AERIAL REMOTE SENSING

UNIT 2

Figure 1. 1:3000 Aerial Photograph (Reduced to 85%)

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SCALE OF THE AERIAL PHOTOGRAPHS

MAP SCALE & SCALE OF AERIAL PHOTOGRAPH

“Map Scale” is the ratio between the map distance and the corresponding distance on the ground.

Similarly, the “Scale of an Aerial Photograph” is the ratio of a distance on the photo to that same distance on the ground.

On a map, scale is uniform everywhere because of its orthographic projection.

But on the aerial photograph, since it is a perspective projection, scale varies with terrain elevations.

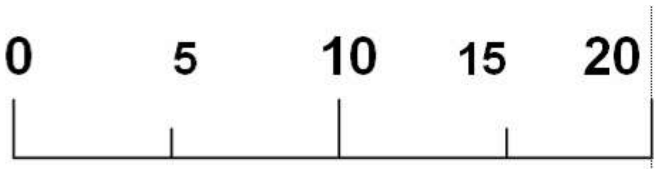
Expressed in 3 ways,

1) Unit equivalents : 1 in. = 1,000 ft.

2) Dimensionless representative fractions : 1/10,000

3) Dimensionless ratio : 1: 10,000

Drawn as “Linear Scale” in map.



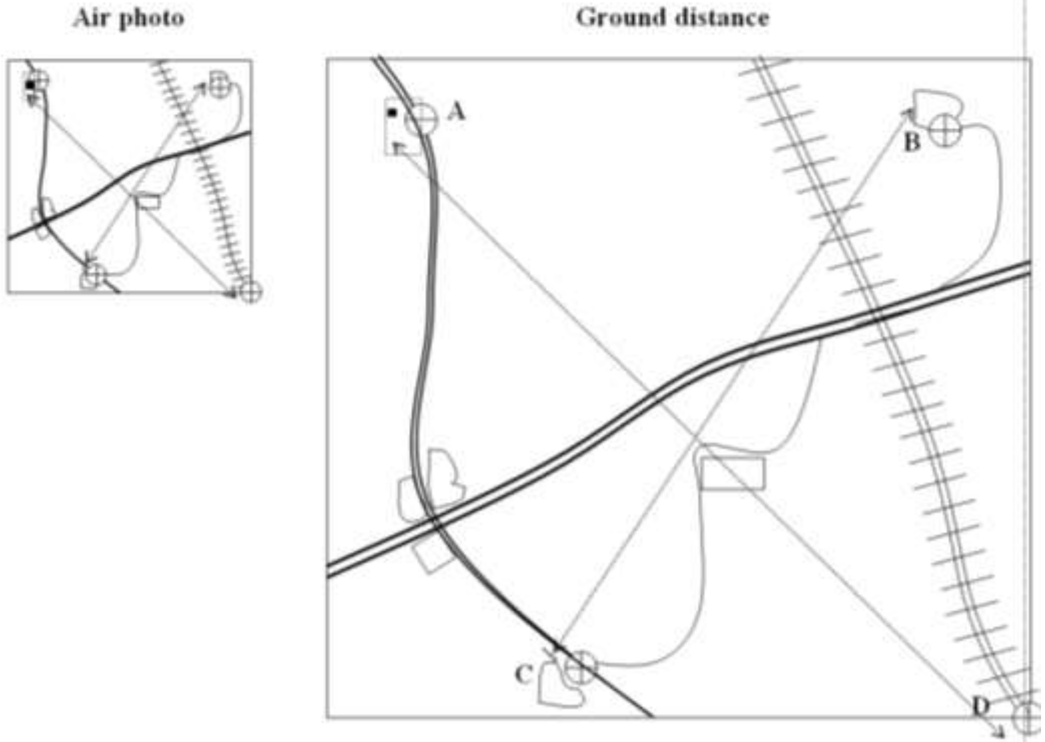
The photo scale can be determined in 3 ways

- ➔ By establishing the selection between the photo distance and ground distance
- ➔ By establishing the relation between photo distance and Map distance
- ➔ By establishing the relation between the focal length of the camera and flying height

By establishing the selection between the photo distance and ground distance

- **This method is usually adopted when the focal length and flying height of the camera are not known.**
- **The scale is calculated by comparing the photo distance and ground distance**
- **Scale = Photo distance : Ground distance**
- **or Scale = Photo distance / Ground distance**

Measurement of Scale by Feature Matching method



(a) Scale = Photo distance : Ground distance

For example,

The distance between points A and D in ground = 6 km and in air photo = 10 cm

6 km = 6 x 1000 x 100 cm

= 6,00,000 = 6 lakhs cm

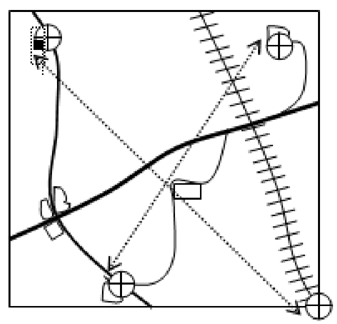
10/6,00,000 = 1/60,000

Therefore, 1 cm in aerial photograph is equal to 60,000 cm in ground.

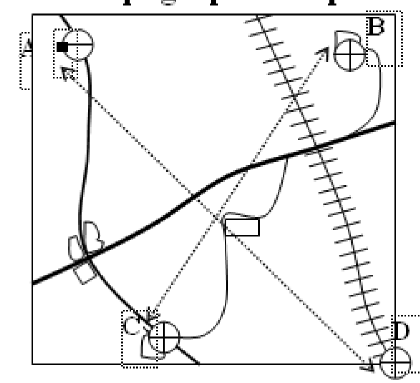
➔ **By establishing the relation between photo distance and Map distance <u>Using Topographic map sheet</u>**

- **Minimum of four points with wider separations is preferable**
- **The scale of the topographic sheet is used, e.g. 1: 50,000.**

Air Photo



Topographic map



(b) Scale $= \dfrac{\text{Photo distance}}{\text{Map distance}} \times$ Map Scale

