Photogrammetry II
3rd Stage

Introduction & Overview

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Geometry of Aerial Photography

Classification of Photographs

- Terrestrial
- Aerial
  - Vertical
    - True
    - Tilted
  - Oblique
    - High
    - Low

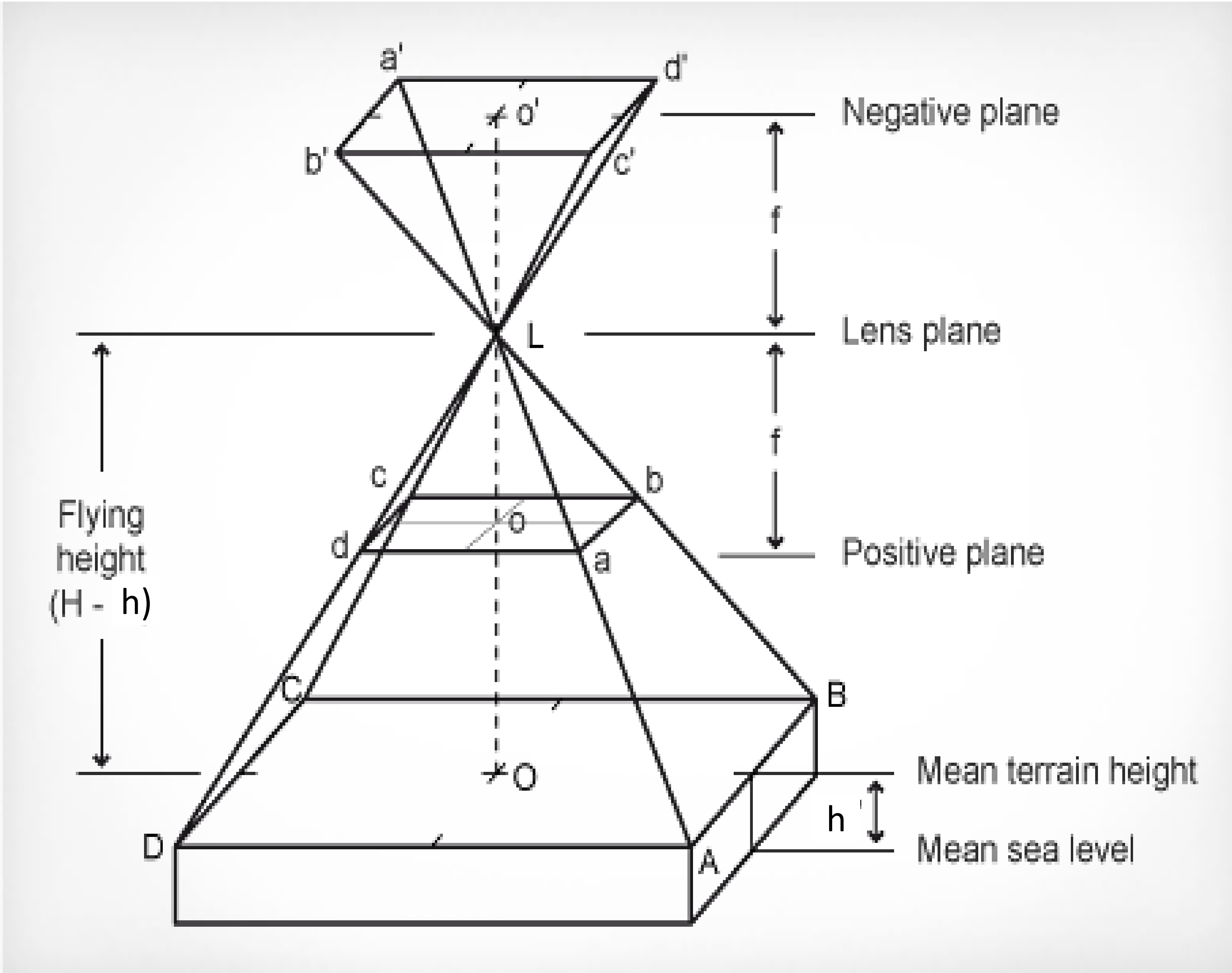
- We can define vertical aerial photograph as a photo taken from an aerial platform (either moving or stationary) wherein the camera axis at the moment of exposure is truly vertical.
- In actuality, vertical aerial photos with less than 3° tilt are considered vertical ; while those with more than 3° tilt are considered oblique.
- There are two basic types of oblique aerial photography.

