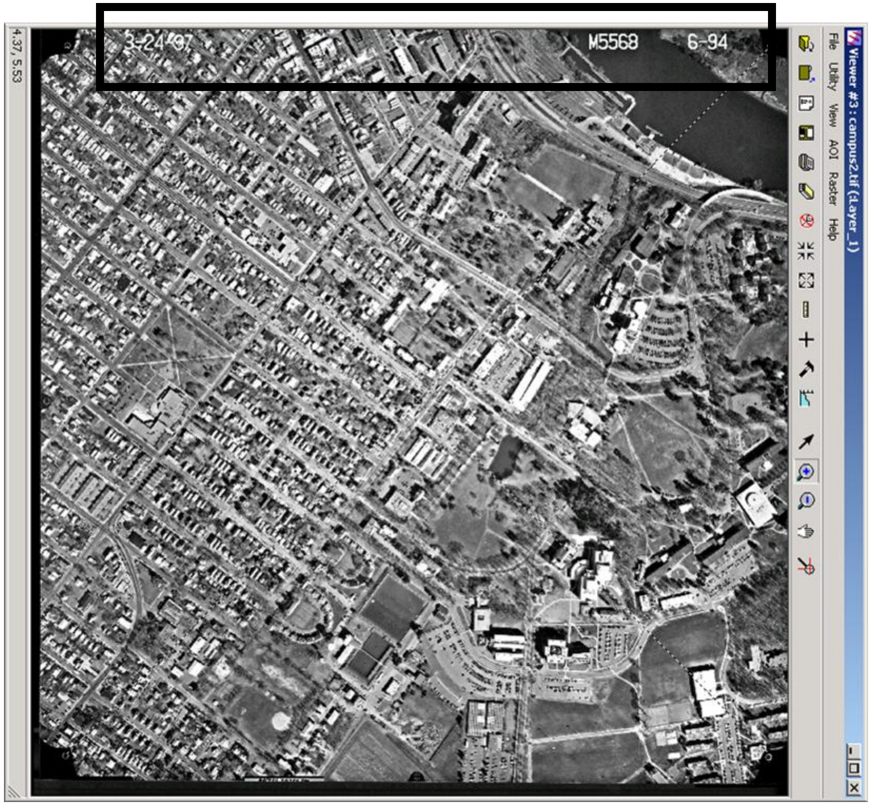
Principles of Photogrammetry: Stereoscopic Parallax

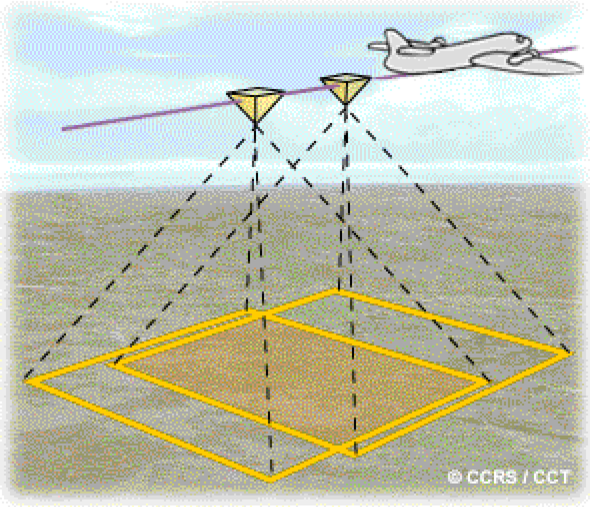
Determining Photo Orientation

- Labels and annotation are almost always along northern edge of photo
- Sometimes eastern edge is used
- Only way to be certain is to cross-reference photo with a map