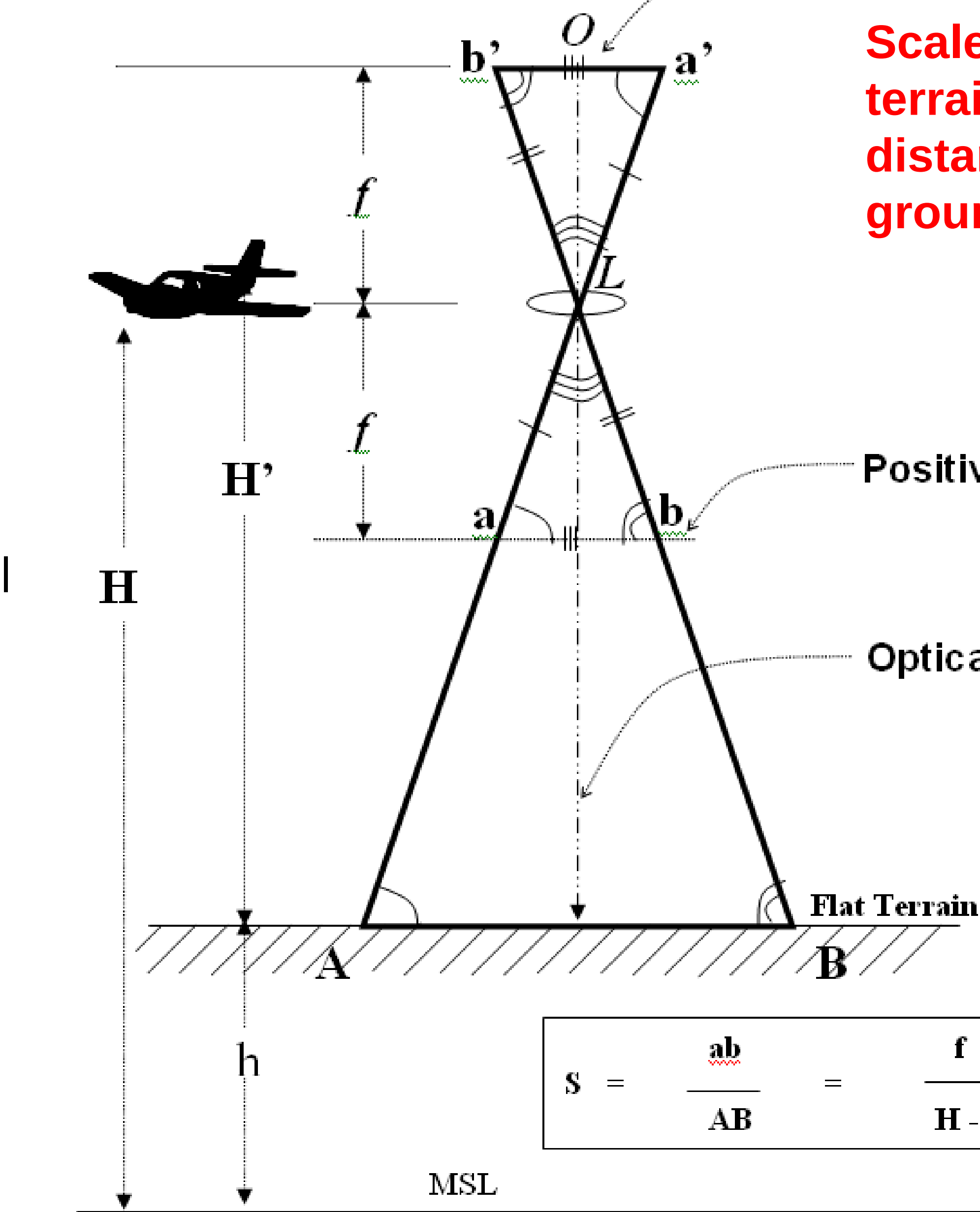
(i) The distance between points A and D in toposheet = 12 cm and in air photo = 10 cm

Then, scale $= \dfrac{10}{12} \times \dfrac{1}{50000}$

$= 10 / 6,00,000 \qquad = 1 / 60,000$

Thus, the scale of aerial photo is = 1 : 60,000

A) SCALE OF A VERTICAL AERIAL PHOTOGRAPH OVER FLAT TERRAIN



$$S = \frac{ab}{AB} = \frac{f}{H - h} = \frac{f}{H'}$$

Scale of a vertical photograph over flat terrain is simple the ratio of the photo distance 'ab' to the corresponding ground distance 'AB'.

The scale may be expressed in terms of camera focal length (f), and flying height above ground (H') by equating the similar triangles 'Lab' and 'LAB',

i.e., the scale of a vertical photo is directly proportional to camera focal length (image distance) and inversely proportional to flying height above ground (object distance).

S = f / H'
f = focal length
H' = Flying height above the ground

Problem 1: Given: 1. Exposure station height = 5200 ft. above MSL
2. Ground elevation = 980 ft.
3. Focal length = 8 inches.

$$\boxed{\text{Flying height, } H' = H - h}$$

Where, H = Height above MSL
h = ground elevation

Therefore, H' = 5200 – 980 = 4220 ft. = 4220 x 12 = 50640 inches

$$\text{Scale} = \frac{f}{H'}$$

Where, f = focal length of the camera, H' = Flying height

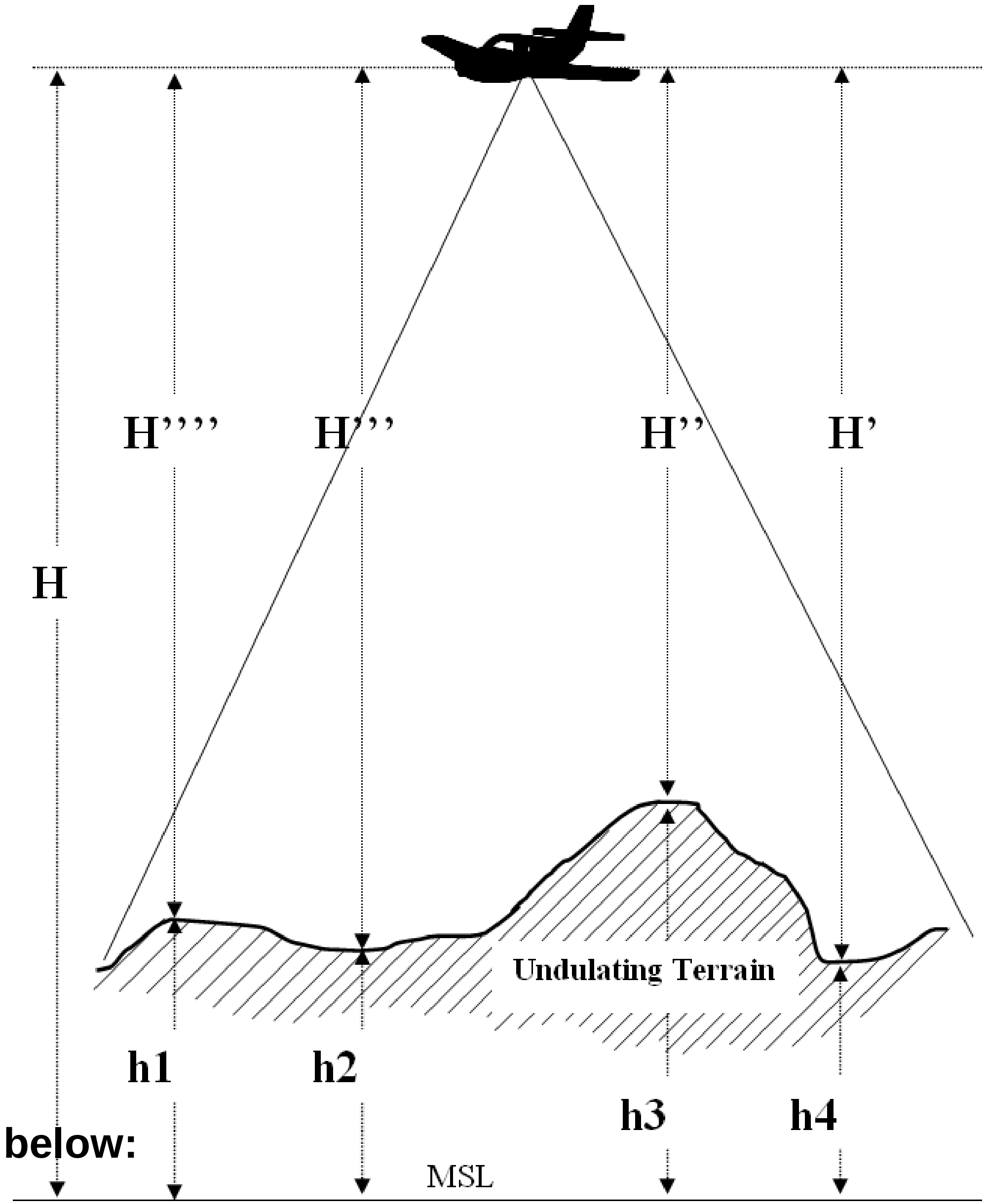
Scale = 8 inches / 50640 inches = 1 / 6330 = 1 : 6330

Scale of A Vertical Aerial Photograph Over Variable Terrain

Photo scale, increases with increasing terrain elevation and decreases with decreasing terrain elevation.