1. High angle oblique
2. Low angle oblique.

High angle oblique

Low angle oblique

- In a high angle oblique, the apparent horizon is shown; while in a low angle oblique the apparent horizon is not shown.


a'
d'
o'
Negative plane
b'
c'
f
L
Lens plane
f
c
b
o
Flying
height
(H - h)
d
a
Positive plane
C
B
O
Mean terrain height
h
Mean sea level
D
A

The basic advantages of vertical aerial photograph

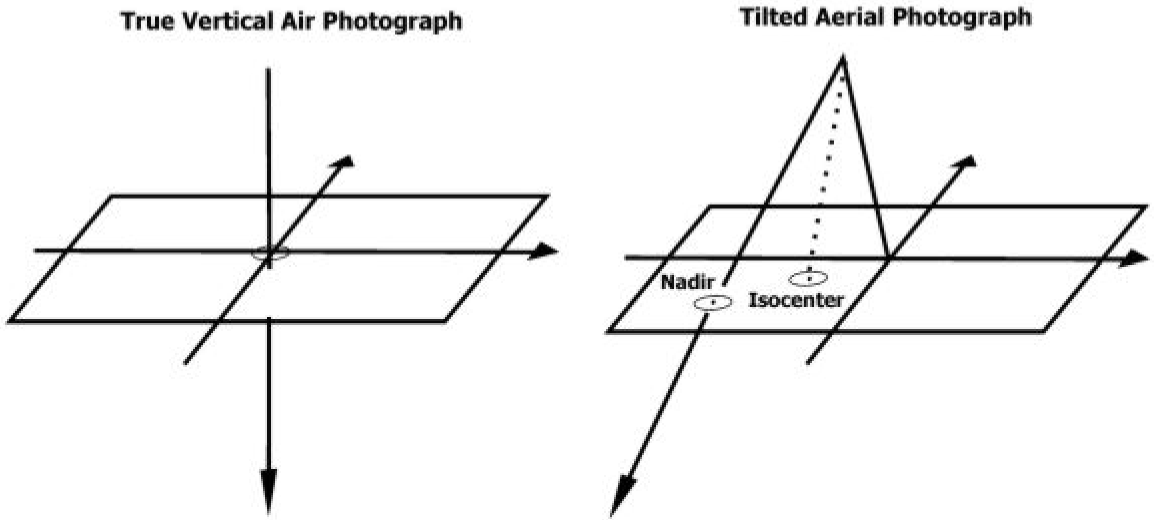
1. The scale is essentially constant;
2. Measurements of directions are easier than on oblique photograph. Directions can also be measured more accurately;
3. Within limits a vertical aerial photograph can be used as a map (if grids and marginal data are added);
4. Vertical aerial photographs are often easier to interpret than oblique and are better for stereo (there is no masking).

The advantages of an oblique aerial photograph

1. Given a constant altitude and camera you can cover a much larger area on a single photo;

2. The view of some objects is more familiar to the interpreter;

3. Some objects not visible on vertical photos may be seen on oblique.



Three terms need defining here, they are Principal Point, Nadir and Isocenter. They are defined as follows:

1. Principal Point - The principal point is the point where the perpendicular projected through the center of the lens intersects the photo image.
2. Nadir - The Nadir is the point vertically beneath the camera center at the time of exposure.
3. Isocenter - The point on the photo that falls on a line half- way between the principal point and the Nadir point.

On a true vertical aerial photograph all three of these would be at the same point.

Scale of vertical photographs

- Photo Scale

$$s_p = \frac{f}{H} \longrightarrow s_p = \frac{f}{H} = \frac{0.5\text{ ft}}{1200\text{ ft}} = \frac{1\text{ ft}}{2400\text{ ft}}$$

which is analogous to a representative fraction of 1:2400.

A simplified formula for determining photo scale, derived from the photo scale ratio, is presented in Equation 6.3.

$$s_p = H/f \tag{6.3}$$

where:

s_p = photo scale denominator (feet)
H = flight height above mean ground level (feet)
f = focal length of camera (inches)

