Aerial Photogrammetry

Introduction

Photogrammetry

The art, science and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and phenomenon.

Aerial photogrammetry

Photographs of terrain in an area are taken by a precision photogrammetric camera mounted in an area flying over an area.

Use of Aerial Photographs

→ Geological Investigations
→ Soil surveys
→ Land surveys
→ Tax mapping
→ Reconnaissance and military intelligence
→ Urban & Regional Development
→ Transportation system investigation
→ Quantity investigation
→ Shore erosion etc.

Types of photographs

1. Terrestrial photograph
2. Aerial photograph

1. Terrestrial photograph

When photographs are taken with photo theodolite having camera station on the ground and the axis of the camera horizontal or nearly horizontal the photographs are called the terrestrial photographs. They are generally used for the survey of structures and architectural or archeological monuments.

2. Aerial photographs

These photographs obtained are the result of photography of ground from air with a camera mounted on an aircraft. An aerial photograph may be regarded as a gonomic or perspective projection.

Depending upon the angle between the axis of camera and the vertical axis, the aerial photographs may be classified as -

a) Vertical photograph
b) Oblique photograph
c) Convergent photograph
d) Trimetrogen photograph.

Early Aerial Camera

→ Pigeon mounted camera
→ Magazine camera

Modern Aerial Camera

→ Drone camera
→ Unmanned aerial vehicle (UAV) camera
→ Satellite camera

Types of Photographs

(P.T.O.)

1. Vertical Photograph → Axis of camera vertical
   Tilt Photograph → Axis of camera axis < 3° (unintentionally)
2. Oblique Photograph → Axis of camera inclined to vertical line > 3° (intentionally)
3. Convergent Photograph → Photograph taken with pair of camera with axis inclined
4. Trimetrogen Photograph → assemblage of three photographs taken at the sametime

1. **Vertical Photograph** – A vertical photograph is taken with the camera pointed as straight down as possible. Allowable tolerance in usually +3° from the perpendicular (plumb) line to the camera axis. The result is coincident with the camera axis.

A vertical photograph has following characteristics:

1) The lens axis is perpendicular to the surface of the earth.

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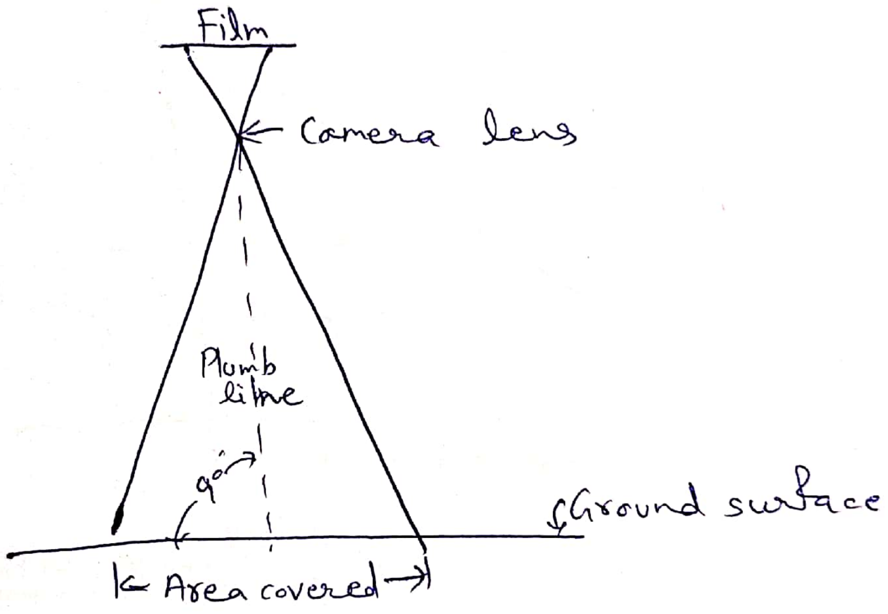
2) It covers a relatively small area.
3) The shape of the ground area covered on a single vertical photo closely approximates a square of rectangle.
4) Being a view from above, it gives an unfamiliar view of the ground.
5) Distance and directions may approach the accuracy of maps if taken over flat terrain.



