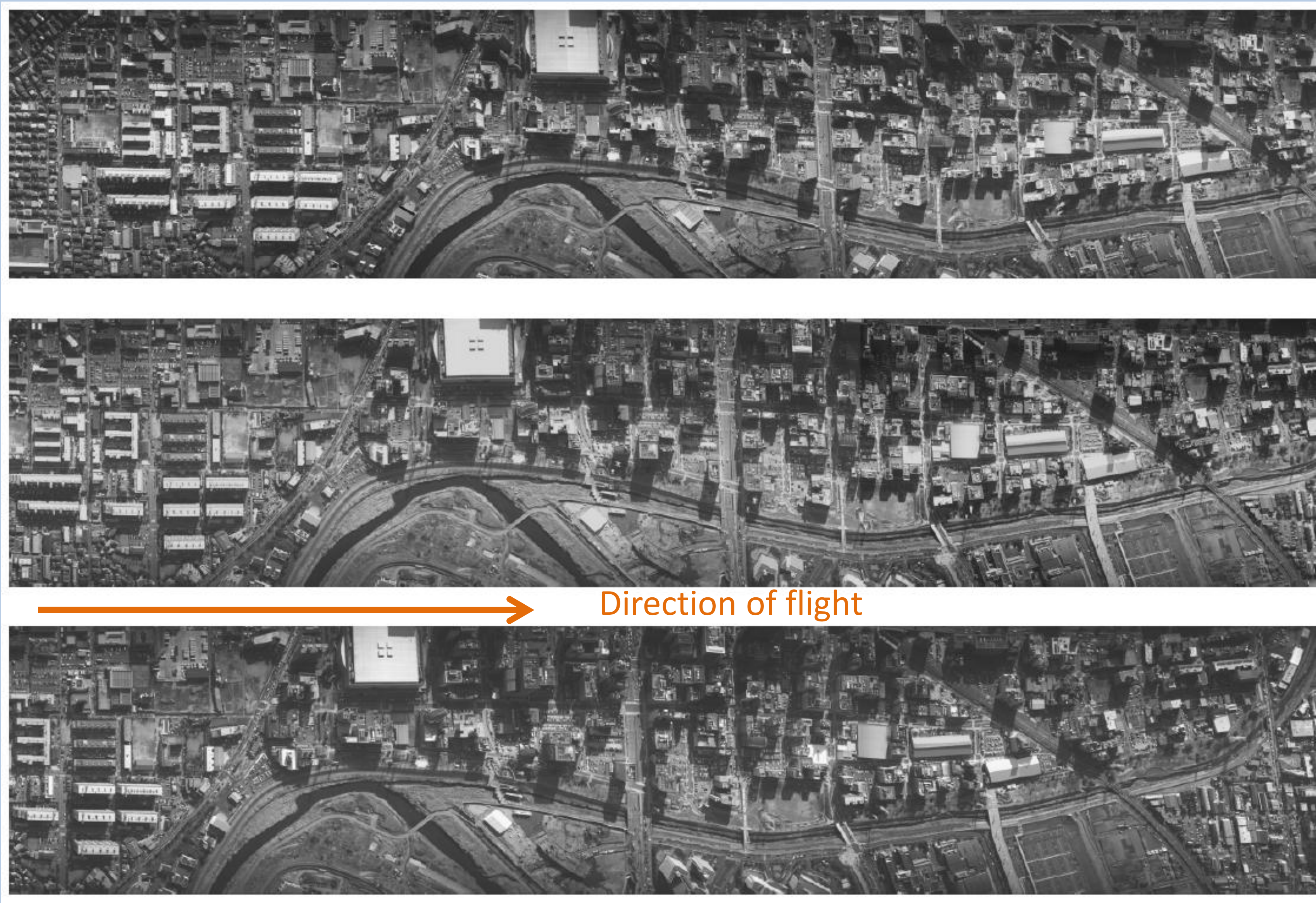


Seamless Image Strip Triplet (Forward, Nadir, and Backward View)

Backward

Nadir

Forward

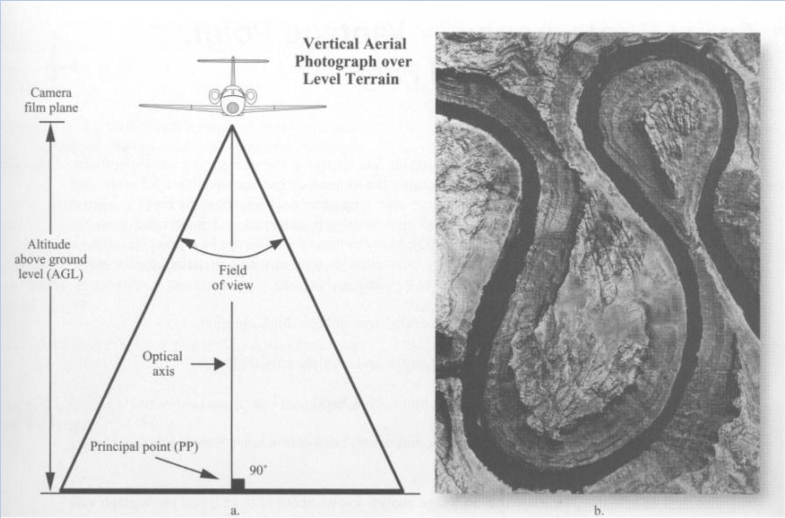


From:
http://www.photogrammetry.ethz.ch/summerschool/pdf/03_Gruen_Pateraki_DAC.pdf

Principles of Aerial Photography

Types of aerial images depending on the angle from which they were taken:

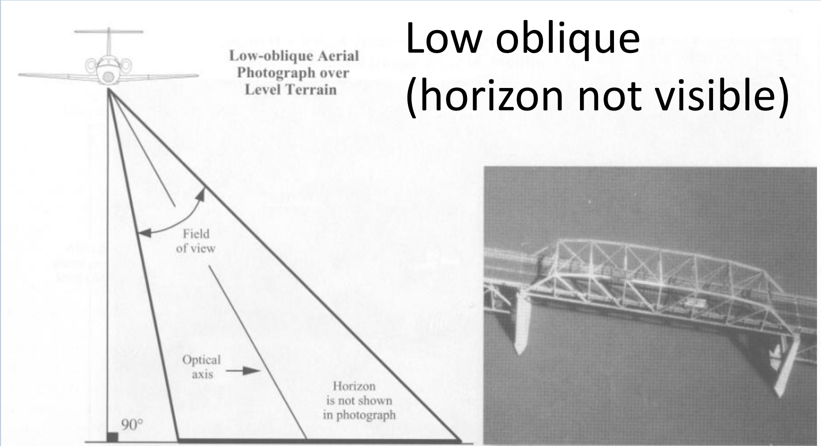
- Vertical – taken vertically straight down, perpendicular to the surface of the Earth.
  - A ‘*truly vertical’* photo, is rarely achieved ; often, photos intended to be vertical are taken at less then 1^{o} and rarely exceeding 3^{o} from vertical. These photos are called *near-vertical* or *tilted* photos and can, for many practical purposes, still be analyzed using ‘truly vertical’ photo principles.



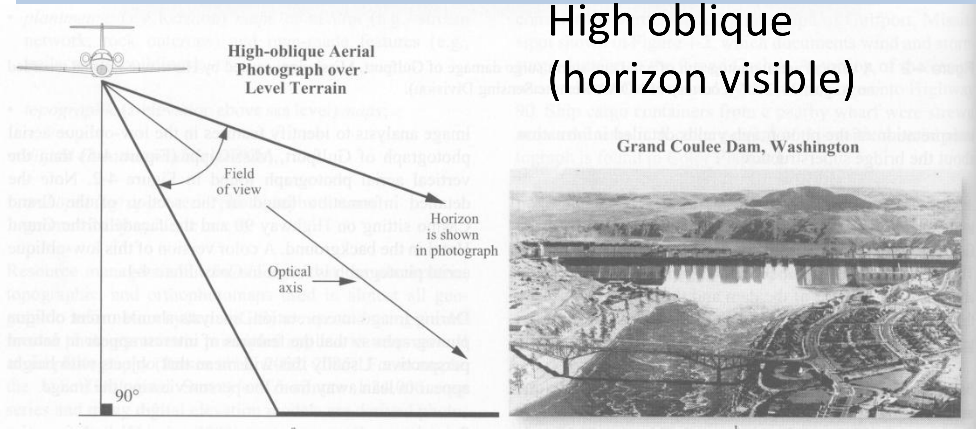
Source: Jensen (2007)

- Oblique – photos taken at > 3^{o} from vertical

Low oblique (horizon not visible)



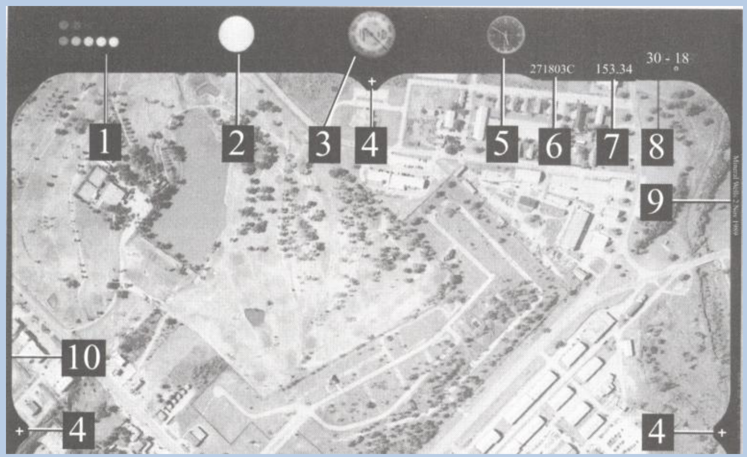
High oblique (horizon visible)



Principles of Aerial Photography

Types of aerial images depending on the storage of recorded electromagnetic waves:

- Analog
  - o Some photo and camera specs information is recorded on the photo (e.g., focal length) and camera orientation can be reconstructed by using the *fiducial marks* on the photo.