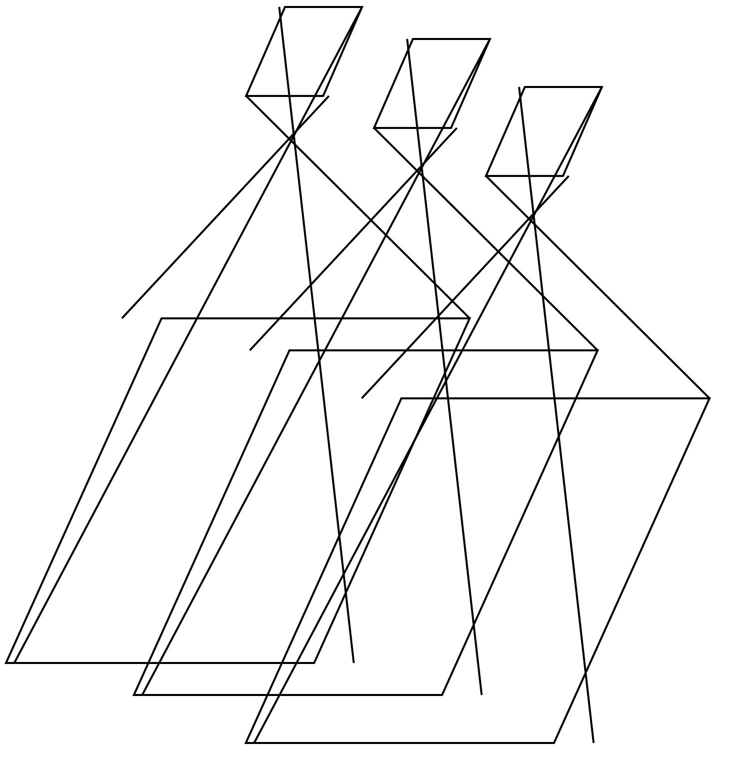
Stereophotography

- Adjacent but overlapping aerial photos are called stereo-pairs and are needed to determine parallax and stereo/3D viewing

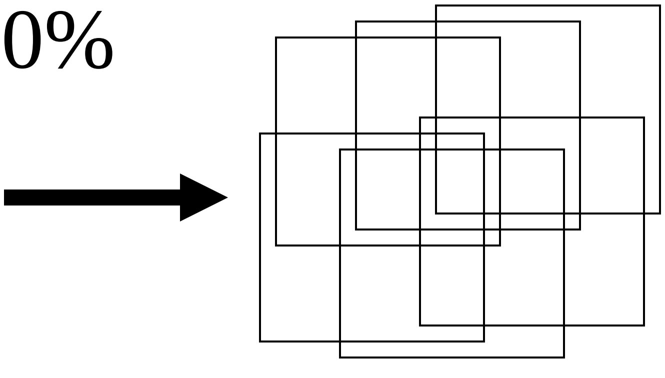


Graphic from http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/stereosc/chap4/