Scale of vertical photographs

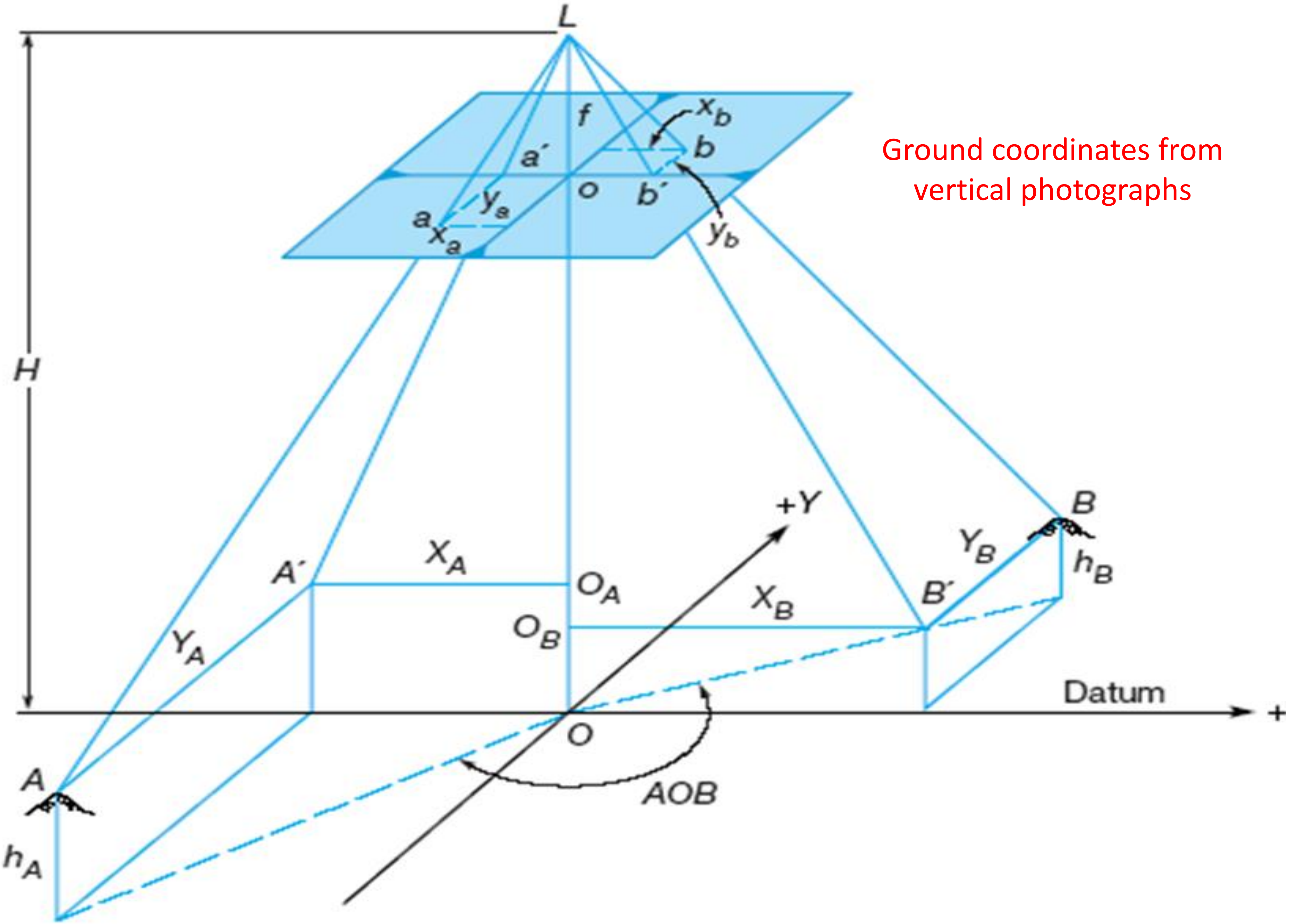
Terms:

- Average photo scale $S_{avg} = \frac{f}{H - h_{avg}}$
- Photo scale over variable terrain $S = \frac{f}{H - h}$
- Maximum photo scale
- Minimum photo scale

If the f, H, and h are not available, but a map is available then:

$$\text{Photo Scale} = \frac{\text{photo distance}}{\text{map distance}} \times \text{map scale}$$

Ground coordinates from vertical photographs



Ground coordinates from vertical photographs

- With image coordinate system defined, we define an arbitrary ground coordinate system.
- That ground system could be used to compute distances and azimuths. Coordinates can also be transformed to any system
- In that ground system:

$$X_a = x_a * (\text{photograph scale at a})$$
$$Y_a = y_a * (\text{photograph scale at a})$$

Flying height of a vertical photograph

- Flying height can be determined by:
  - Readings on the photos
  - Applying scale equation, if scale could be computed
    - Example: what is the flying height above datum if f=6”, average elevation of ground is 900ft, scale is 1”:100ft? Is it 1500’?
  - Or, if two control points appear in the photograph, solve the equation:

    $L^2 = (X_B - X_A)2 + (Y_B - Y_A)^2$

then solve the same equation again replacing the ground coordinates with the photo coordinates.