(see Lecture 3)

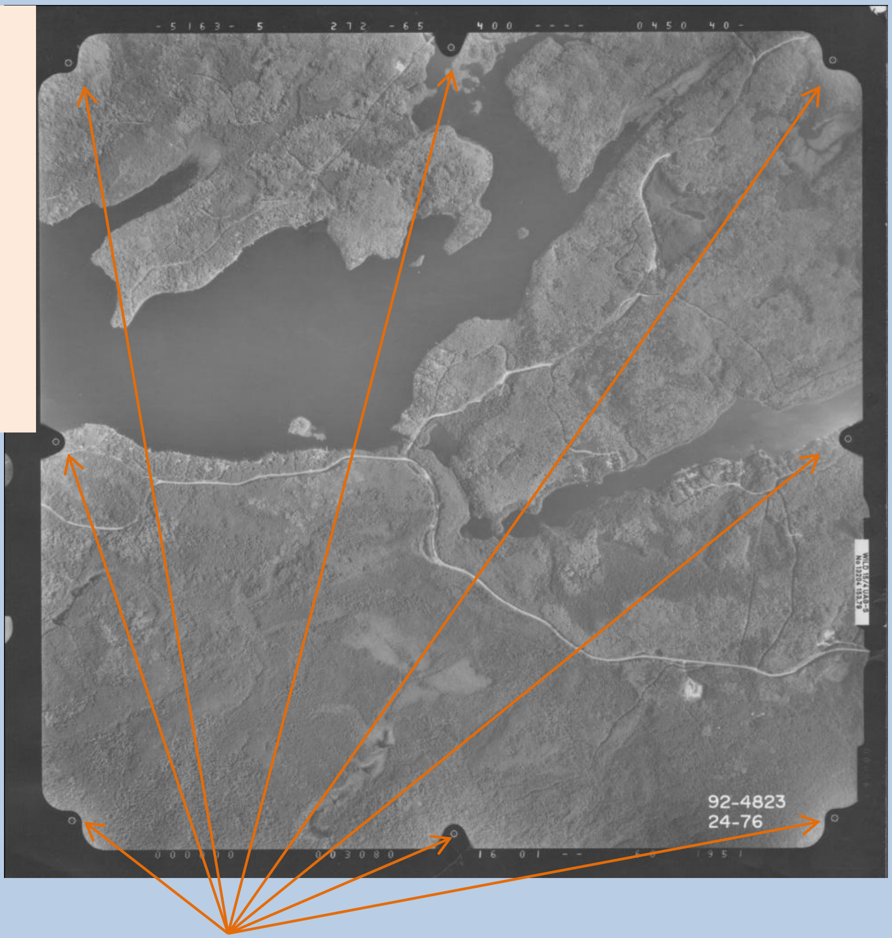
- Digital
  - o Camera specs and camera orientation information is recorded in a separate file.
  - o Inertial Measurement Unit (IMU) is used to provide the velocity and orientation of the aircraft.

Principles of Aerial Photography

Types of aerial images depending on their format:

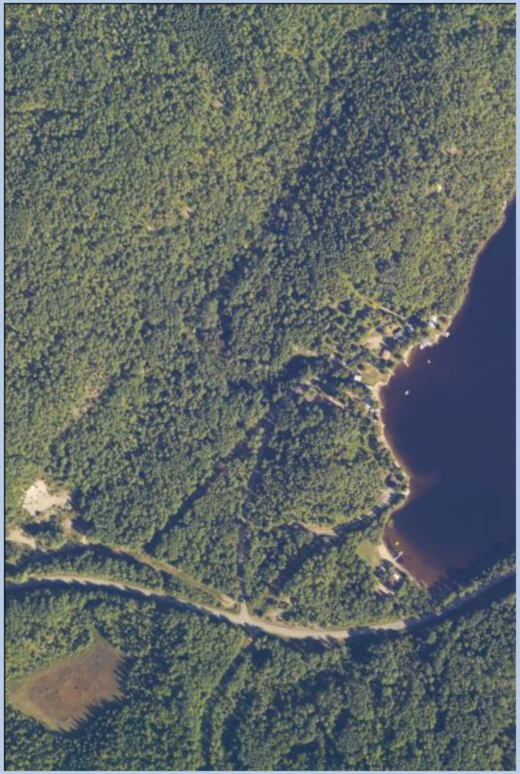
1. Singular, frame images (analog or digital).

Analog (a photo-print made from a chemical film)



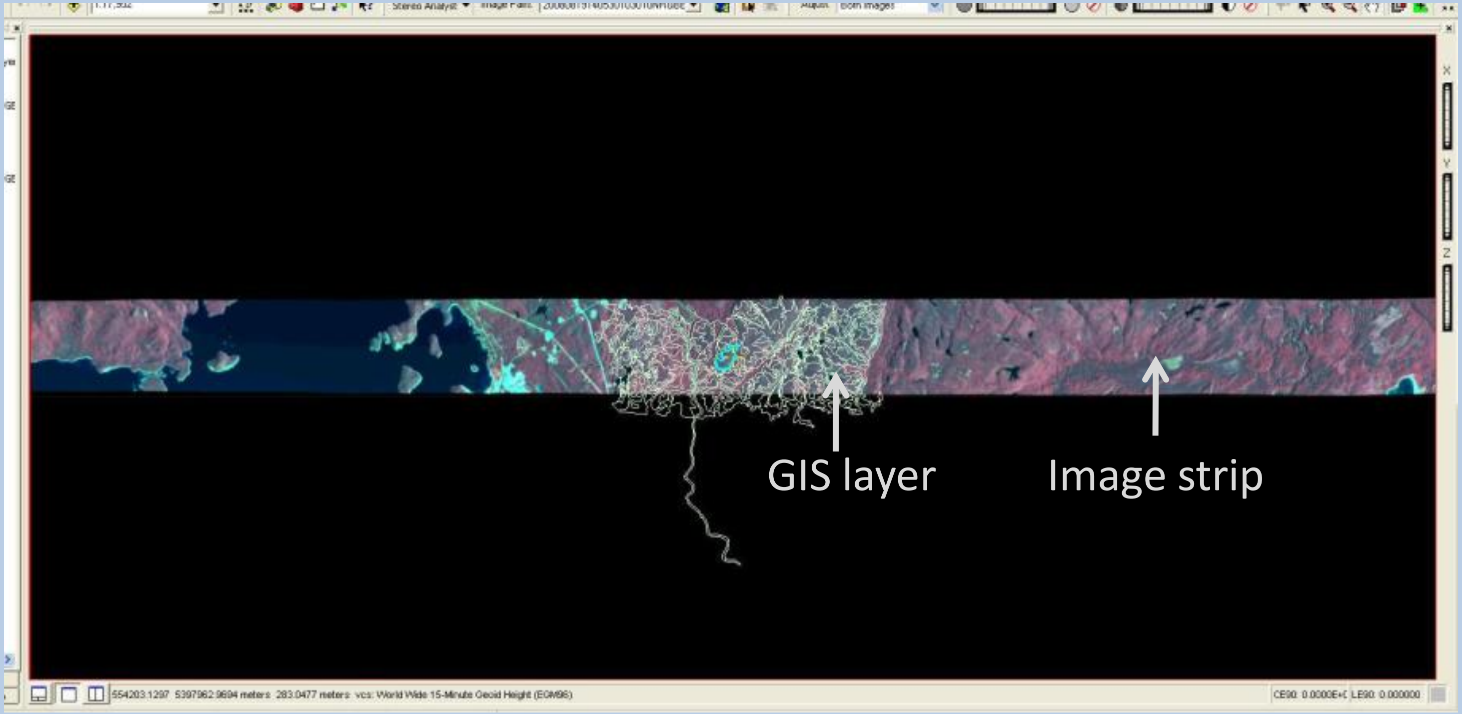
Fiducial Marks

Digital

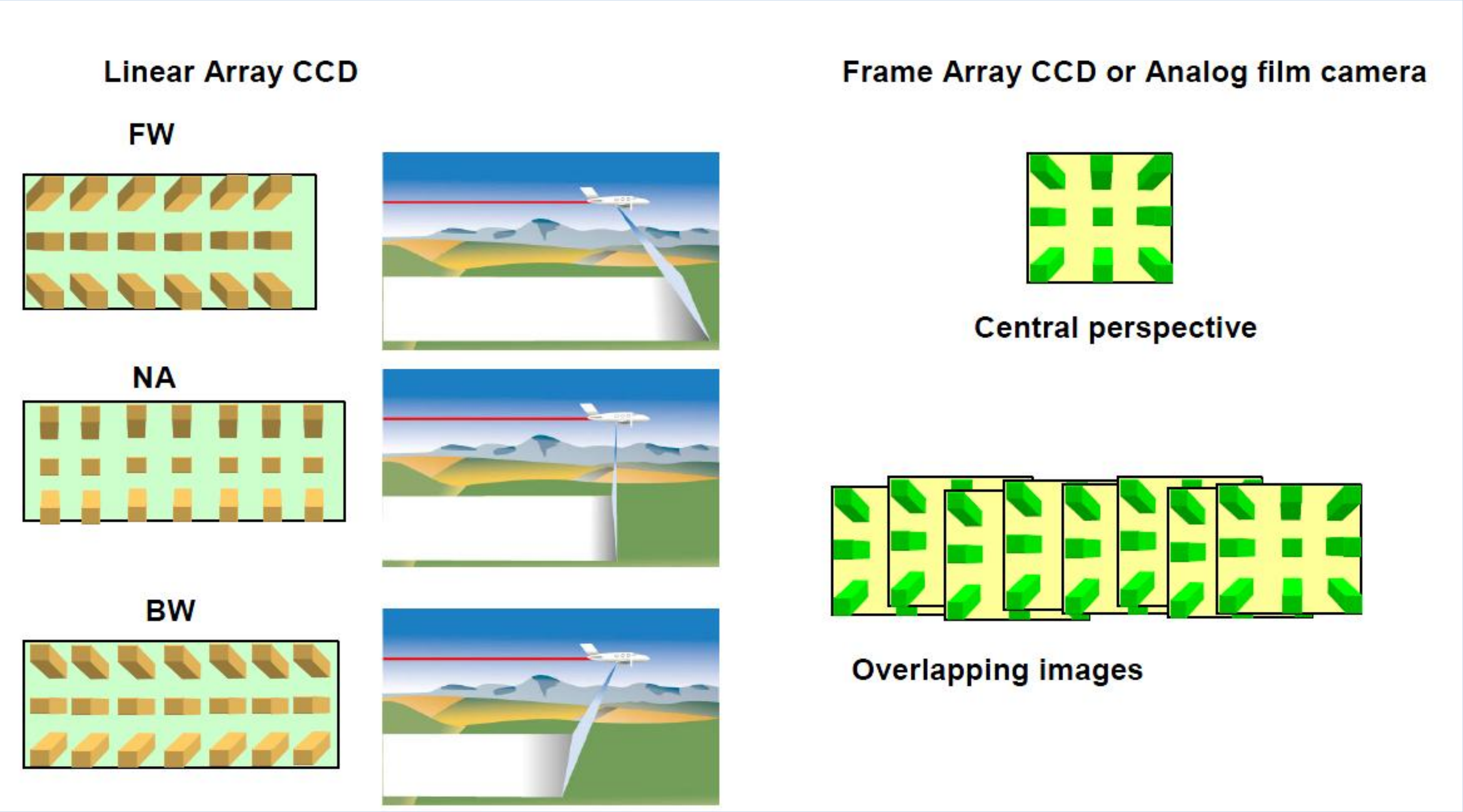


Types of aerial images depending on their format:

2. Seamless image strip (digital).

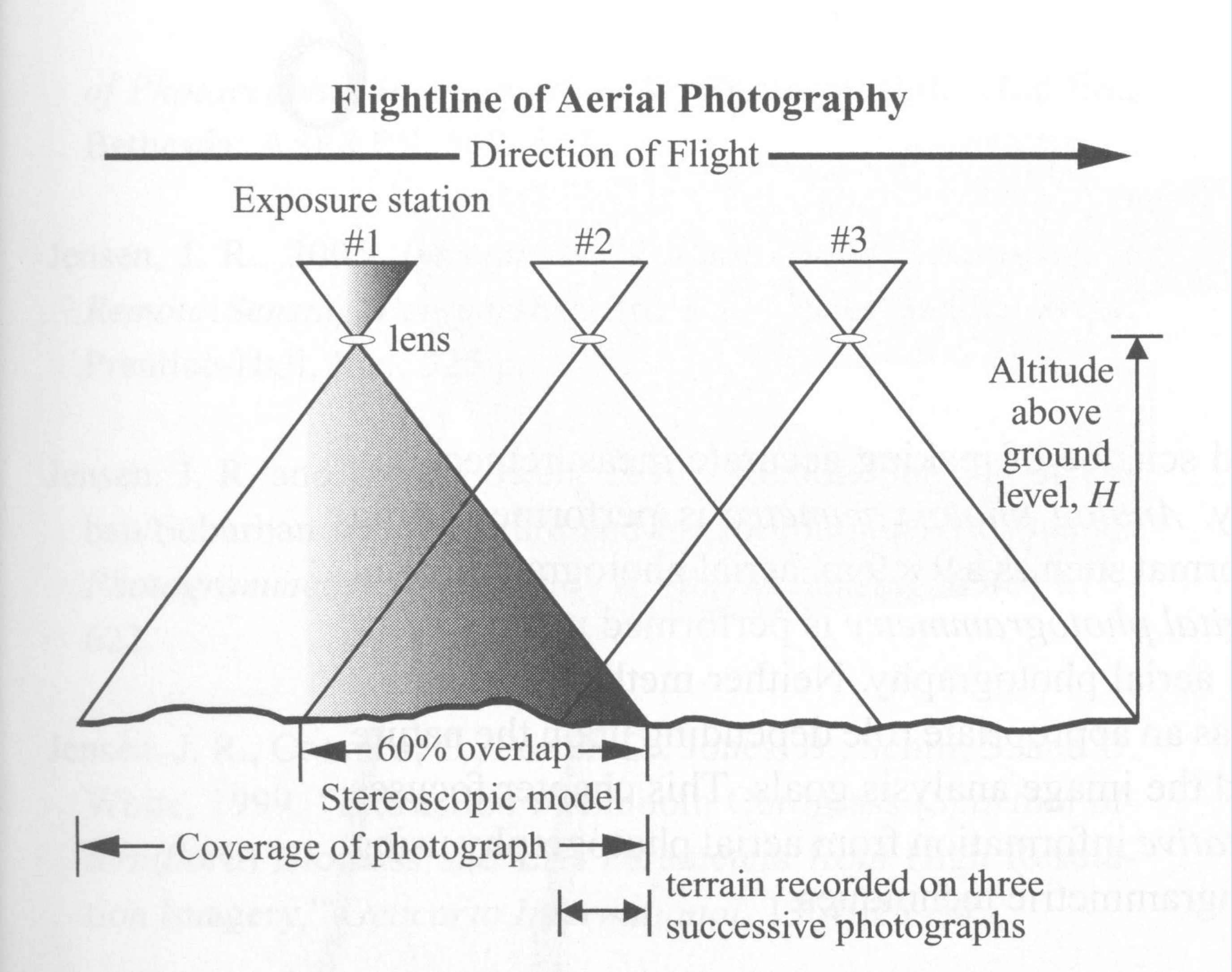


Linear arrays vs. Frame Photos



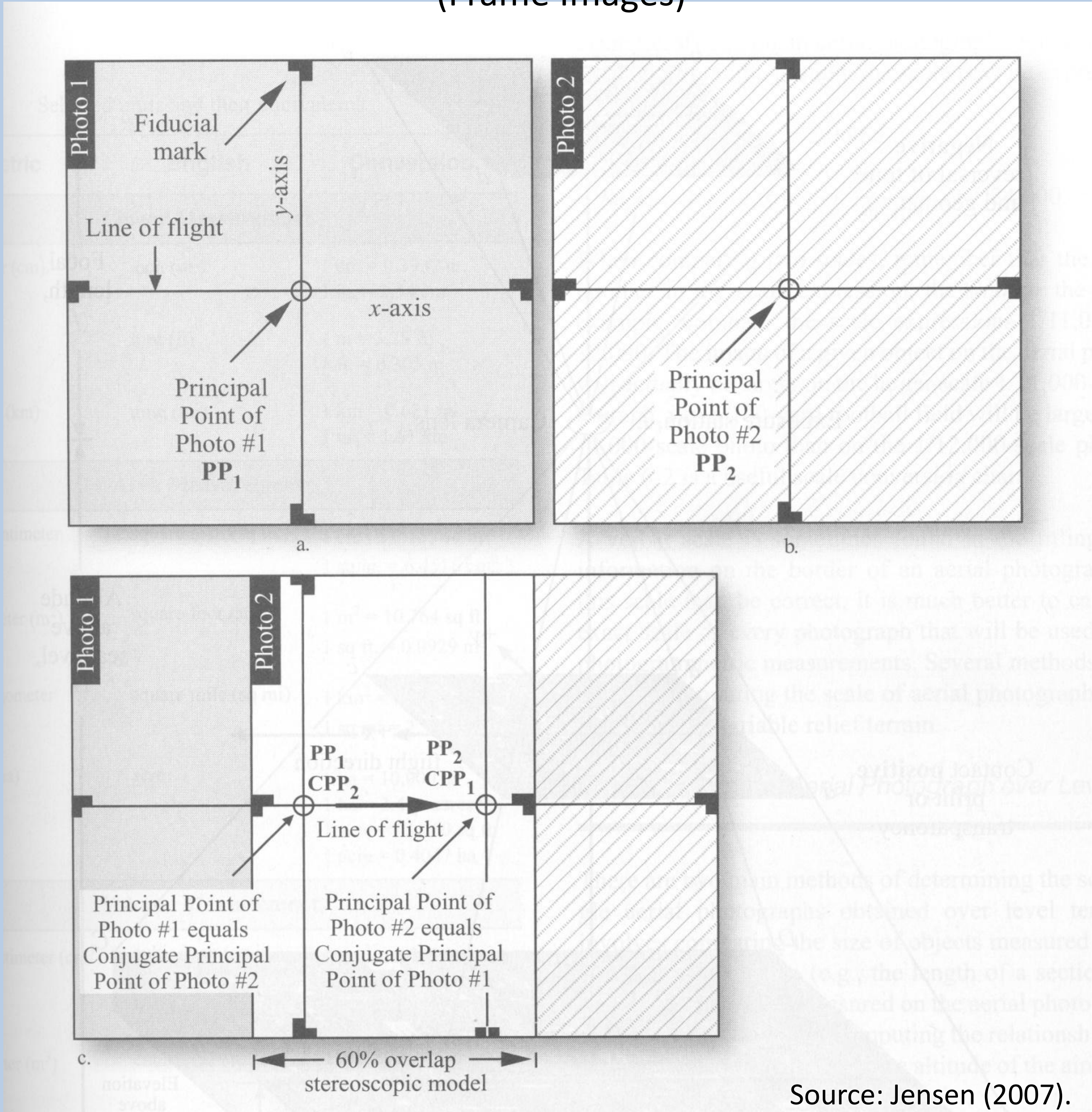
From Pateraki (2006).

Principles of Aerial Photography (Frame Images)



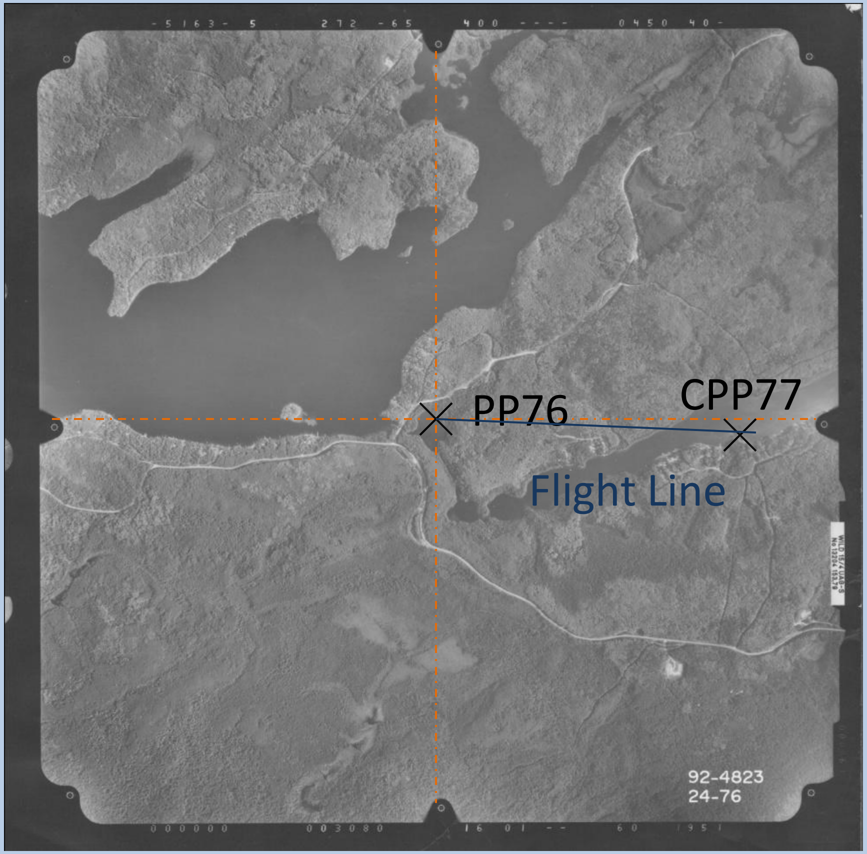
Source: Jensen (2007).