Photo Scale at different points can be calculated using the following equation

$$S = \frac{f}{H^{n'}}$$



C) Average Photo Scale

Calculate the average terrain elevation as below:

Average Object Height

$h_{avg} = (h1 + h2 + h3 + h4 + \ldots h_n) / n$

Then, calculate Average Flying Height $H' = H - h_{avg}$

Average photo scale can be calculated.

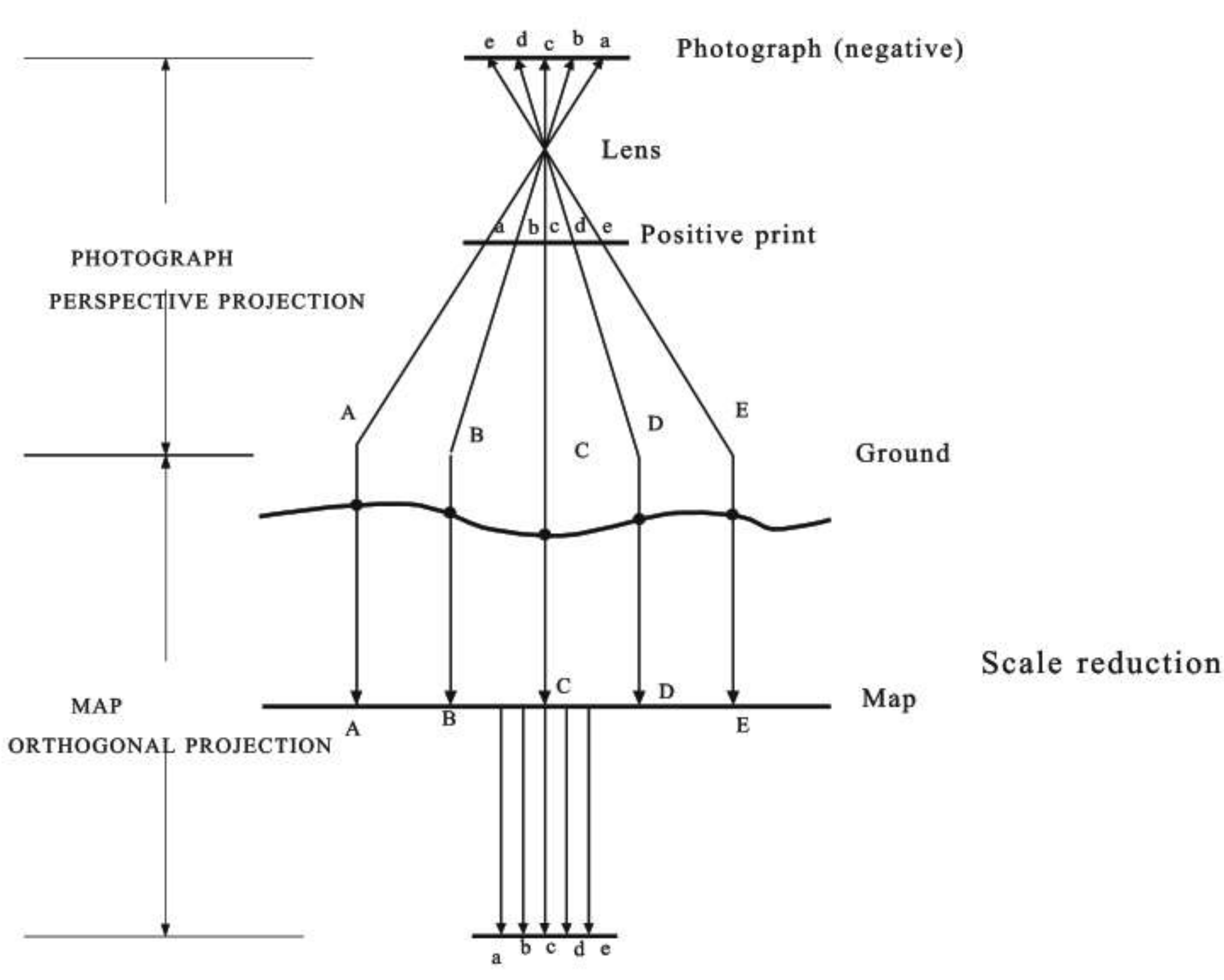
DISTORTION AND DISPLACEMENT

Because of the optical characteristics inherent in a vertical aerial photograph and the anomalies from the camera components, a vertical photograph is not a map.

According to Paine (1981), distortion in aerial photography is defined as any shift in the position of an image on a photograph that alters the perspective characteristics of the image and

Displacement is any shift in the position of an image on a photograph that does not alter the perspective characteristics of the photograph.

Displacement results mainly from the perspective viewing of the camera resulting in a perspective or central projection on the photograph. In contrast, a map is the product of an orthographic projection.