Overlapping Stereophotography

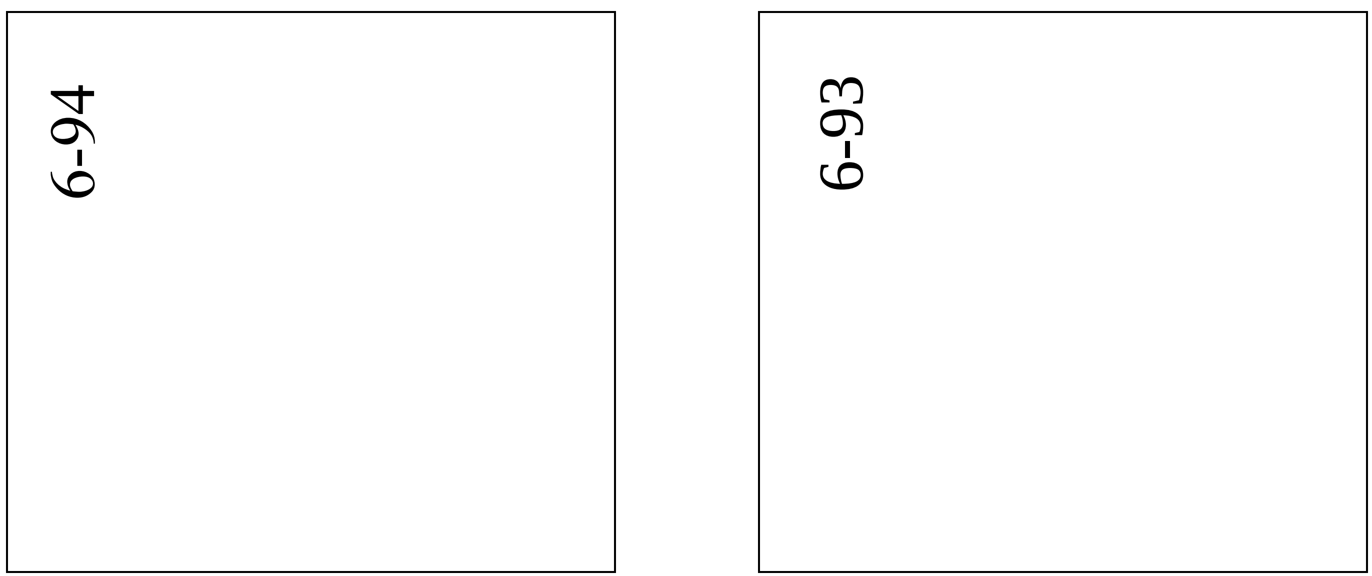


- Overlapping photography
- Endlap - ~60%
- Sidelap - ~20-30%



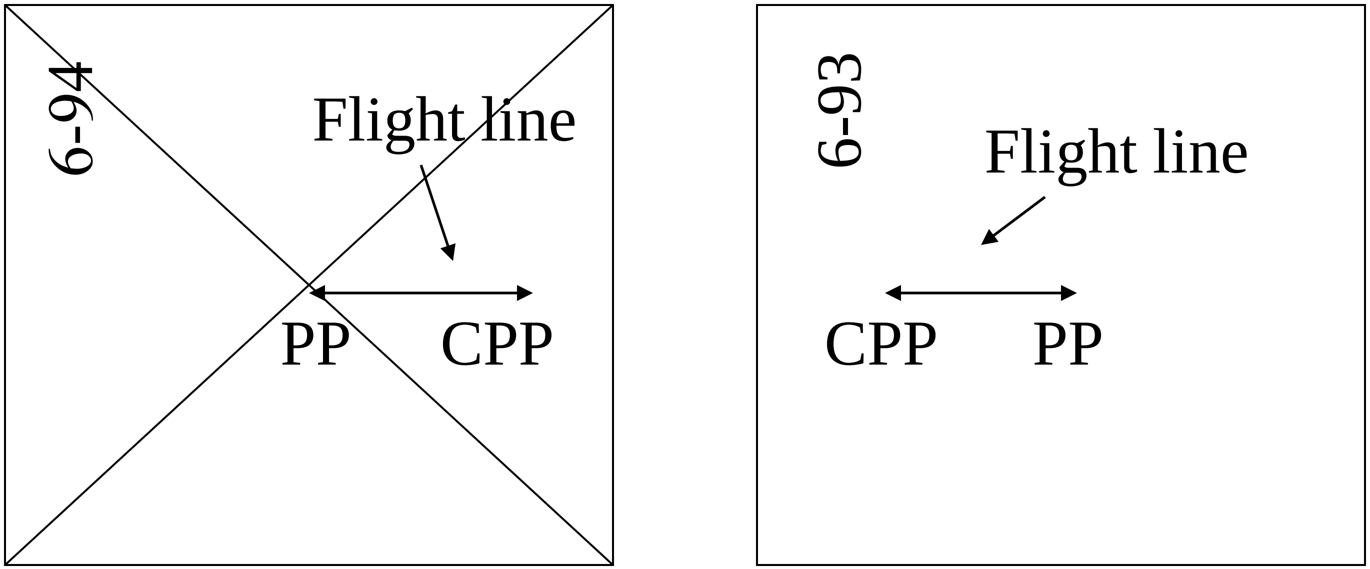
Orienting a Stereopair

- Take adjacent overlapping photos and align them up such that the flight line #'s are oriented along the left side of the photo.
- In this case, the higher Photo # is to the left and the lower Photo # to the right.



Orienting a Stereopair

- Locate the principal point (PP, optical center or nadir) of each photo by drawing a line between the corner fiducial marks (e.g., UL-LR & UR-LL)
- Locate the conjugate principal point (CPP) which is the PP of the adjacent photo
-Draw the line between the PP and CPP - this is the flight line
- Align the photos so that all 4 points lie on a straight line



Viewing with a Pocket Stereoscope

- Overlap the photos (93 on top of 94) until the separation distance between an object on one photo and its conjugate on the other photo is approx. equivalent to the eye base of the viewer (distance between pupils)
- One lens of the stereoscope should be over one photo, while the other lens is over the other photo with the long axis of the stereoscope aligned in parallel with the photo flight line

Map vs. Photo Projection Systems

- Maps have a orthographic or planimetric projection, where all features are located in their correct horizontal positions and are depicted as though they were each being viewed from directly overhead. Vertical aerial photos have a central or perspective projection, where all objects are positioned as though they were viewed from the same point.

Image Displacement

- A photo's central projection leads to image displacement where objects are shifted or displaced from their correct positions
- Relief displacement is due to differences in the relative elevations of objects. All objects that extend above or below a specified ground datum plane will have their images displaced.
- The taller the object, the greater the relief displacement

Relief Displacement

- Even from great flying heights, tall objects can exhibit image displacement.
- In this example from a Quickbird satellite image, the Washington Monument appears to lean outwards

http://www.mfb-geo.ch/text_d/news_old_d8.html

Radial Displacement

- Objects will tend to lean outward, i.e. be radially displaced.
- The greater the object is from the principal point, the greater the radial displacement.
- Example: storage tanks towards the edge of photo show greater radial displacement.