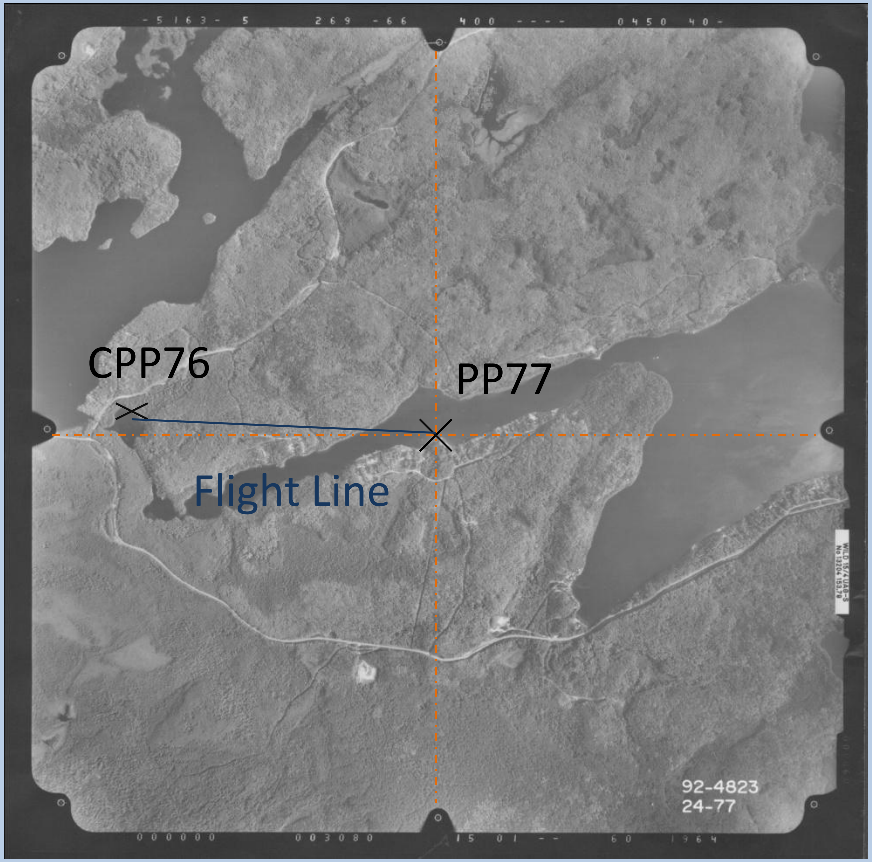
Principle Points (PPs), Conjugate Principle Points (CPPs) and Lines of Flight (Frame Images)



Source: Jensen (2007).

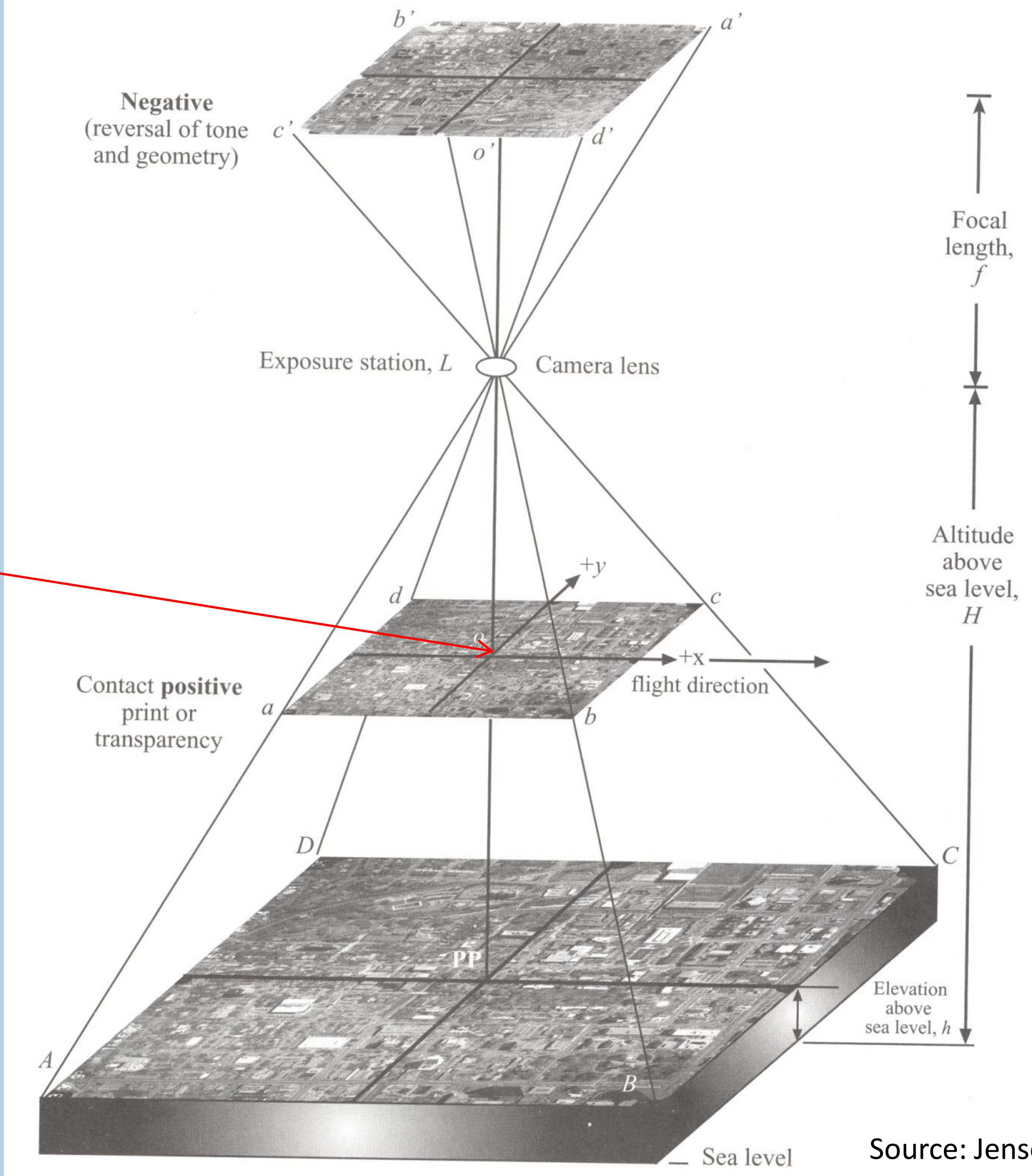
Principle Points (PPs), Conjugate Principle Points (CPPs) and Lines of Flight (Frame Images)





Geometry of a Vertical Aerial Frame Photograph Over Flat Terrain

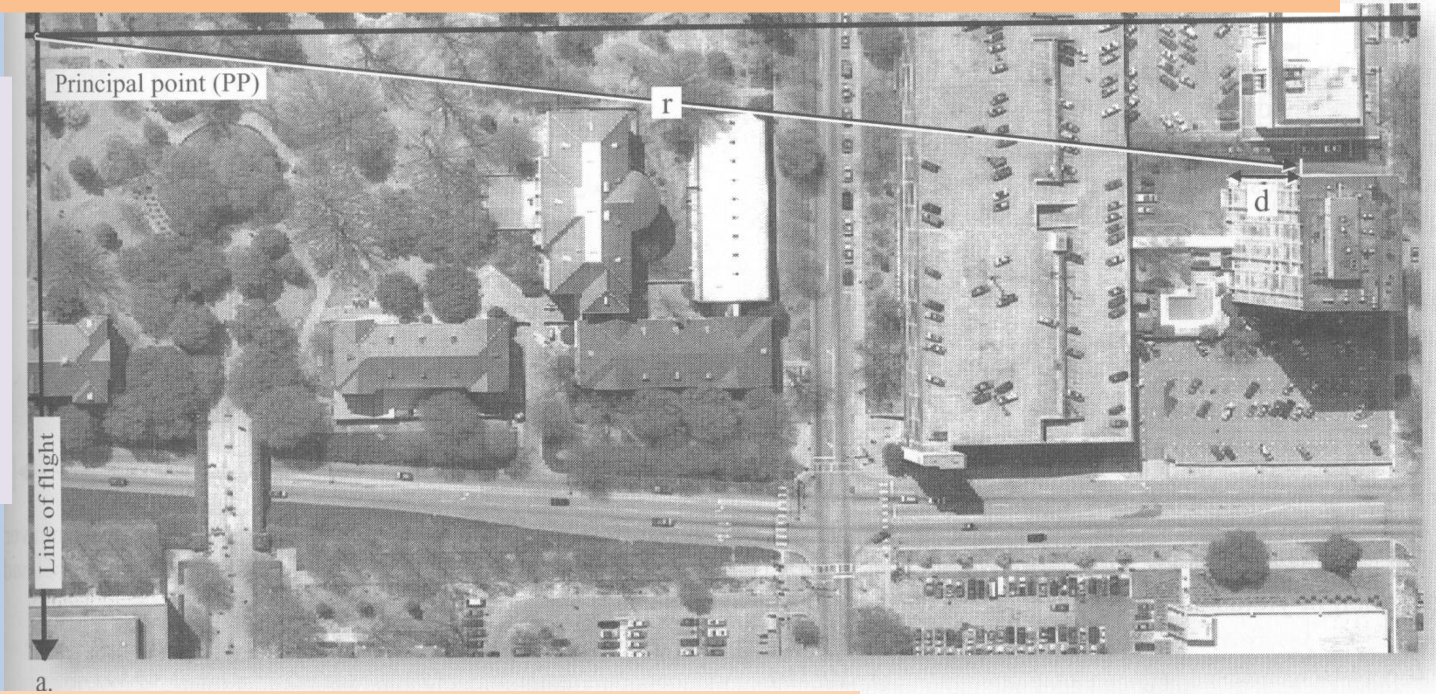
- The photographic coordinate axes x and y radiate from the principal point in the positive contact print.