Perspective and Projection

- On a map <u>objects and features are both planimetrically and geometrically accurate</u>. That is objects are located on the map in exactly the same position relative to each other as they are on the surface of the Earth, <u>except with a change in scale</u>. This is due to the fact that maps use an orthographic projection (i.e. using parallel lines of site) and constant scale to represent features.
- Aerial photographs on the other hand are created using a central or perspective projection. Therefore, the relative position and geometry of the objects depicted depends upon the location from which the photo was taken.

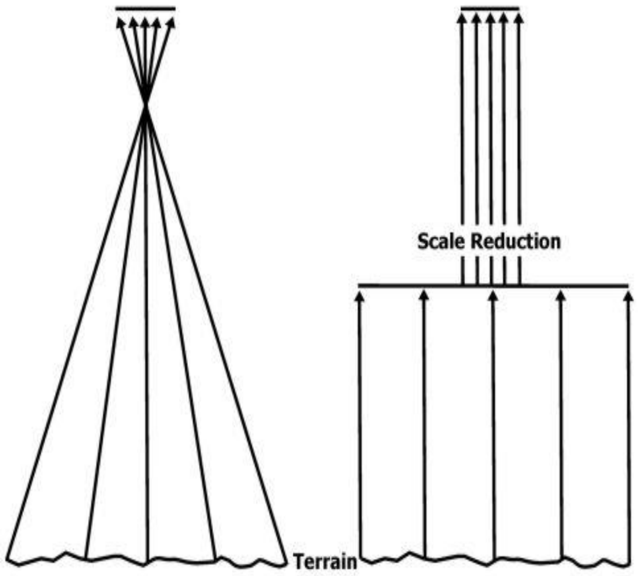
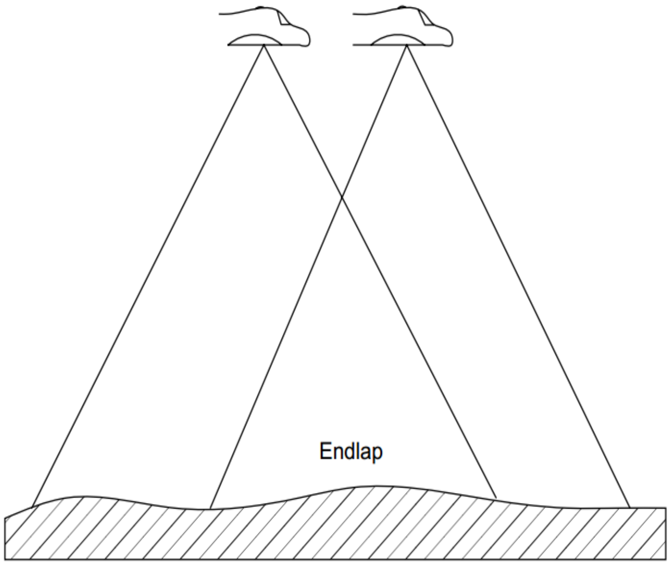
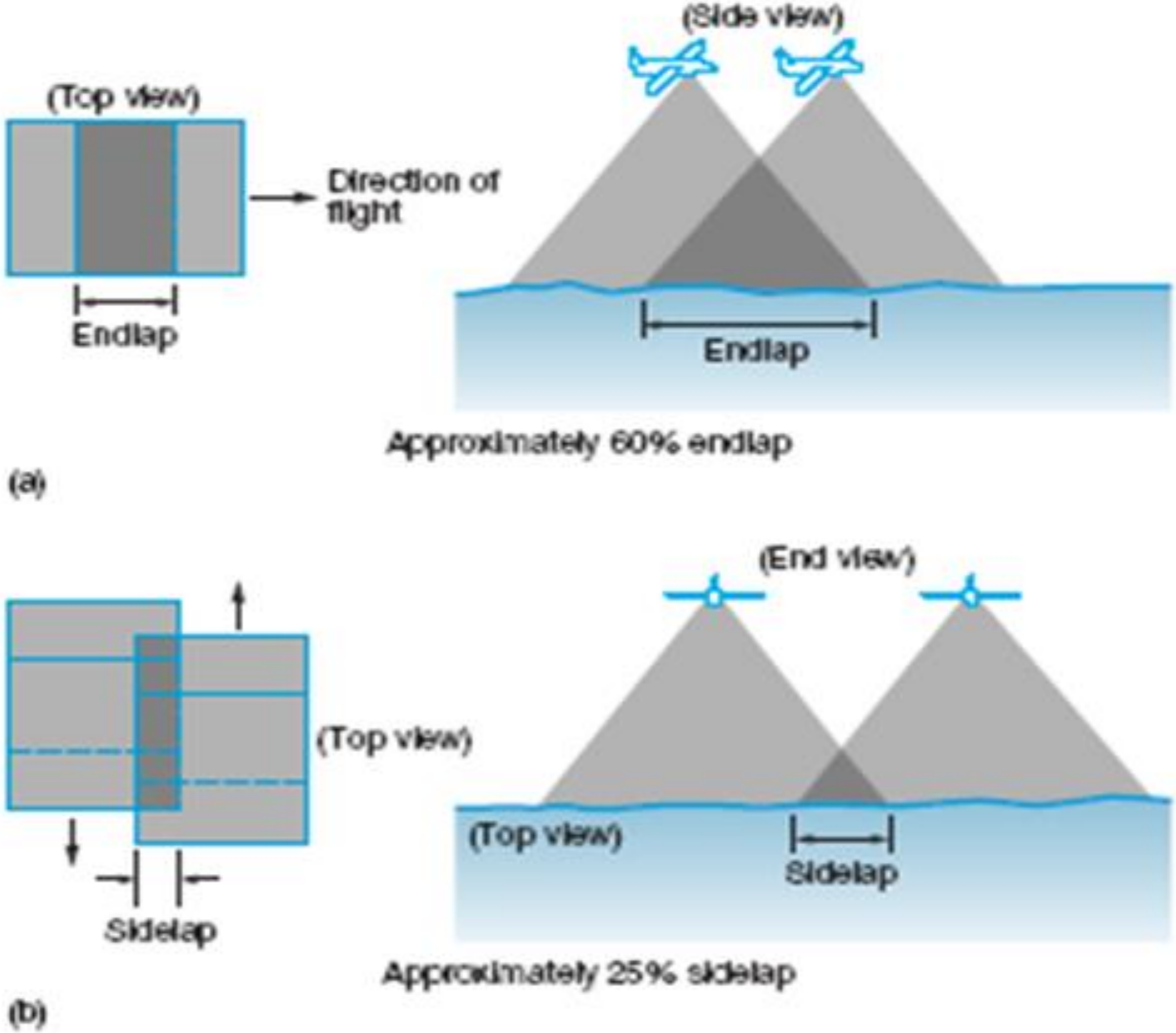