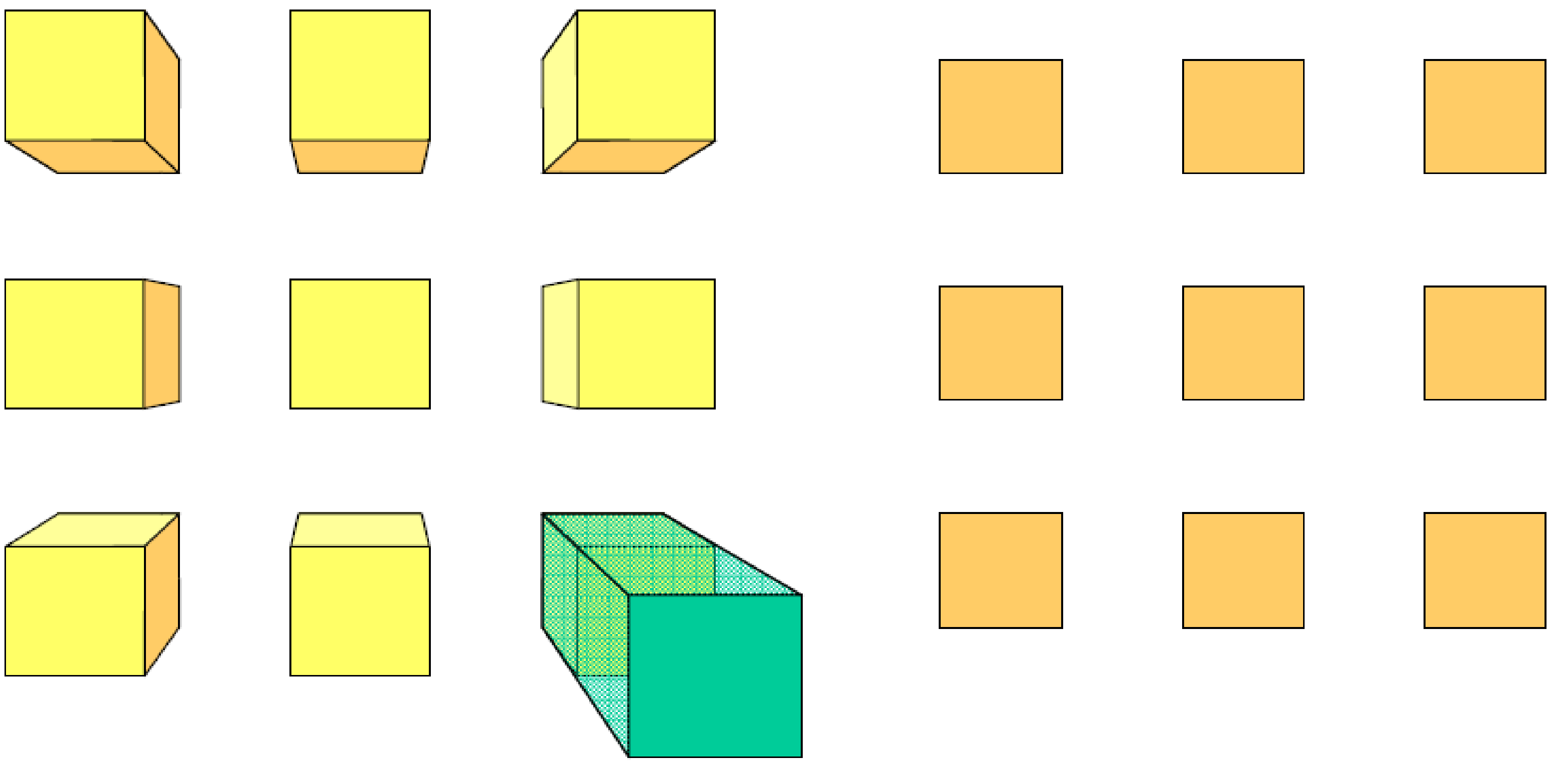


e d c b a
Photograph (negative)
Lens
a b c d e
Positive print
PHOTOGRAPH
PERSPECTIVE PROJECTION
A
B
C
D
E
Ground
Scale reduction
C
D
Map
MAP
A
B
E
ORTHOGONAL PROJECTION
a b c d e

Central Perspective

Imagine nine high-rise buildings wiewed from above

Central Projection (photo): *Orthogonal Projection (map):*



- Radial displacement
- Scale differences

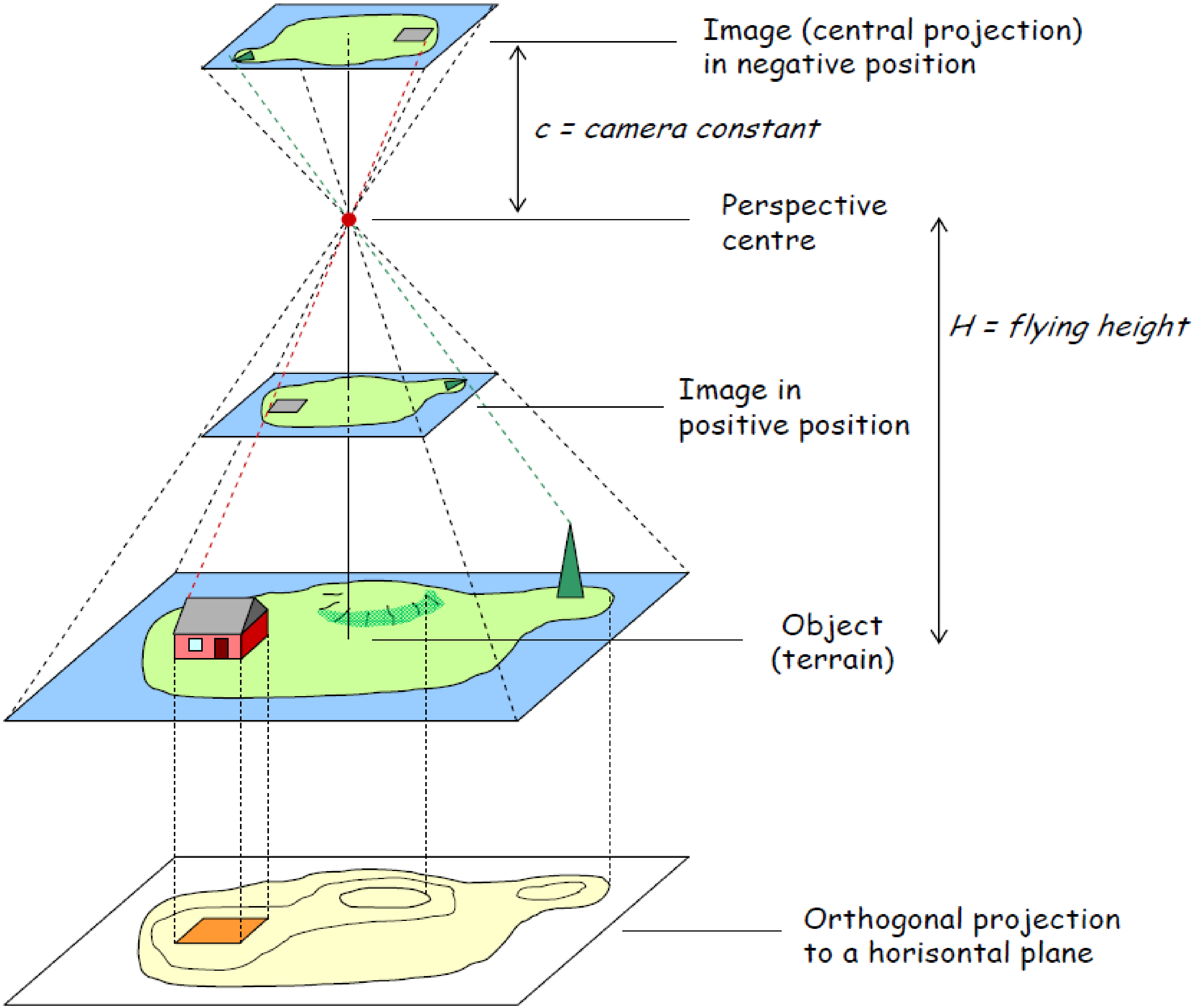
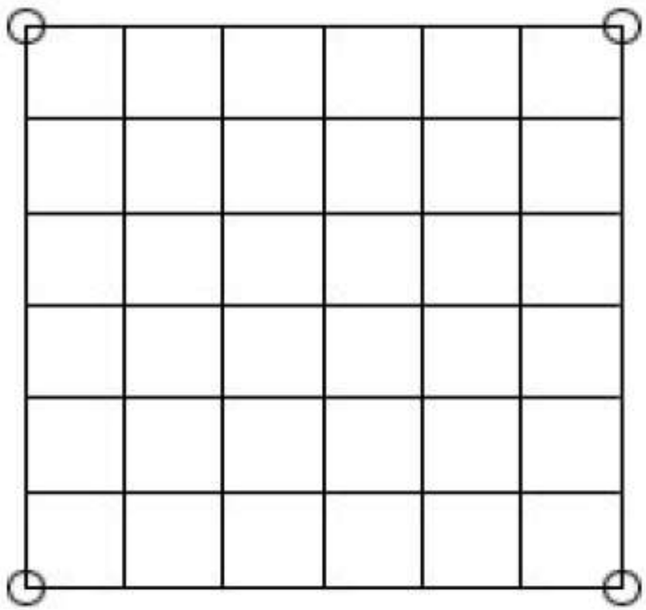
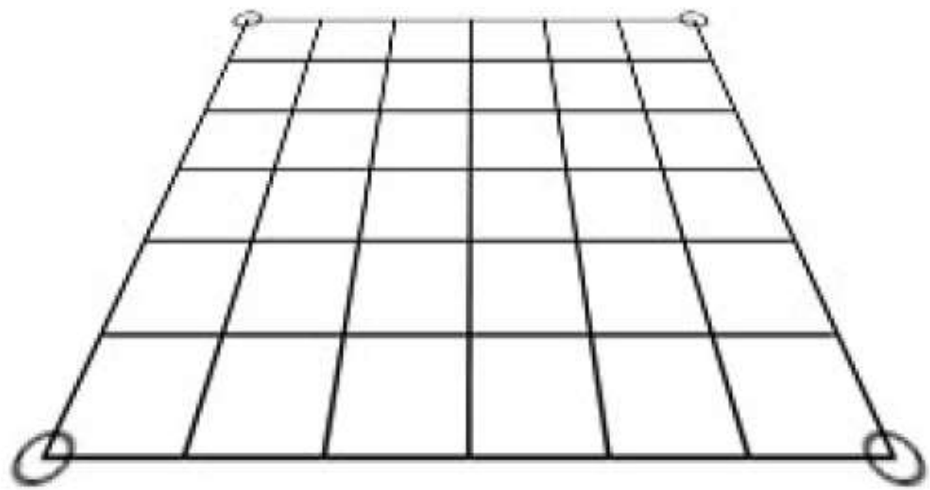