Source: Jensen (2007).

Relief Displacement on a Vertical Frame Photography

Relief displacement is the shift or displacement in the photographic position of an image caused by the relief of the object (Wolf 1974) .



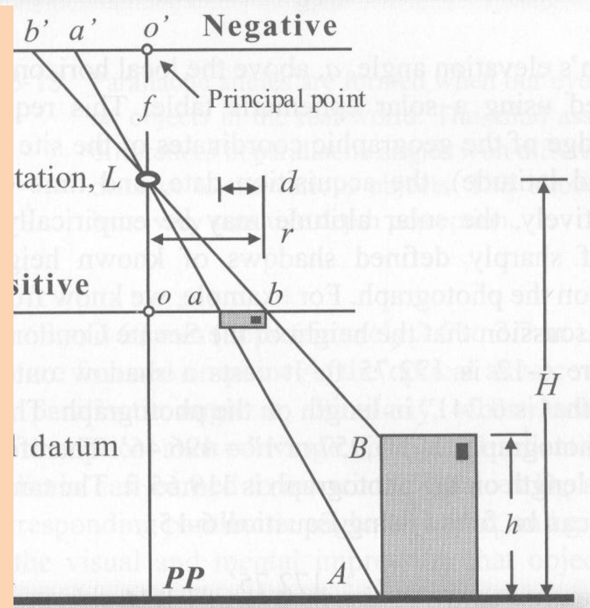
The amount of relief displacement, *d*, is:

• directly proportional to the difference in elevation, *h,* between the top of the object whose image is displaced and the local datum.

• directly proportional to the radial distance, *r* between the top of the displaced image and the principal point.

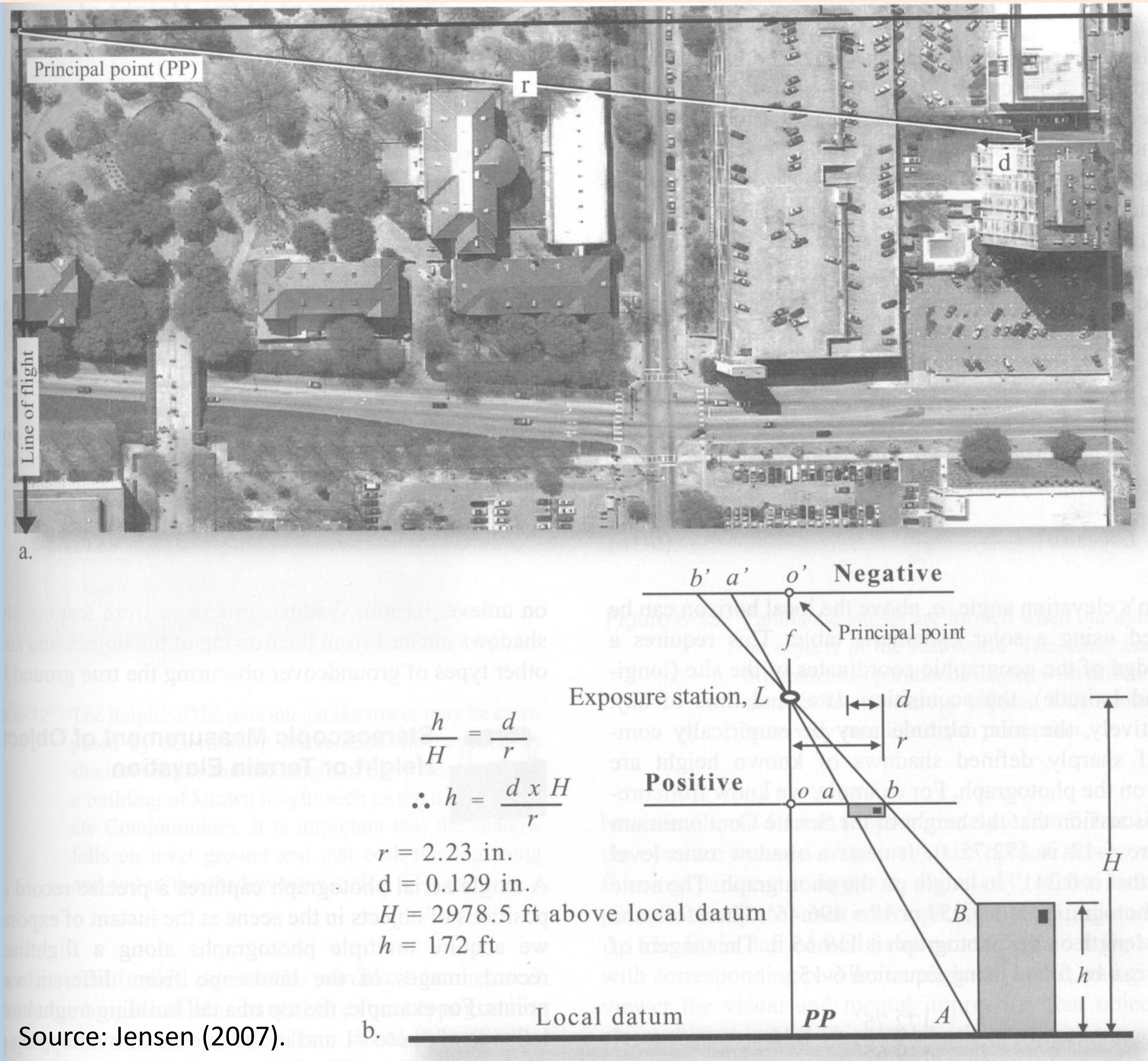
• inversely proportional to the altitude, H, of the camera above the local datum.

$$\frac{h}{H} = \frac{d}{r}$$



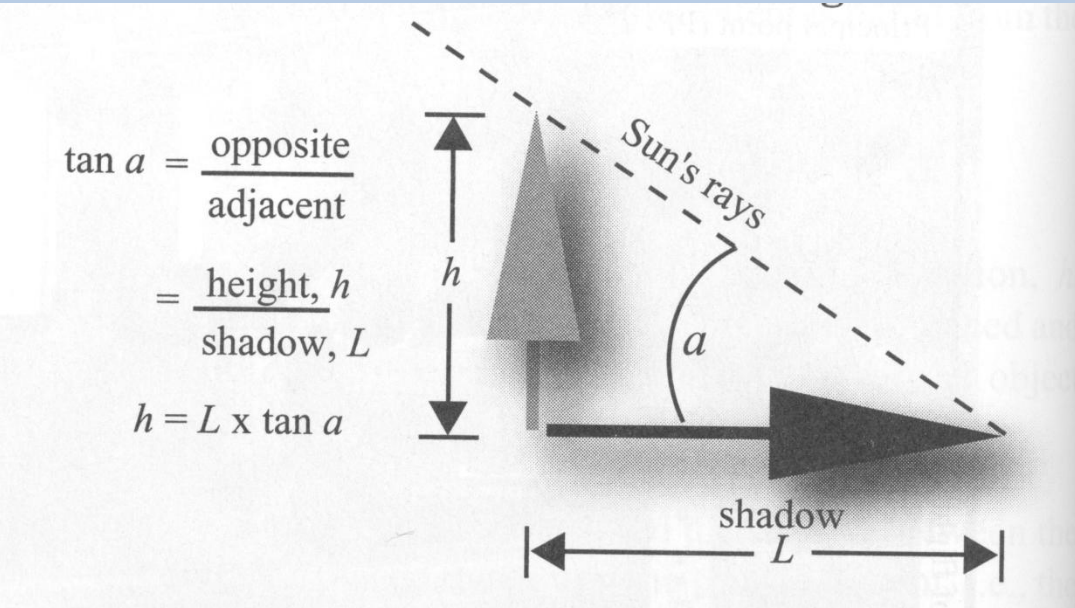
Source: Jensen (2007).

Relief Displacement Based Height Measurement on Vertical Frame Photos



Source: Jensen (2007).

Height Measurement Based on Shadow Length



Source: Jensen (2007).

•The Sun's elevation angle, *a,* above the local horizon can be determined using a solar ephemeris table. This requires knowing the longitude and latitude of the site, the acquisition date, and time of day.

Height Measurement Based on Shadow Length

•Alternatively, heights can be measured first determining the tan *a* based on a shadow of an object with a known height.