Photo overlap - Endlap

- Aerial photo projects for all mapping and most image analyses require that a series of exposures be made along each of the multiple flight lines.
- To guarantee <u>stereoscopic coverage</u> throughout the site, the photographs must overlap in two directions: in the line of flight and between adjacent flights.



Endlap on two consecutive photos in a flight line.


(Top view)
Direction of flight
Endlap
(Side view)
Endlap
Approximately 60% endlap
(a)
(Top view)
Sidelap
(End view)
(Top view)
Sidelap
Approximately 25% sidelap
(b)

Normally, endlap ranges between 55 and 65% of the length of a photo, with a nominal average of 60% for most mapping projects. Endlap gain, the distance between the centers of consecutive photographs along a flight path, can be calculated by using Equation 6.5.

$$g_{end} = s_p * w * \left[\left(100 - o_{end}\right)/100\right] \tag{6.5}$$

where:

g_{end} = distance between exposure stations (feet)
s_p = photo scale denominator (feet)
o_{end} = endlap (percent)
w = width of exposure frame (inches)

When employing a precision aerial mapping camera with a 9 × 9 in. exposure format and a normal endlap of 60%, the formula is simpler. In this situation, two of the variables then become constants:

w = 9 in.
o_{end} = 60%

Photo overlap - Sidelap

Sidelap, sometimes called side overlap, encompasses the overlapping areas of photographs between adjacent flight lines. It is designed so that there are no gaps in the three-dimensional coverage of a multiline project. Figure 6.5 shows the relative head-on position of the aircraft in adjacent flight lines and the resultant area of exposure coverage.

Usually, sidelap ranges between 20 and 40% of the width of a photo, with a nominal average of 30%. Figure 6.6 portrays the sidelap pattern in a project requiring three flight lines.