Center of photo

Edge of photo

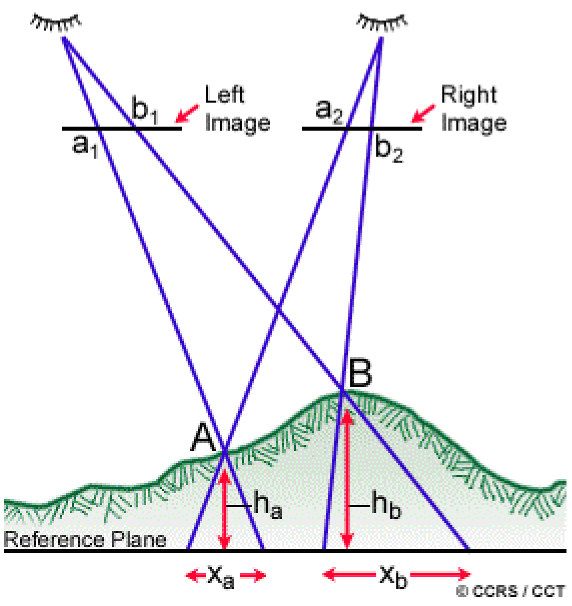
Maps vs. Aerial Photos

- Maps: Scale is constant
  No relief displacement

- Photos: Scale varies with elevation
  Relief displacement

Stereoscopic Parallax

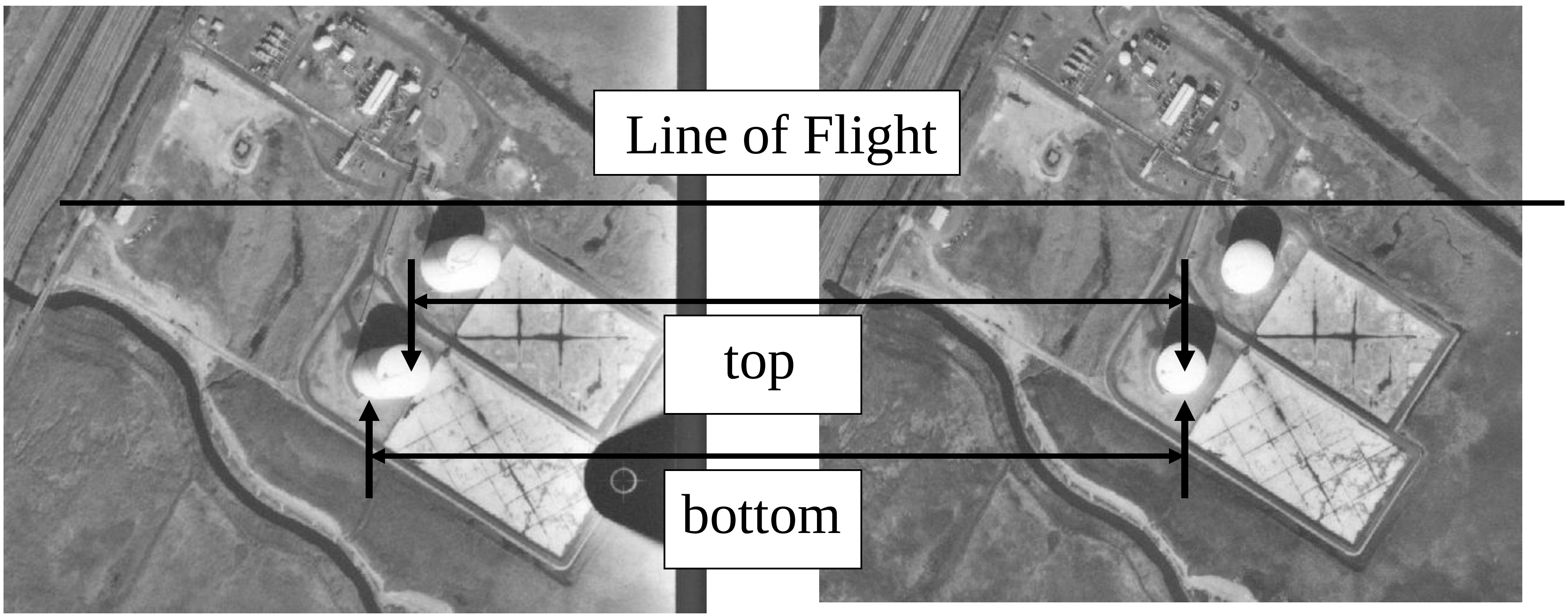
- The displacement of an object caused by a change in the point of observation is called parallax.
- Stereoscopic parallax is caused by taking photographs of the same object but from different points of observation.