Image (central projection)
in negative position
c = camera constant
Perspective
centre
H = flying height
Image in
positive position
Object
(terrain)
Orthogonal projection
to a horisontal plane

Geometry of the Perspective View



A regular grid viewed orthogonally from above.



Same grid but viewed from an oblique angle.
Note that the perspective view creates scale differences and removes parallellity.

Types of Distortion

1. Film and print shrinkage
2. Atmospheric refraction of light rays
3. Image motion
4. Lens distortion

Types of Displacement

1. Curvature of the Earth
2. Tilt
3. Topographic or relief

Film and print shrinkage or expansion: the quality of the film and paper print is very important to the quality of data storage and accuracy.

Dilatation or shrinkage of film and print under heat or cold may change the scale of the photographs and the actual position of the objects on the photographs.

Scale distortions due to Lens Thickness

Lens distortion causes imaged positions to be displaced from their ideal locations. lens distortion radiates from the principal point, which causes object displacement either toward (closer to) or away (farther) from the principal point (the optical or geometric center) of the photograph than it actually is.

Because this distortion is radial from the principal point, objects near the edge of the photograph are more distorted.

There are two type of lens distortion one is symmetric radial distortion and decentring distortion. In modern precision aerial mapping cameras, lens distortions are typically less than 5 micro meters.

Symmetric radial lens distortion is an unavoidable product of lens manufactures although with careful design its effects can be reduced to a very small amount.

Decentering distortion is primarily a function of the imperfect assembly of lens elements, not the actual design.

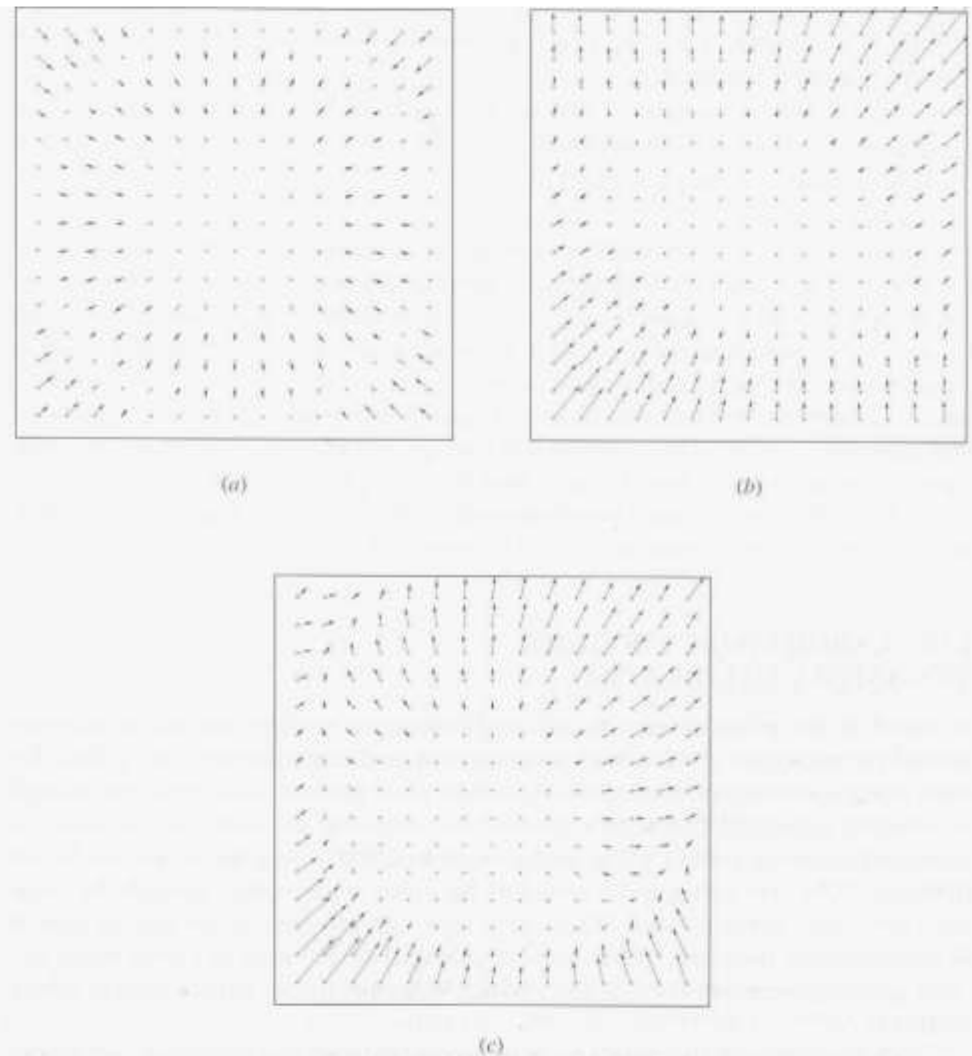
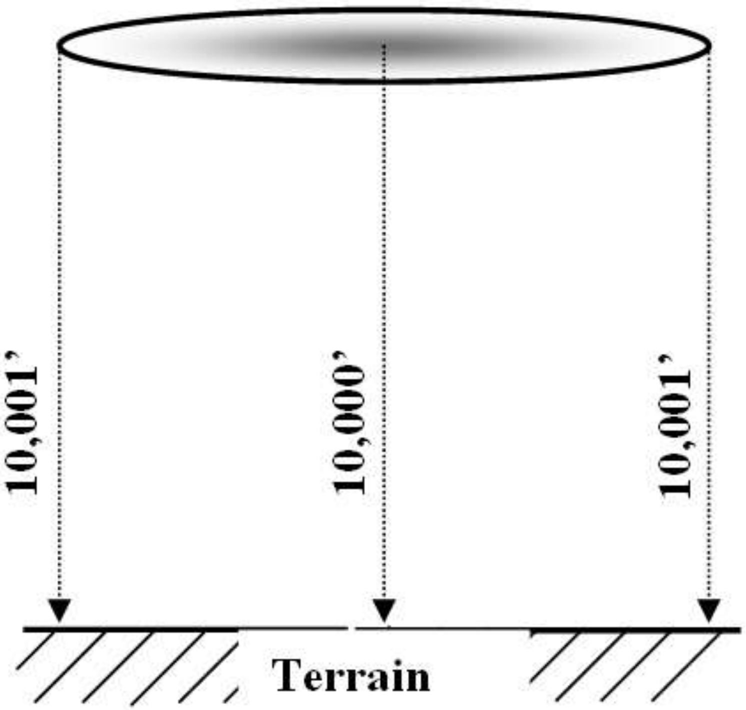
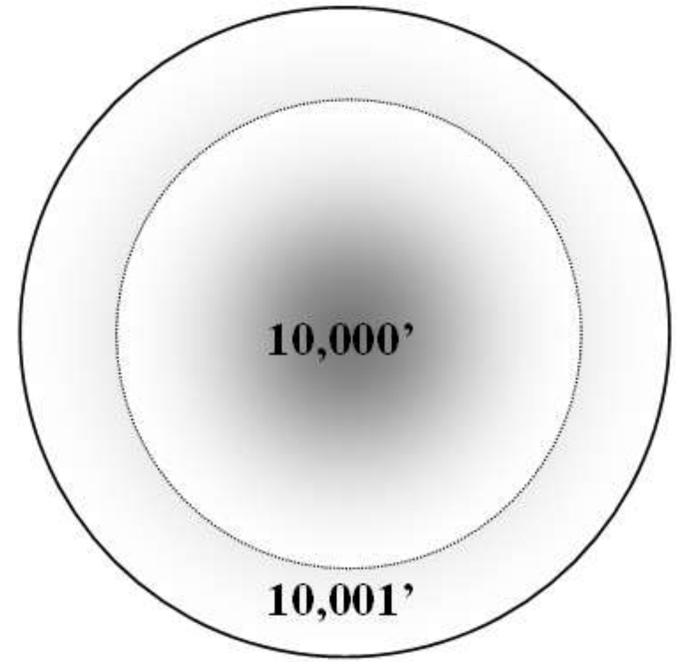