Sidelap gain, the distance between the centers of adjacent flight lines, can be calculated by using Equation 6.7.

$$q_{side} = s_p * w * \left[\left(100 - o_{side} \right) / 100 \right] \tag{6.7}$$

where:

g_{side} = distance between flight line centers (feet)
s_p = photo scale denominator (feet)
o_{side} = sidelap (percent)
w = width of exposure frame (inches)

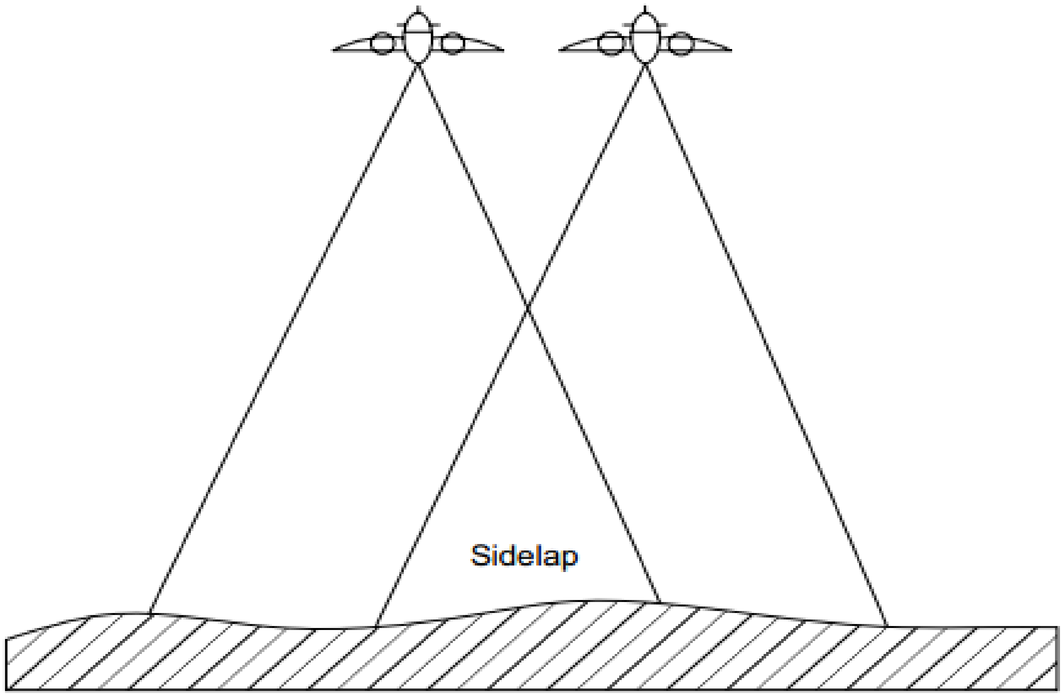


Figure 6.5 Sidelap between two adjacent flight lines.

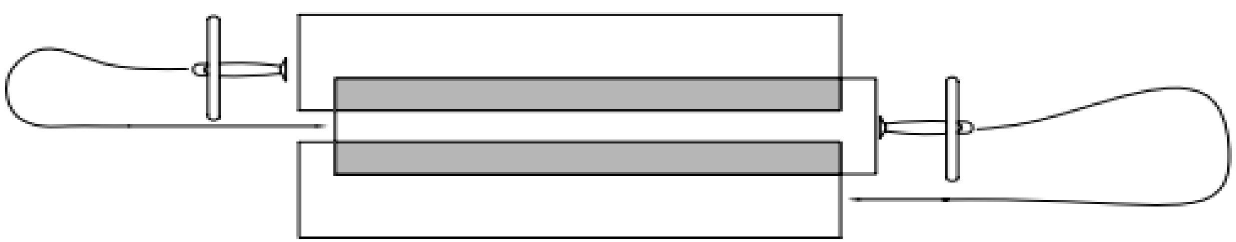


Figure 6.6 Sidelap on three adjacent flight lines.

Distortion and Displacement

There are basically four types of distortions and three types of displacement.

- Types of distortion include:

1. Film and Print Shrinkage;
2. Atmospheric refraction of light rays;
3. Image motion;
4. Lens distortion.

- Types of displacement include:

1. Curvature of the Earth;
2. Tilt;
3. Topographic or relief (including object height).

Distortion and Displacement

- The effects of film shrinkage, atmospheric refraction and the curvature of the Earth are usually negligible in most cases - the exception is precise mapping projects.
- Displacement is typically the largest problem/effect impacting our analyses.
- Both distortion and displacement cause changes in the apparent location of objects in photos.