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

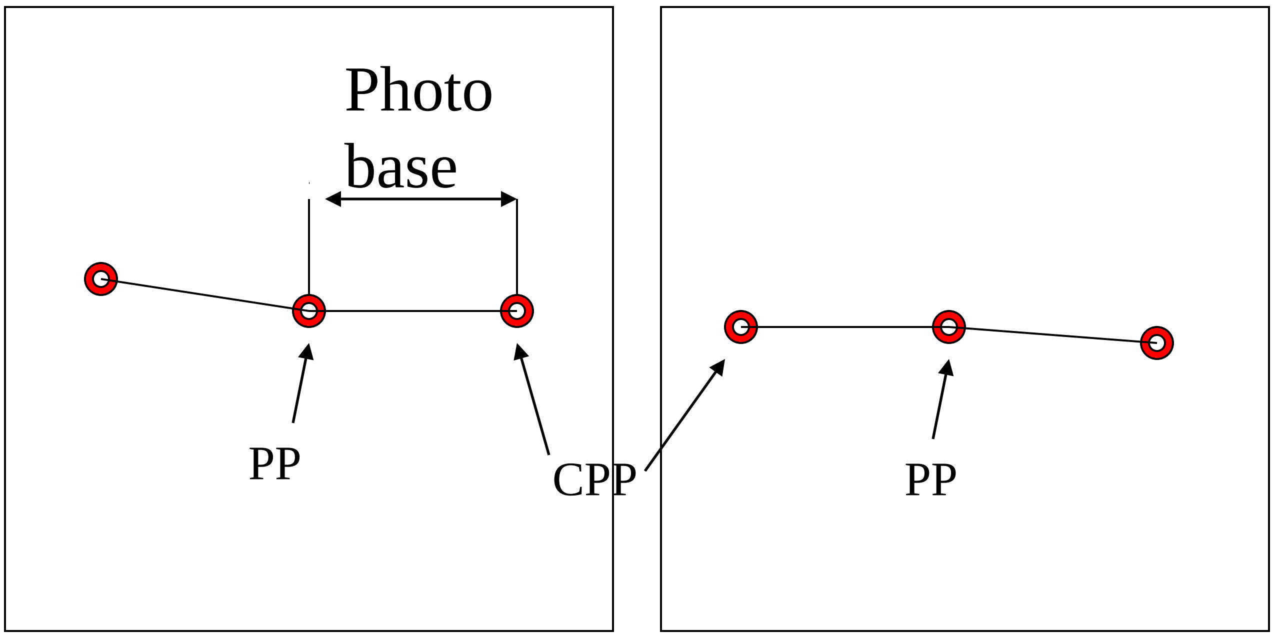
Stereoscopic parallax

Note the displacement between the top and base of the storage towers in this photo stereo-pair