FIGURE 3-12
Lens distortion patterns: (*a*) symmetric radial, (*b*) decentering, and (*c*) combined symmetric radial and decentering.

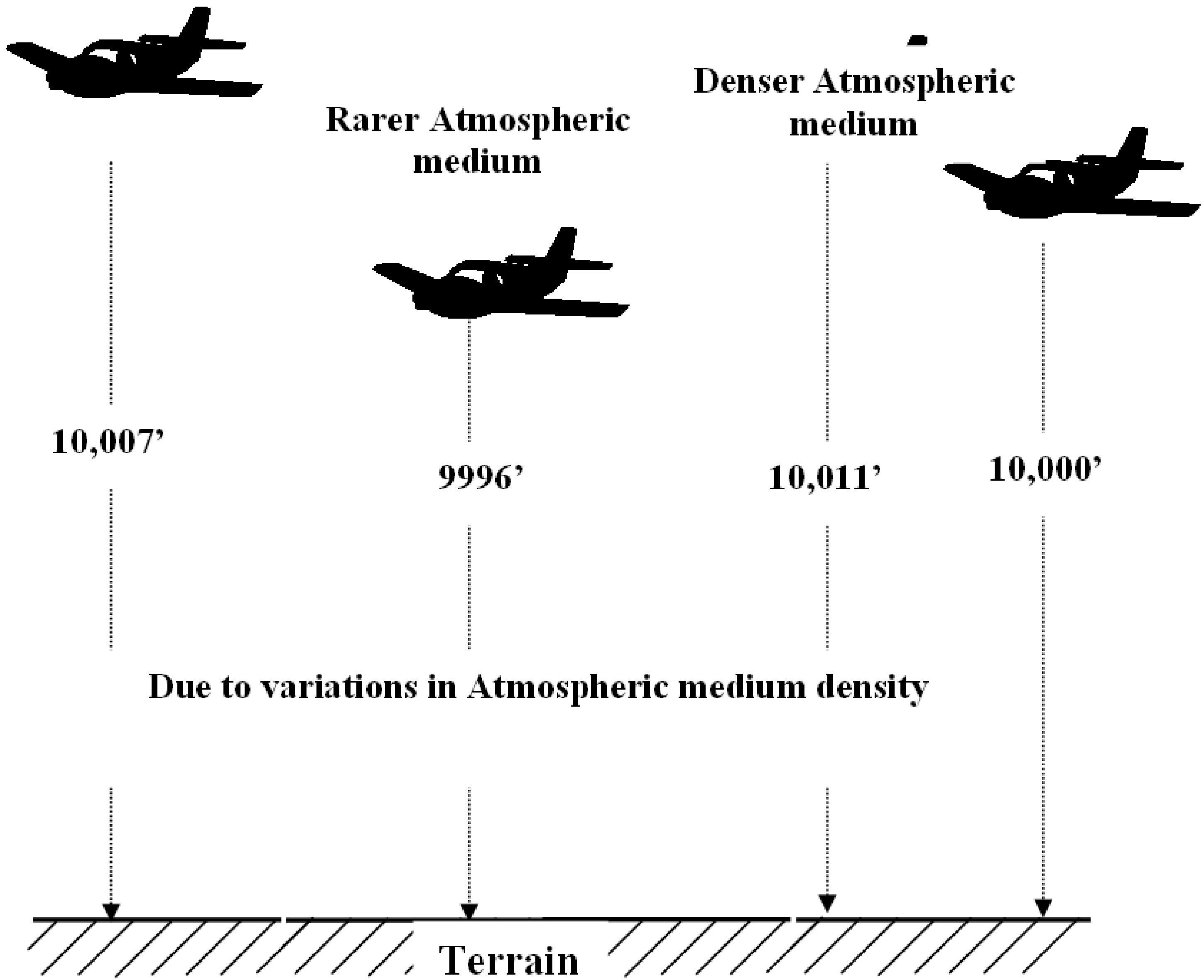
Vertical Cross Section View of Biconvex Lens