Distortion and Displacement

- Distortion - Shift in the location of an object that changes the perspective characteristics of the photo.
- Displacement - shift in the location of an object in a photo that does not change the perspective characteristics of the photo (The fiducial distance between an object's image and it's true plan position which is caused by change in elevation.)
- These types of phenomena are most evident in terrain with high local relief or significant vertical features.
- As stated above we will consider here three main types of problems/effects caused by specific types of distortion and displacement. These are the problems/effects associated with:

  1. Lens distortion;
  2. Tilt Displacement;
  3. Topographic Displacement.

- Lens distortion - Small effects due to the flaws in the optical components (i.e. lens) of camera systems leading to distortions (which are typically more serious at the edges of photos). These effects are radial from the principal point (making objects appear either closer to, or farther from the principal point than they actually are); and may be corrected using calibration curves.
- Tilt Displacement - A tilted photograph presents a slightly oblique view rather than a true vertical record. All photos have some tilt. Tilt is caused by the rotation of the platform away from the vertical. This type of displacement typically occurs along the axis of the wings or the flight line. If the amount and direction of tilt are known then the photo may be rectified.
- Topographic Displacement - This is typically the most serious type of displacement. This displacement radiates outward from Nadir. Topographic displacement is caused by the perspective geometry of the camera and the terrain at varying elevations.

Topographic displacement is not necessarily bad as it allows:

1. Stereo viewing;
2. Height measurement;
3. Topographic mapping.

Relief/height/topographic/ displacement

- The formula for topographic or height displacement on a single photo is:

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

Where:

d = Radial displacement (with respect to the Nadir).

r = Radial photo distance from Nadir (use PP) to the point of displacement (usually the top of the object).

h = Height of the object or difference in elevation.

H = Flying height above the base of the object.

Relief displacement

Relief displacement

A close look at the equations involved in the calculations of relief displacement show that some important general relationships are involved. These relationships can be stated as follows:

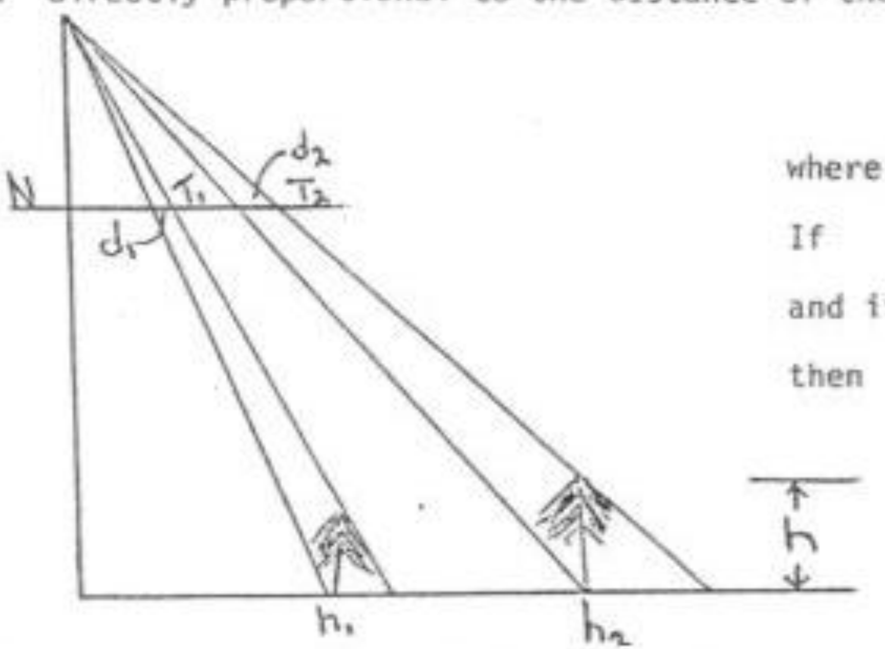
1. There is no topographic displacement at Nadir. If r is zero, then so is d.

2. Assuming datum elevation to be at Nadir, points above the datum are displaced radially away from Nadir while points below datum are displaced radially towards Nadir.