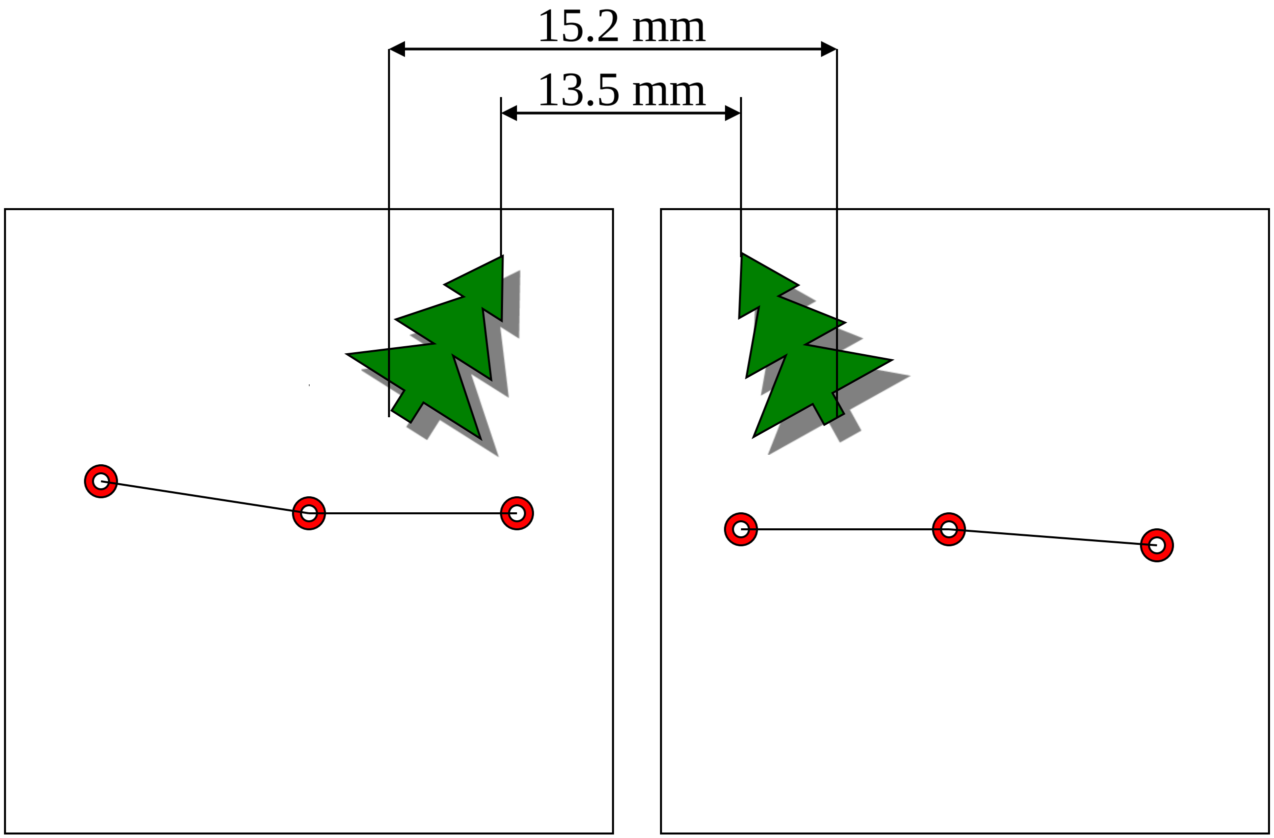
Absolute stereoscopic parallax

- PP = Principal point = center of photo
- CPP = Conjugate principal point = adjacent photo's PP
- Absolute stereoscopic parallax → the average photo base length = average distance between PP and CPP



Differential parallax

- Differential parallax - the difference between the stereoscopic parallax at the top and base of the object.



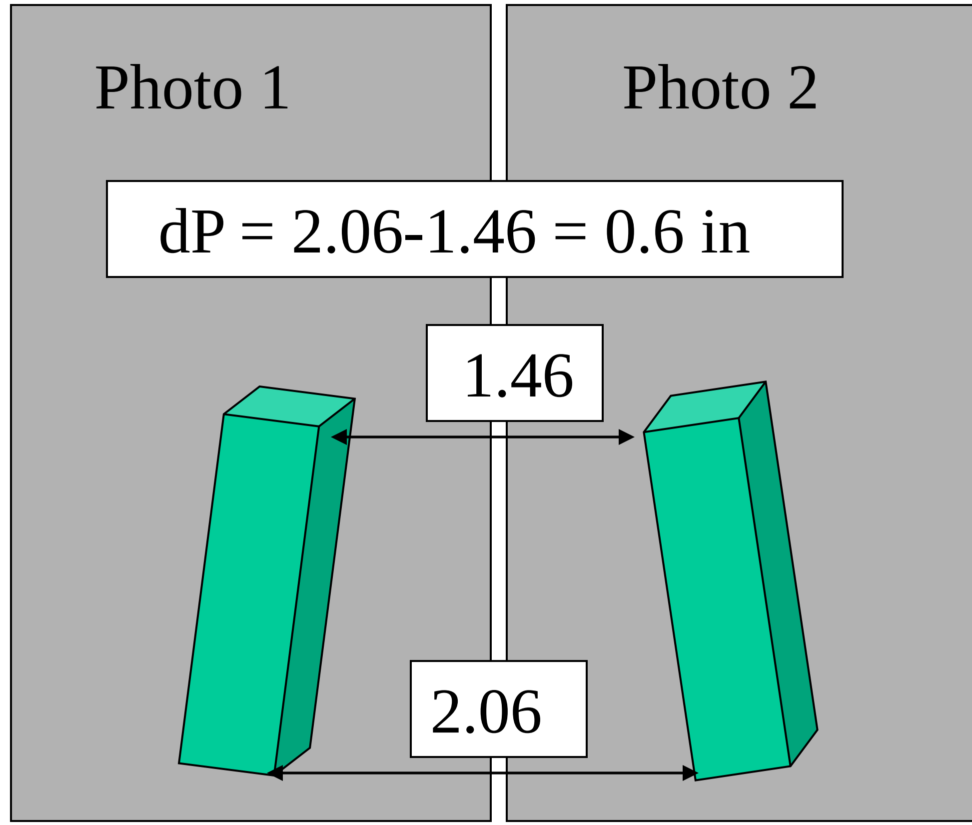
dP = 15.2mm – 13.5mm = 1.7 mm

Computing height using stereoscopic parallax

- $h = (H') * dP / (P + dP)$
  where h = object height
  H’ = flying height
  dP = differential parallax
  P = average photo base length

Calculating Object Heights using Stereoscopic parallax

Following example taken from:
T.E. Avery & G.L. Berlin. 1992,
Fundamentals of Remote Sensing and Air Photo Interpretation, MacMillan P