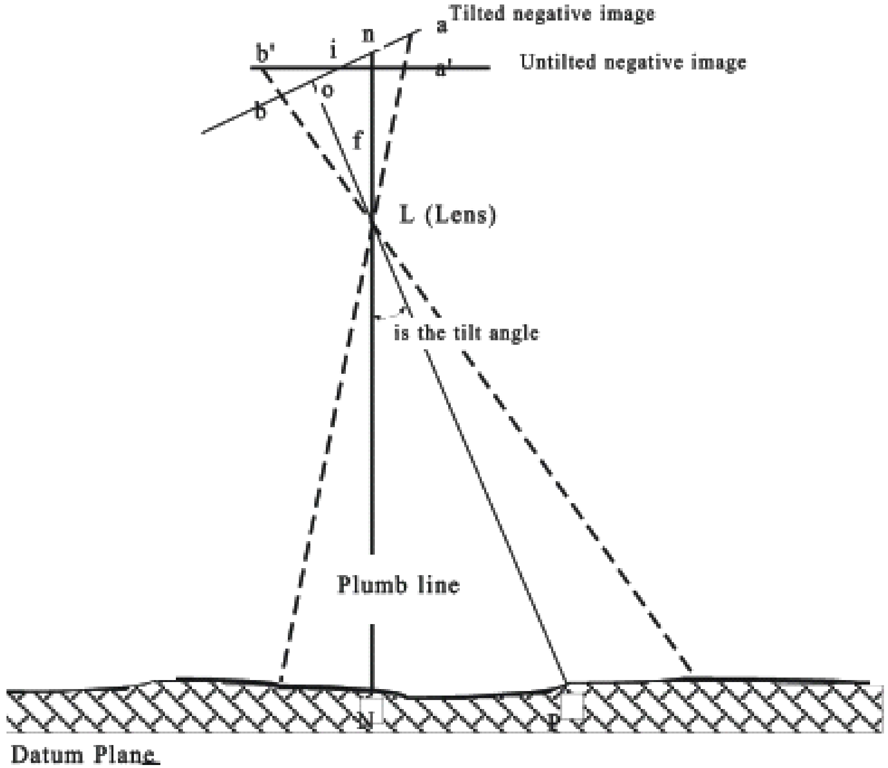
Top view



distortions due to sudden change in Flying height



Scale displacement due to Tilt in the Aircraft



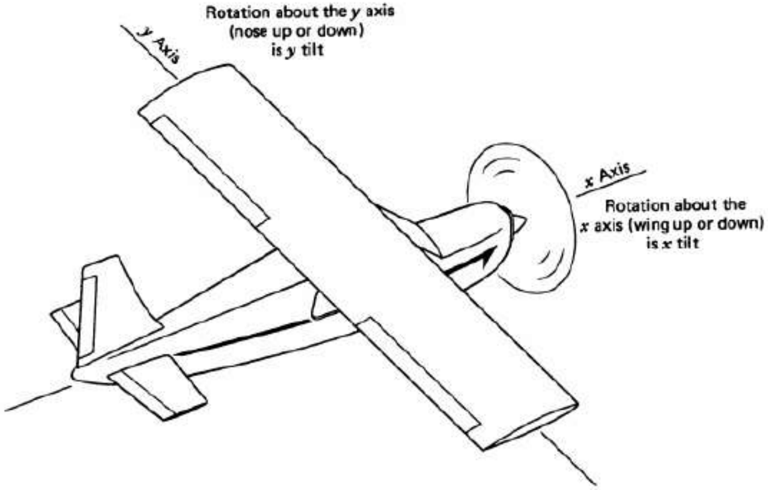
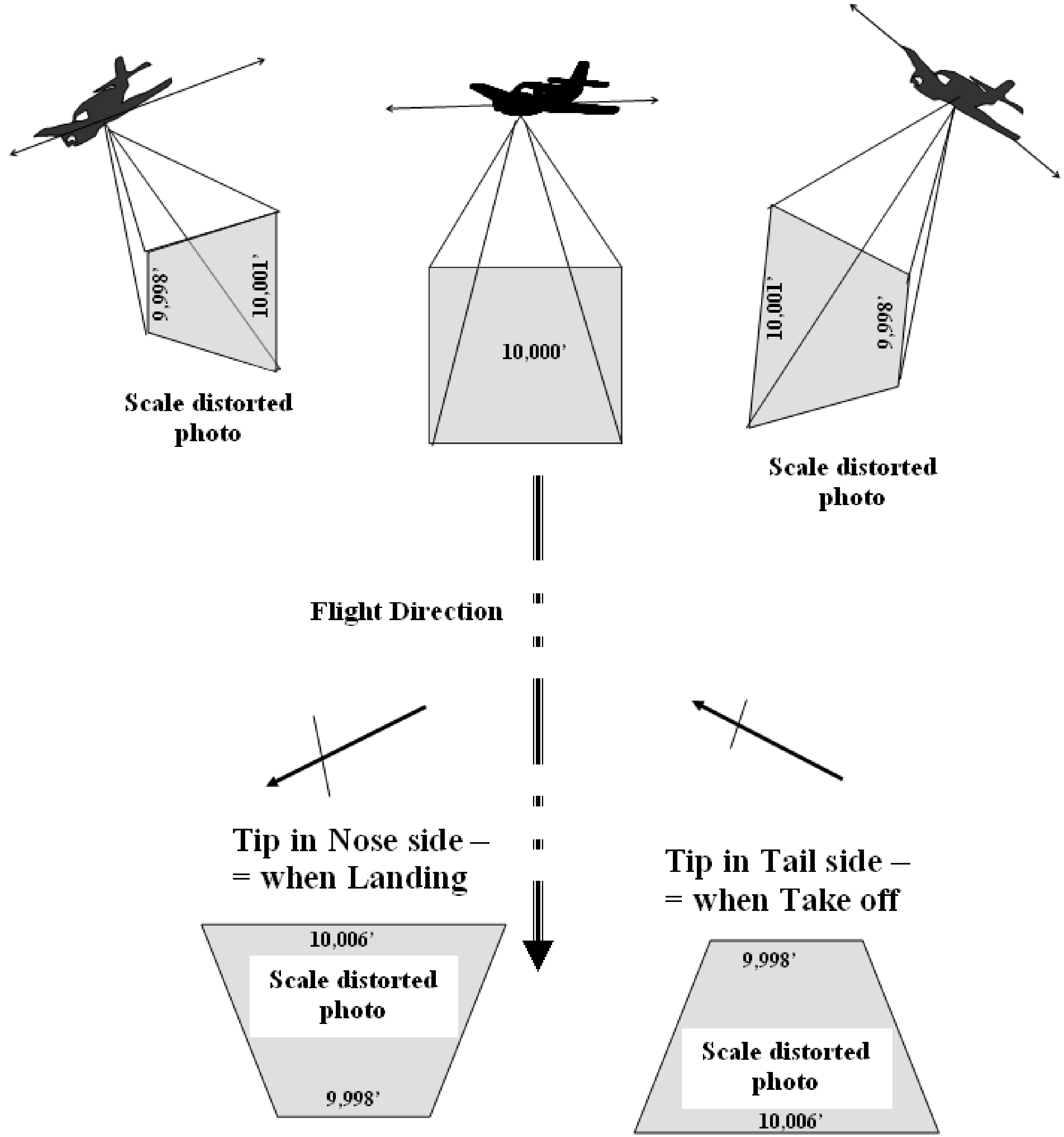


Figure 2.9. *x* and *y* tilt caused by the attitude of the aircraft (actually the camera) at the instant of exposure.