Relief displacement

3. Topographic displacement varies directly with the radial distance from the Nadir to the object.

A. directly proportional to the distance of the displaced image from the photo nadir.



where N is the photographic Nadir

If $h_1 = h_2$

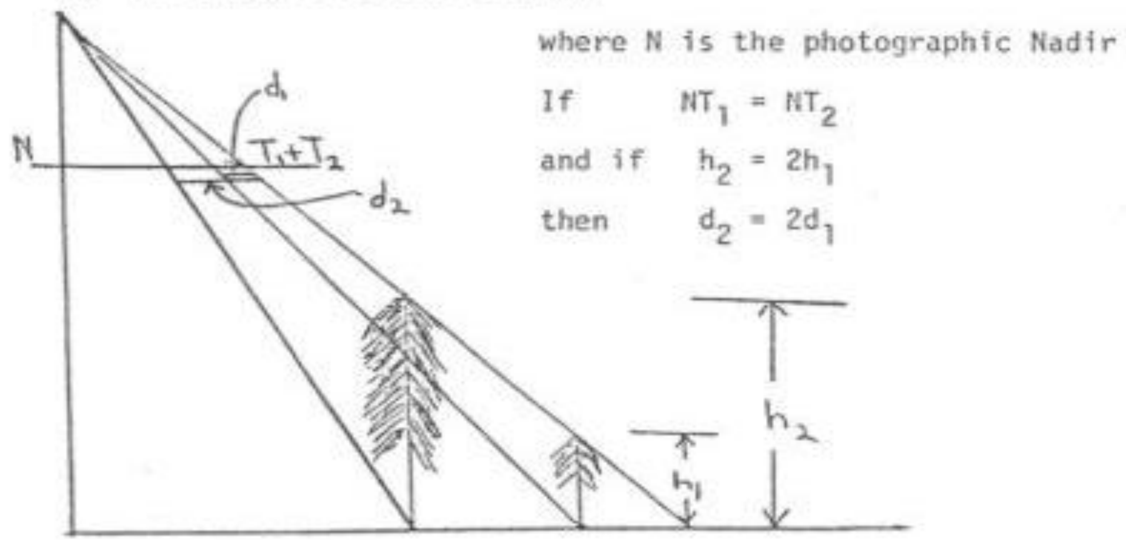
and if $NT_2 = 2NT_1$

then $d_2 = 2d_1$

Relief displacement

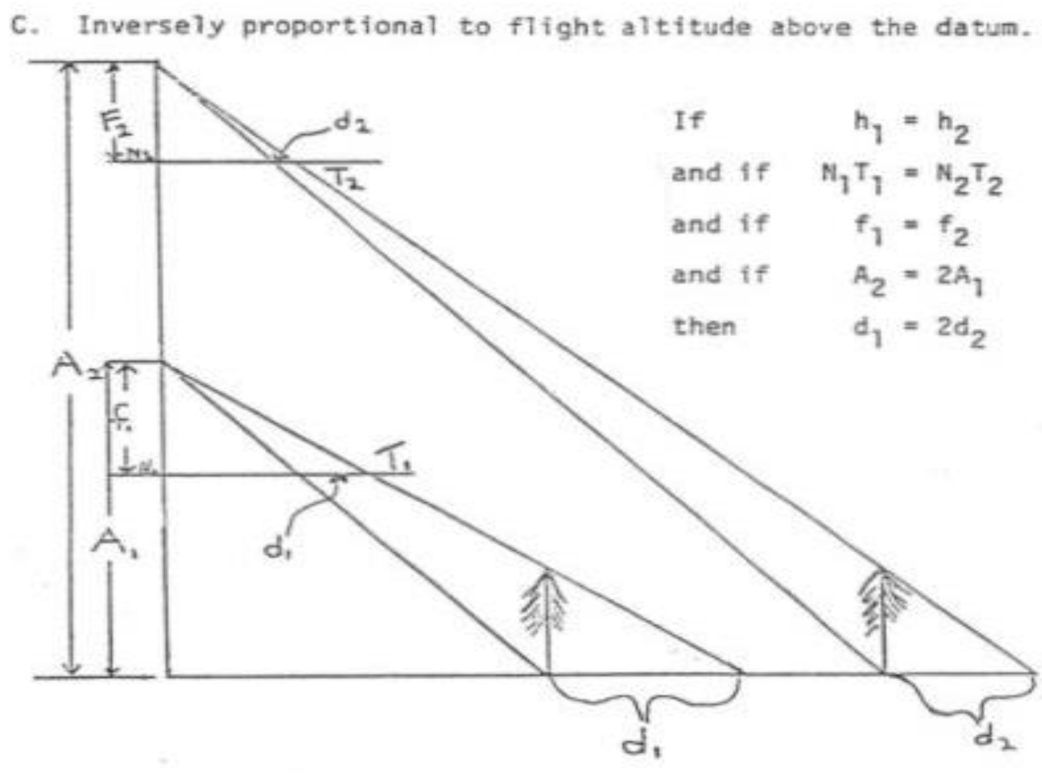
4. Topographic displacement varies directly with the height of an object. A 100 ft. tree would be displaced twice as far as a 50 ft. tree the same distance from Nadir.

B. directly proportional to the height of the displaced image above the datum (or its depth below the datum).



Relief displacement

5. Topographic displacement varies inversely with the flying height of the base of the object. As a result there is little apparent topographic displacement on space photography.



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