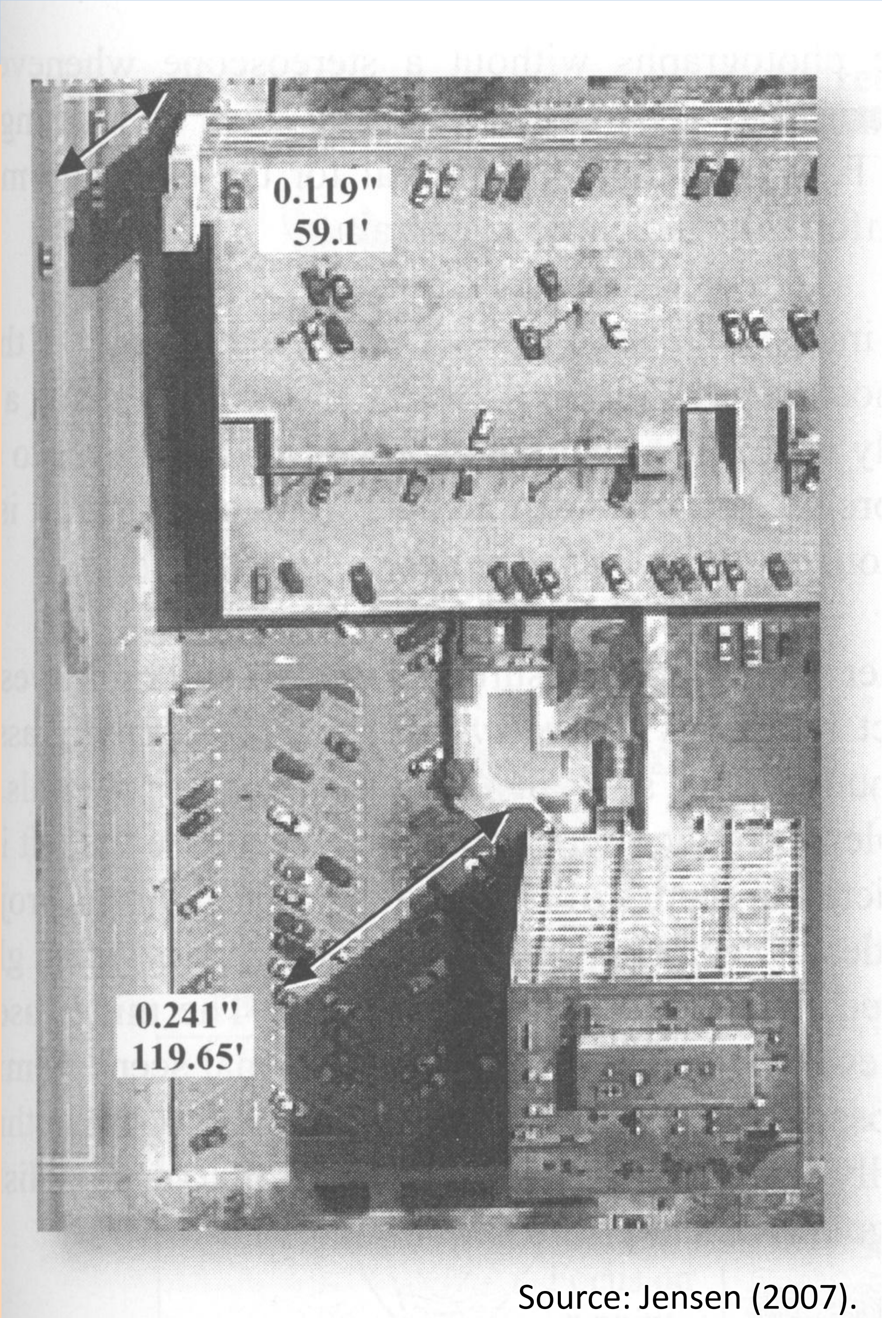
Example:

The height of the bottom building, *h,* is known to be 172.75 ft. It casts a shadow that measures 0.241 in on the photo. The photo scale is measured to be 1:5,957, which means that the ground distance of the shadow, *L*, is 119.65 ft. That means that:

$$\tan a = \frac{h}{L} = \frac{172.75}{119.65} = 1.44$$

tan*a* can now be used with other objects after their shadow lengths are measured. For example, the top building , having a shadow of 59.1 ft on the ground, has the height of:

$$h = L \times \tan a = 59.1' \times 1.44 = 85.10'$$



Source: Jensen (2007).

Relief Displacement on a Vertical Frame Photography

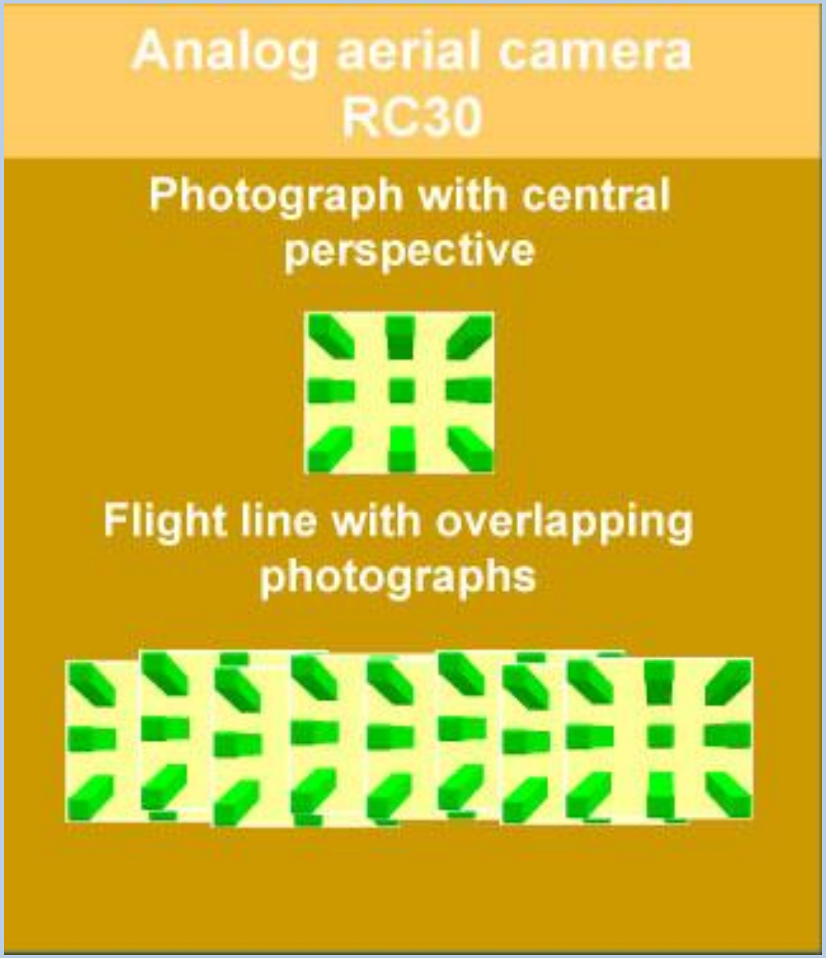
Relief displacement causes straight roads, fence lines, etc., on rolling ground to appear crooked on a vertical photograph.

Not corrected (not orthorectified) photo

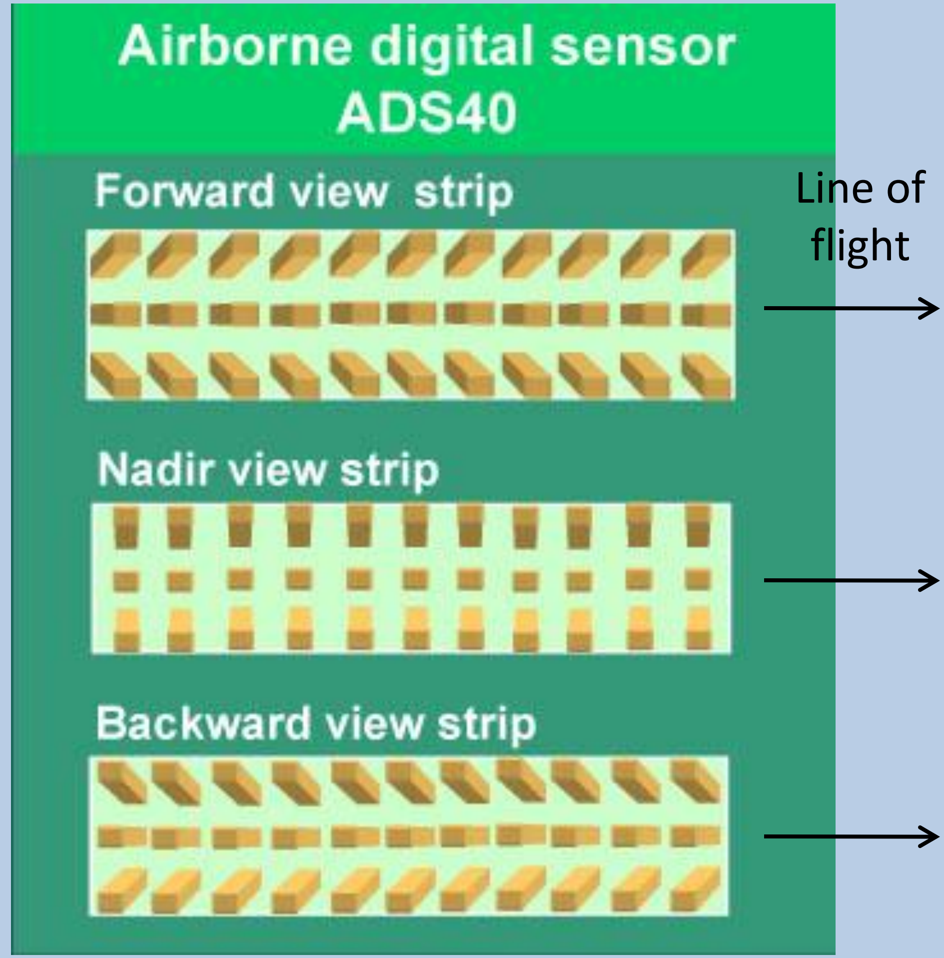
Corrected (orthorectified) photo

Relief Displacement on a Vertical Frame Photography and Film Strip (Linear Scanner Camera)