Calculating the height of the Washington Monument via stereo parallax

Example: Computing height using stereoscopic parallax

- h = (H’) * dP / (P + dP)
  where h = object height
  H’ = flying height = 4,600ft
  dP = differential parallax = 0.6in
  P = average photo base length = 4.4in
- h = (4,600ft * 0.6in) / (4.4in + 0.6in)
  = 2760 ft in / 5 in = 552 ft
- True height = 555.5 ft

Alternate formulation: taken from one photo

h = (H’) * d / (r)

where h = object height

H’ = flying height = 4,600ft

d = relief displacement from base to top = 0.6in

same as dP

r = distance from PP to top of object

same as (P + dP)

h = (4,600ft * 0.6in) / (5.0in) = 2760 ft in / 5 in = 552 ft

Calculating Object Heights

- Object heights can be determined as follows:
  - calculate flight altitude (H’) by multiplying the RF denominator by the focal length of the camera
  - h = d * H’ / r   where:

    h = Object height

    d = length of object from base to top

    r = distance from P.P. to top of object

Example: Calculating object height from relief displacement

Photo Relief displacement for Tank, d = 2.0 mm

Radial distance from P.P. to top of Tank, r = 71.5 mm

Flying Height above terrain, H' = 918 m

Example: Calculating object height from relief displacement

Photo Relief displacement for Tank, d = 2.0 mm

Radial distance from P.P. to top of Tank, r = 71.5 mm

Flying Height above terrain, H' = 918 m

$$h = d * H' / r = (2.0 \text{ mm} * 918 \text{ m}) / 71.5 \text{ mm}$$

$$= 25.7 \text{ m} = 26 \text{ m}$$

Stereoscopic Instruments

- Parallax wedge - simplest device for determining differential parallax
- Parallax bar - movable floating mark can placed at base and tops of objects to measure differential parallax

Stereoscopic Plotting Instruments

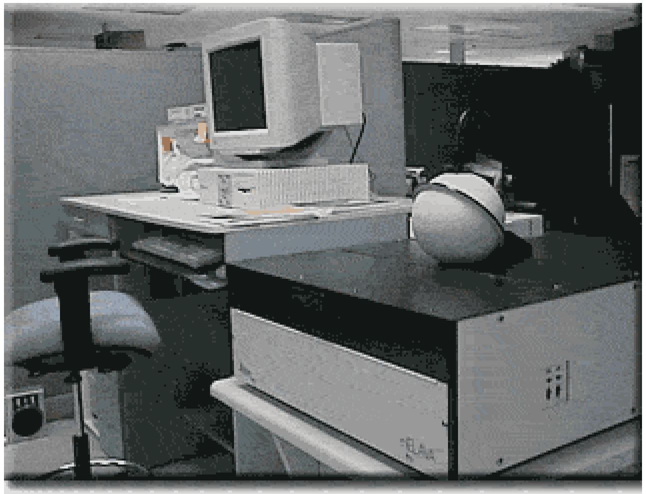
- Stereoplotters - precision instruments designed to duplicate the exact relative position and orientation of the aerial camera at the time of photo acquisition to recreate the stereo-model. A floating mark can be used trace specific elevations. Relief displacement is removed creating a planimetric map.

Photo from http://www.wsdot.wa.gov/mapsdata/Photogrammetry/PhotogImages/earlyStation.gif

Stereoscopic Plotting Instruments

- Soft-copy photogrammetry workstations - computer software recreates the stereomodel and allows for digital mapping
- Soft-copy photogrammtery has largely replaced optical-mechanical systems