Displacement due to tilt is caused by the aircraft or other airborne platform not being perfectly horizontal at the moment of exposure. Rotation of the camera about the y axis (nose up or down) is y tilt and rotation about the x axis (wing up or down) is x tilt

Both radiate from the isocentre and cause images to appear to be displaced radially toward the isocentre on the upper side of the photo positive (not the negative) and radially outward or away from the isocentre on the lower side.


9,998’
10,001’
Scale distorted photo
10,000’
10,001’
9,998’
Scale distorted photo
Flight Direction
Tip in Nose side – = when Landing
10,006’
Scale distorted photo
9,998’
Tip in Tail side – = when Take off
9,998’
Scale distorted photo
10,006’

Relief Displacement on a vertical aerial photograph

Relief displacement is the shift or displacement in the photographic position of an image caused by the relief of the object

Relief displacement:
- Caused by the terrain undulations.
- The amount of displacement depends on the height of the object and the radial distance of the object from the image nadir.
- The most important source of positional error.

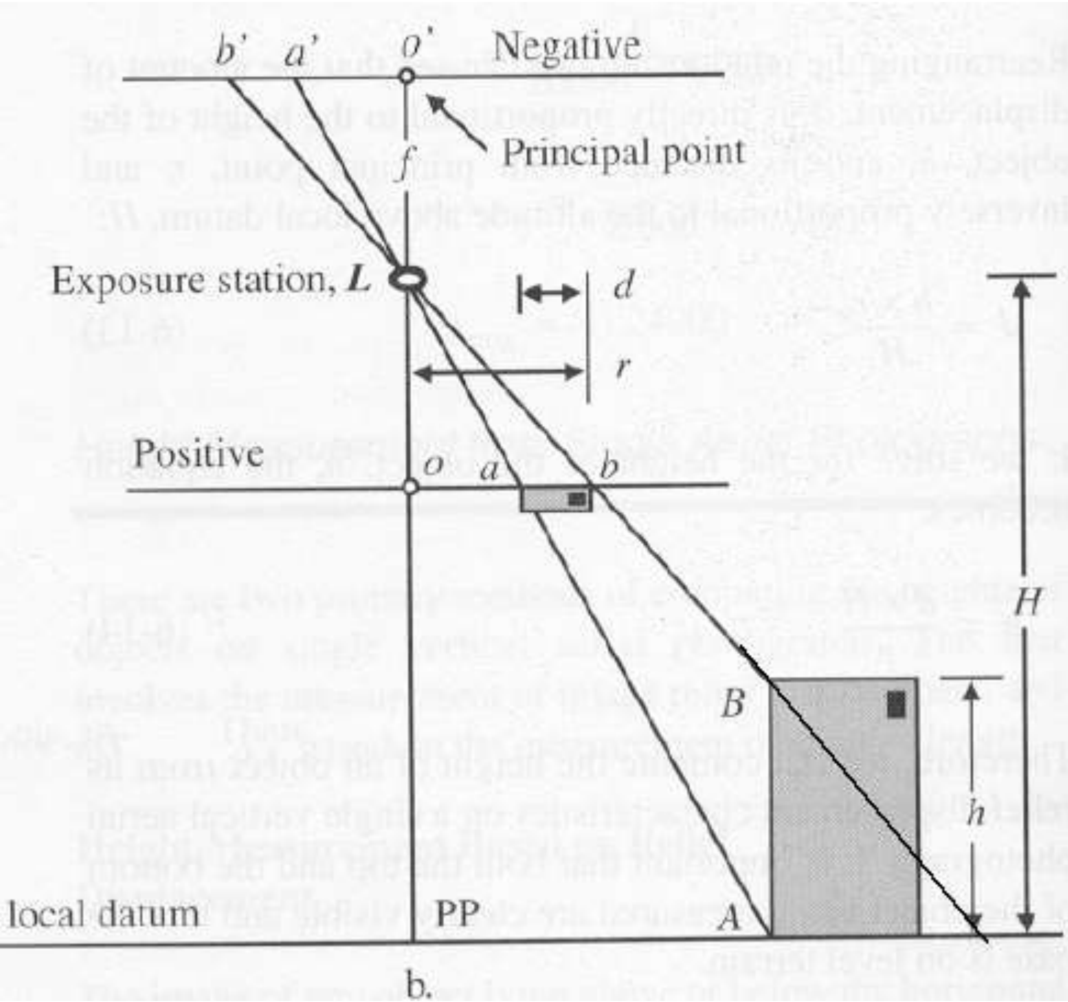
Relief Displacement

- Objects at edges of photo will appear to lean away from the principal point
- There is a mathematical relationship between object heights and the amount of displacement, which allows us to determine the heights of objects
- Relief displacement can also be used to create three-dimensional images

Avery and Berlin, *Fundamentals of Remote Sensing and Air Photo Interpretation*

Relief Displacement

Relief Displacement on a vertical aerial photograph



Relief displacement increases with
increase of radial distance from principle point (R) and Increase of object height (h)

Relief displacement decreases with
increase of Flying height above the datum (H)

From the above, we can calculate the Relief displacement as follows

$$D = \frac{rh}{H}$$

Two towers were identified on a perfectly vertical photograph taken from 2500 m above the datum. The distances from the base of the towers to the photo center are equal and are measured to be 8.35 cm. If the height of tower1 is 120 m and that of tower2 is 85 m above the datum, find the relief displacement of the summit of these towers on the photograph? Conclude.

$$D = \frac{rh}{H}$$

Where h = height above datum of the object point whose image is displaced

d = relief displacement

r = radial distance on the photograph from the principal point to the displaced image (the units of d and r must be the same).

H = flying height above the datum selected for measurement of h

$$d = \frac{8.35\,cm \,.\, 120\,m}{2500\,m - 120\,m} = 4.21\,mm \qquad d = \frac{8.35\,cm \,.\, 85\,m}{2500\,m - 85\,m} = 2.94\,mm$$

Conclusion: **Relief displacement varies directly as the height of the object. Because tower1 is higher than tower2, its image is displaced more.**

A vertical photograph taken from an elevation of 535 m above MSL contains the image of a tall vertical radio tower. The elevation at the base of the tower is 259 m above MSL. The relief displacement ‘d’ of the tower was measured as 54.1mm, and the radial distance to the top of the tower from photo centre was 121.7 mm. What is the height of the tower?.

$$d = rh/H$$

$$h = dH/r$$

d-relief displacement, **h**-height above datum of object point whose image is displaced, **r**-radial distance on photograph from principal point to displaced image

$H = 535 - 259$

$d = 54.1\text{mm}$, $r = 121.7$ mm, $H = 535 – 259 = 276$ m

$$h = \frac{54.1 \text{ mm} * 276 \text{ m}}{121.7 \text{ mm}} = 122.69 \text{ or } 123 \text{ m}$$

$h = 123$ m