Analog or digital aerial camera



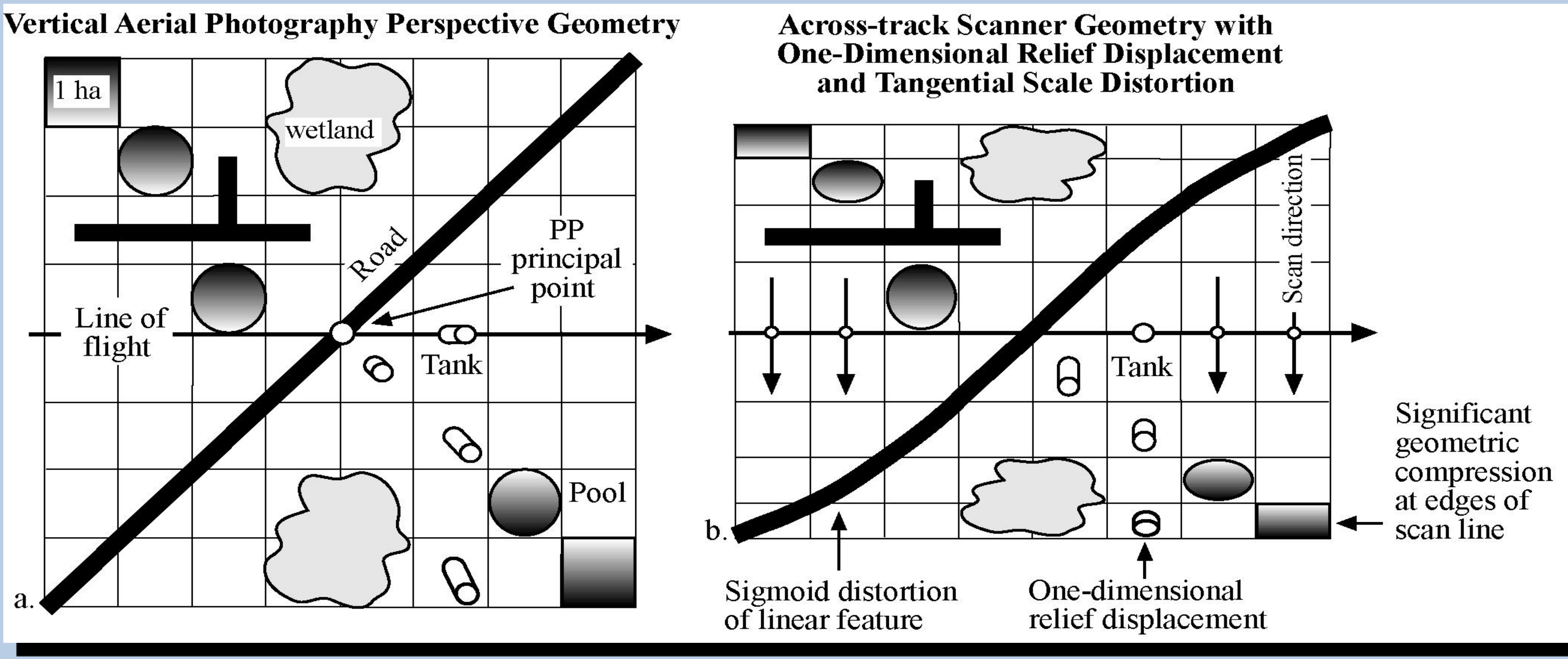
Digital aerial camera



Line of flight

Courtesy of Earth Data

Relief Displacement and Tangential Scale Distortion



Source: Jensen (2007).

Photo Scale

<u>Photo (Map) Scale</u> - the ratio of a distance on a photo or a map to the corresponding distance on the ground.

Three ways of expressing scale:

1. Fraction: $\frac{1}{20000}$

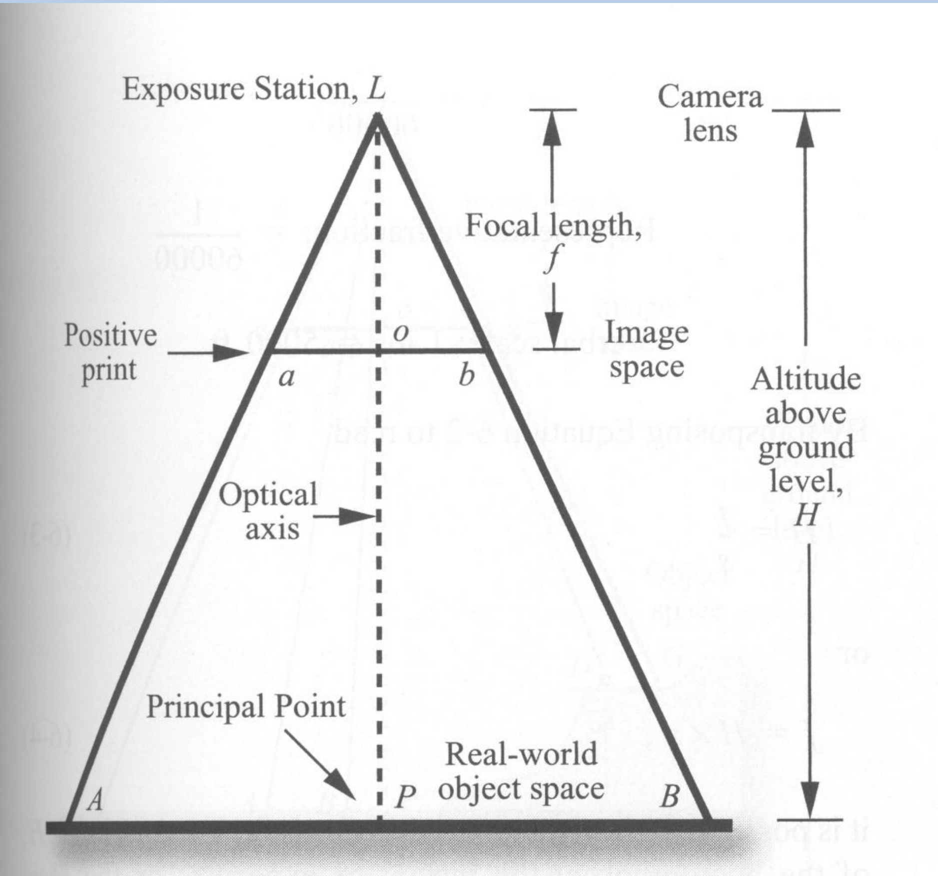
2. Representative fraction: 1:20000

• Scale fractions should always be expressed as a ratio of 1 over another number.

3. Unit: 1 cm = 200 m

Photo Scale

$$s = \frac{Photo\_Distance}{Ground\_Distance} = \frac{ab}{AB}$$

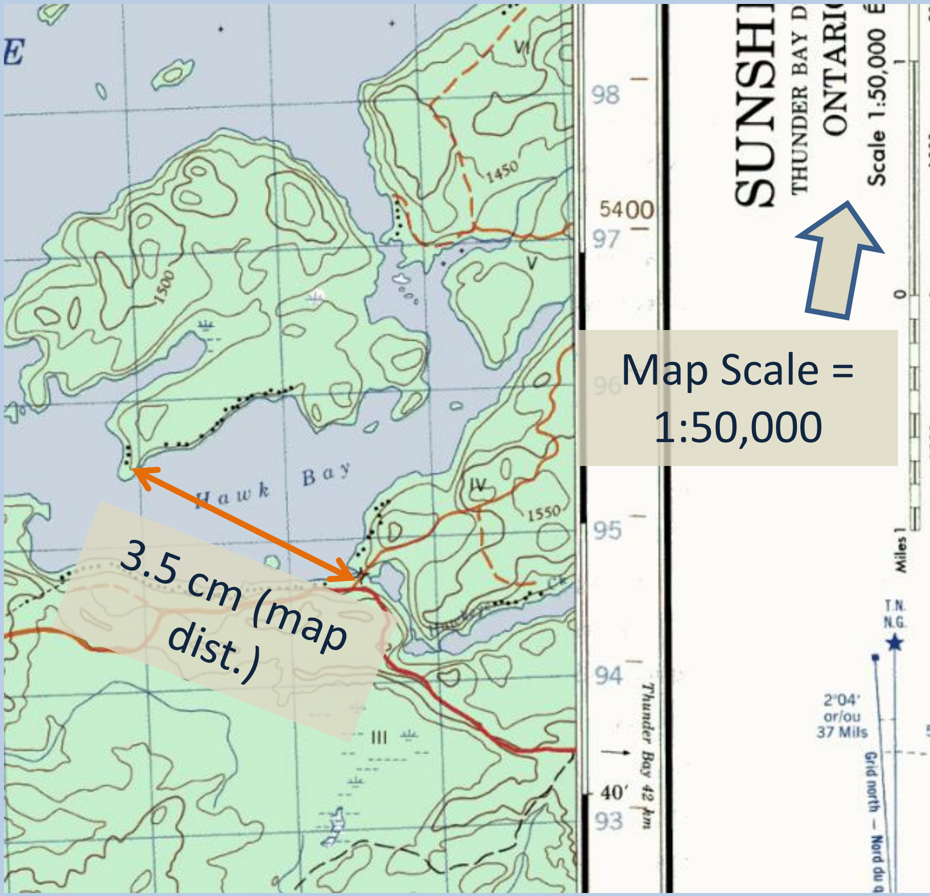


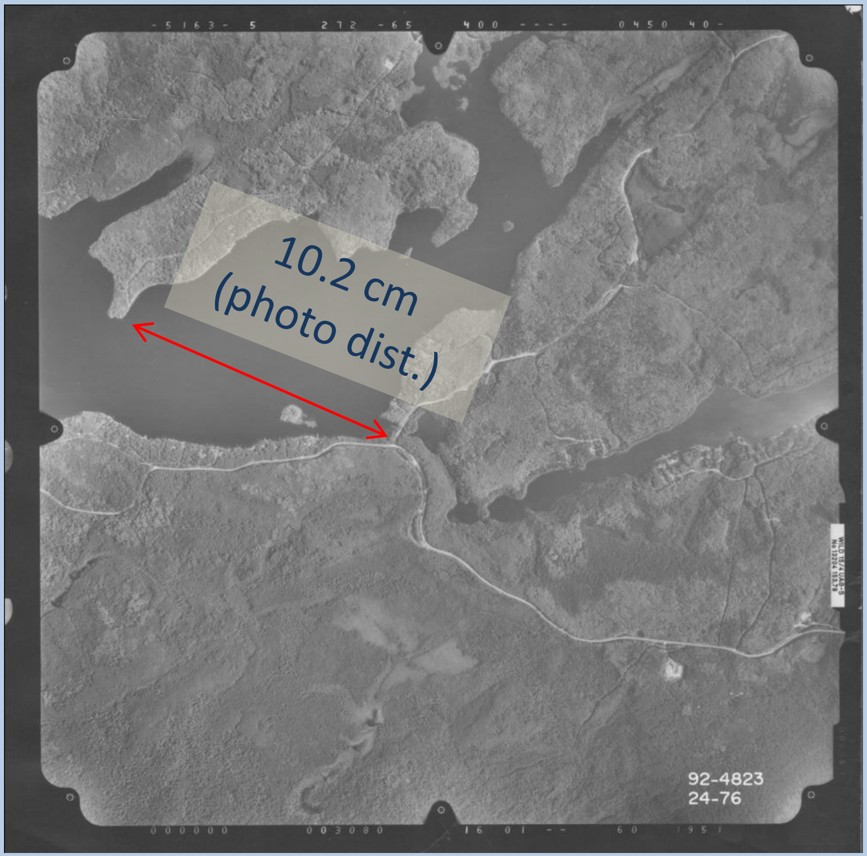
Source: Jensen (2007).