Digital scanner



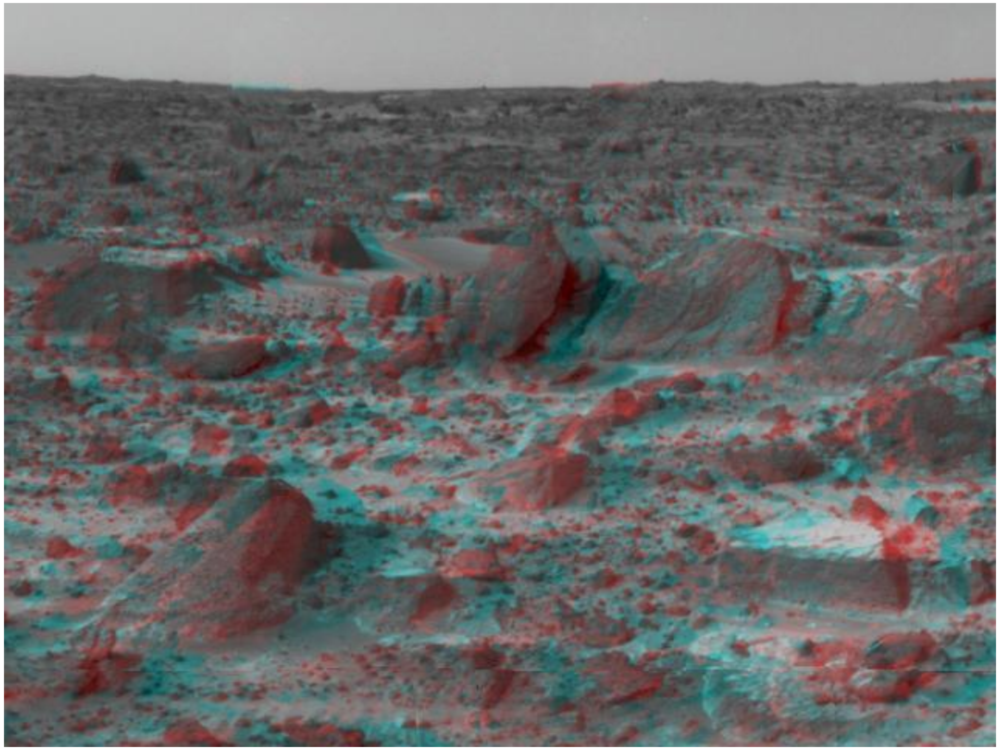
Soft copy workstation

Photos from: http://www.wsdot.wa.gov/mapsdata/

Photogrammetry/About.htm

Simulated 3-D Stereo viewing

- One view displayed in red; the other perspective view in blue spatially shifted
- The spatial shift is a function of the differential parallax
- To visualize, use red-blue glasses



NASA Mars Lander

Orthophotography

- Orthophoto - reconstructed airphoto showing objects in their true planimetric position
- Geometric distortions and relief displacements are removed
- Orthophotoquad - orthophotos prepared in a standard quadrangle format with same positional and scale accuracy as USGS topographic maps

Digital Orthophotography

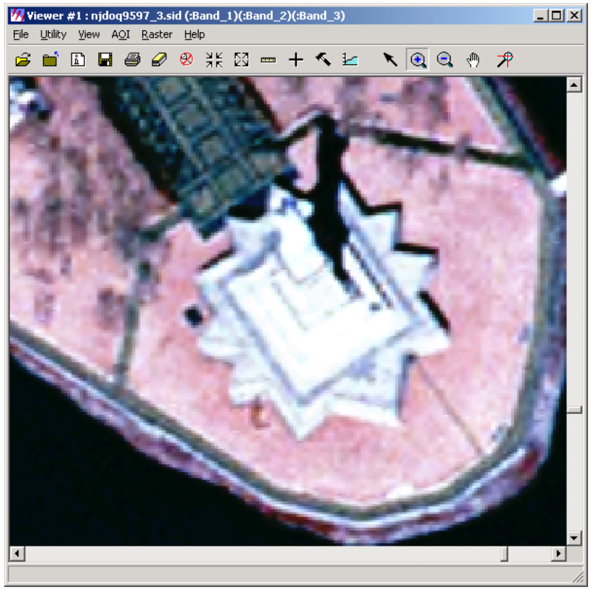
- Digital ortho-photography/ortho-imagery is increasingly the imagery of choice for many applications
- Sometimes referred to as DOQ - **d**igital **o**rthophoto **q**uad
- NJ has DOQ imagery for 1995 and 2002

Digital orthophoto on computer screen

Photo from: http://www.wsdot.wa.gov/mapsdata/Photogrammetry/About.htm

Extra Puzzler 1

- You measure the displacement of the Statue of Liberty (to the top of the torch) using a single photo as 13mm, and the distance from the PP to the top as 140mm. The flying height of the mission was 1000 m. What is the height of the Statue of Liberty?



Extra Puzzler 1

h = d * H’ / (r)

where h = object height

H’ = flying height = 1,000m

d = relief displacement from base to top = 13mm

r = distance from PP to top of object = 140mm

h = (1,000m * 13mm) / (140mm) = 13,000 m / 140 = 93.0m

Extra Puzzler 2

If you didn’t know the flying height of the aircraft or the focal length of the camera but you did know the height of a single object in the photo, how could you estimate the heights of other objects in the photo?

Extra Puzzler 2

For the known object, measure d and r, then solve for H'.

$h = d * H' / (r)$ $H' = (h * r)/ d$

where h = object height

H' = flying height

d = relief displacement from base to top

r = distance from PP to top of object

Then use H' in $h = d * H' / (r)$ to solve for other unknown objects.