Example: $$s = \frac{8.75cm}{1750m} = \frac{0.0875m}{1750m} = \frac{1}{20000}$$

Photo Scale

$$s = \frac{Photo\_Distance}{Map\_Distance} x Map\_Scale$$





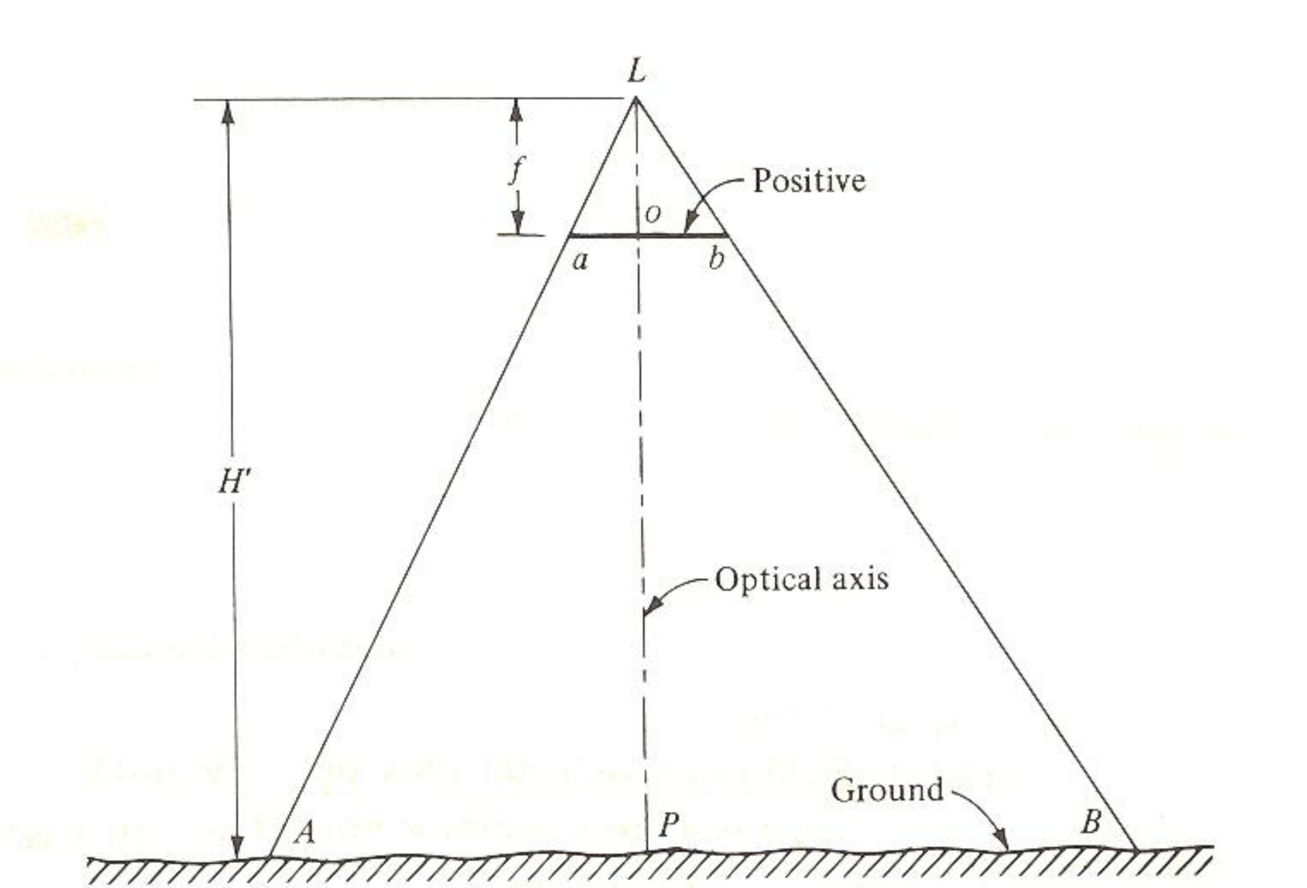
Example: $s = \frac{10.2}{3.5} x \frac{1}{50000} = \frac{10.2}{175000} = \frac{1}{17156.9} = \frac{1}{17157}$

Photo Scale (Vertical Frame Photography)

- The scale of a vertical photo is directly proportional to the camera focal length and inversely proportional to flying height above ground.

- The focal length based calculation should be directly applied to only the photo printouts (positives) that are at a 1:1 scale versus their negative. Otherwise a scaling of the printout measures to the sensor (film frame) measures is required.

$$S = \frac{f\ (\text{focal\_length})}{\text{H}\,(\text{flying\_height})}$$

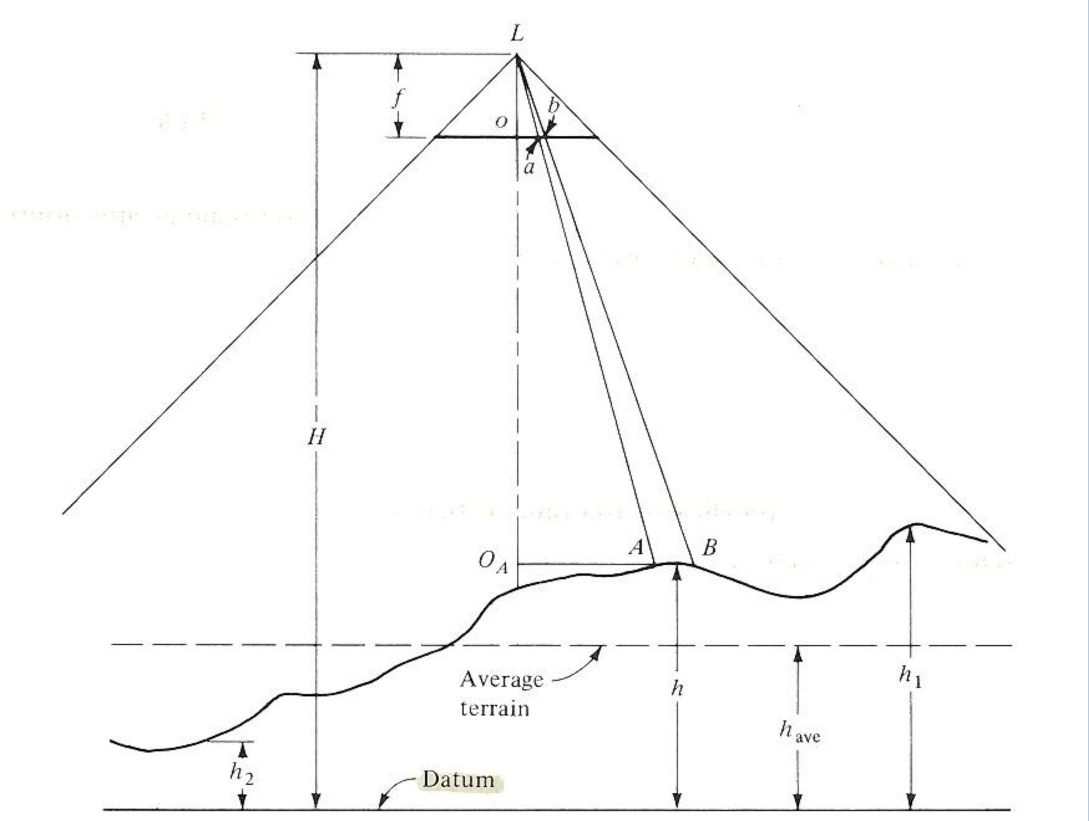


Source: Wolf (1974).

Example: $S = \frac{0.5'}{10000'} = \frac{1}{20000}$

Focal Length Based Photo Scale on Variable Terrain (Vertical Frame Photography)

$$S_{avg} = \frac{f}{H - h_{avg}}$$



Source: Wolf (1974).

Example:

f = 105 mm = 0.105 m
H = 4500 m asl
h = 400 m
h1 = 450 m
h2 = 50 m

h_{avg}= 300

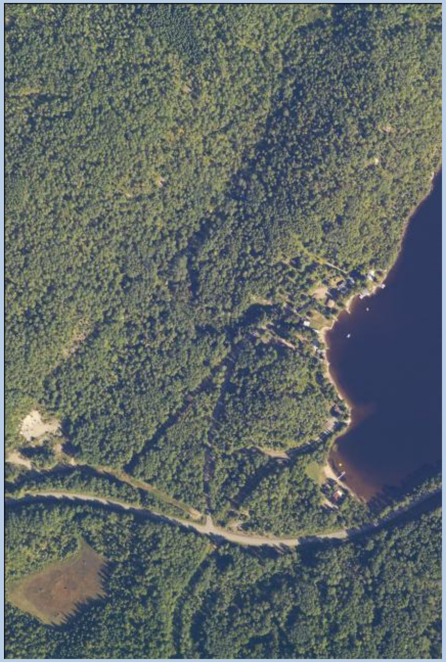
$$S_{avg} = \frac{0.105}{4500 - 300} = \frac{1}{40000}$$

Photo Scale (Vertical Frame Photography)

- When it comes to digital photos, since the printouts are larger than the sensors that captured the photo, the focal length based calculation needs to be adjusted for this difference

Camera sensor (CCD): 24 x 35 mm;
Camera focal length: 105 mm.
Flying height: 3120 m (GPS measured - a.s.l.)
Average terrain height: 440 m

Photo printout: 193 x 290 mm.



$$S(\text{sensor}) = \frac{f}{H - h_{avg}} = \frac{0.105}{3120 - 440} = \frac{1}{25524}$$

Photo (short side) / sensor (short side) = 193/24 = 8
Photo (long side) / sensor (long side) = 290/35 = 8

Photo scale = $\frac{1}{25524} \times 8 = \frac{1}{3190}$

References:

Jensen., J. R. 2007. Remote Sensing of the Environment: An Earth Resource Perspective. Pearson Prentice Hall.

Wolf, P. R. 1974. Elements of Photogrammetry. McGraw-Hill, Inc.

Pateraki, M. 2006. Digital Aerial Cameras. International Summer School "Digital Recording and 3D Modelling". Crete, Greece.