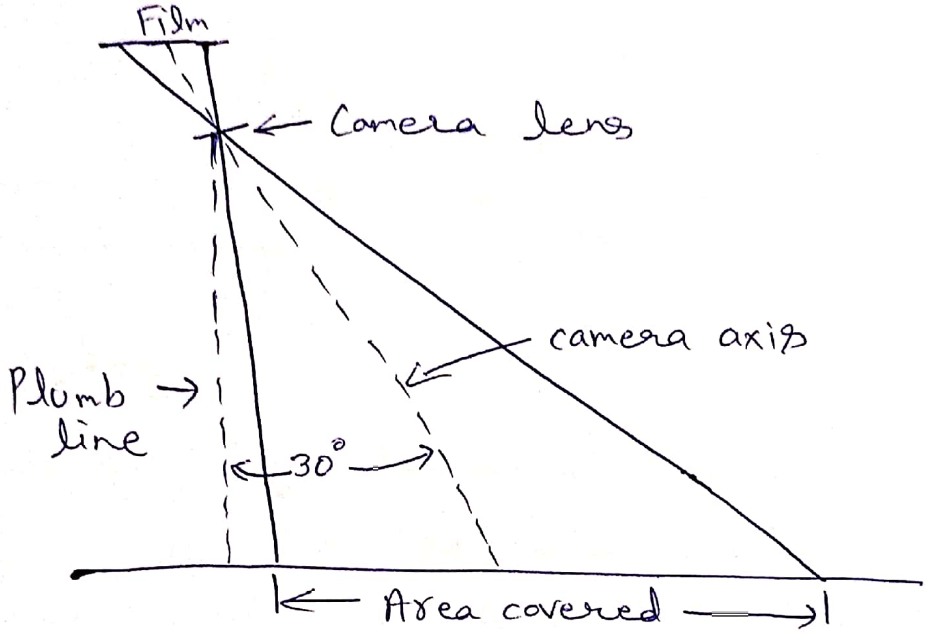
2) Oblique Photograph P.T.O.

It is used to study an area before an attack, to substite for a reconnaissance, to sublstitute for a map or to supplement a map.
An oblique has following characteristics:

1) It covers a relatively smaller area.
2) The ground area covered is trapezoid, although the photo is square or rectangular.
3) The objects have a more familiar view, comparable to viewing from the top of a high hill or tall building.

4) No scale is applicable to the entire photograph, and distance cannot be measured. Parallel lines on the ground are not parallel on this photograph; therefore, direction (azimuth) cannot be measured.

5) It does not show the horizon.

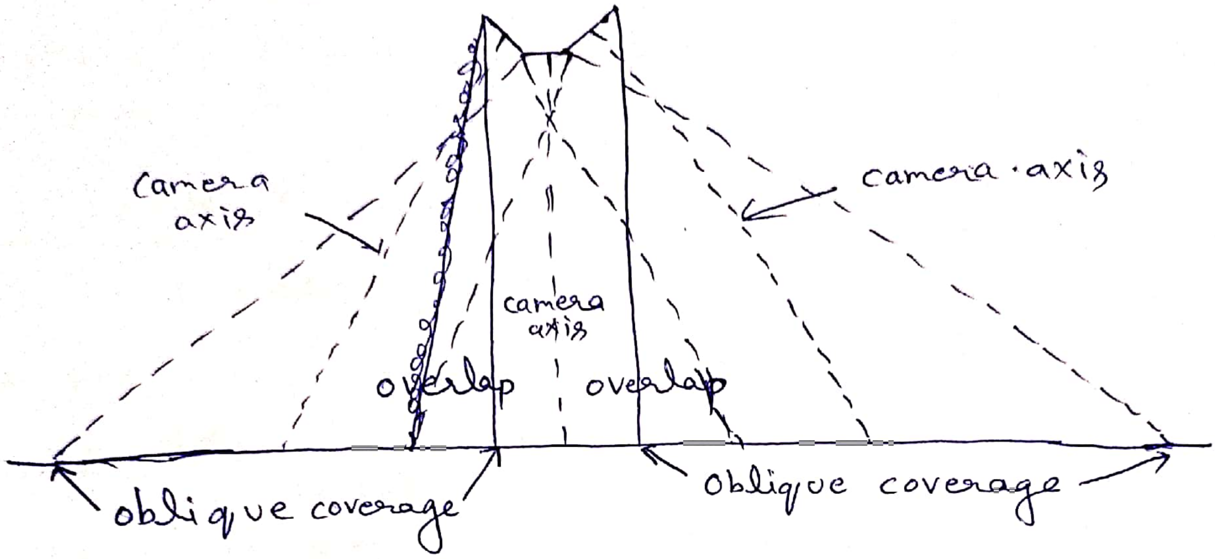


3) Convergent photograph

~~Photographs~~ These are done with a single twin-lens, wide-angle camera, or with two single-lens, wide-angle cameras coupled rigidly in the same mount so that each camera axis converges when intentionally tilted a prescribed amount (usually 15 to 20°) from the vertical.

4) Trimetrogen photographs

This is an assemblage of three photographs taken at the same time, one vertical and two high obliques, in a direction at right angle to the line of flight. The obliques, taken at an angle of 60° from the vertical, side from the vertical photography, producing composites from horizon to horizon.



Basic Principles

In ~~photograph~~ photogrammetry, photographs are taken by means ~~by~~ of a phototheodolite which is combination of a camera and a theodolite or camera mounted on a ~~e~~aircraft.

In this, the directions of same objects photographed from extremities of measured base are known, their positions can be located by the intersection of two rays to the same object.

Definitions used in Aerial Photogrammetry —

Exposure station (o) :- The point in the ~~camera~~ atmosphere occupied by center of camera lenses at instance of photography.

Flying height : Vertical distance between exposure station and mean sea level.

Flight line :- Line traced by exposure station in atmosphere (track of aircraft).

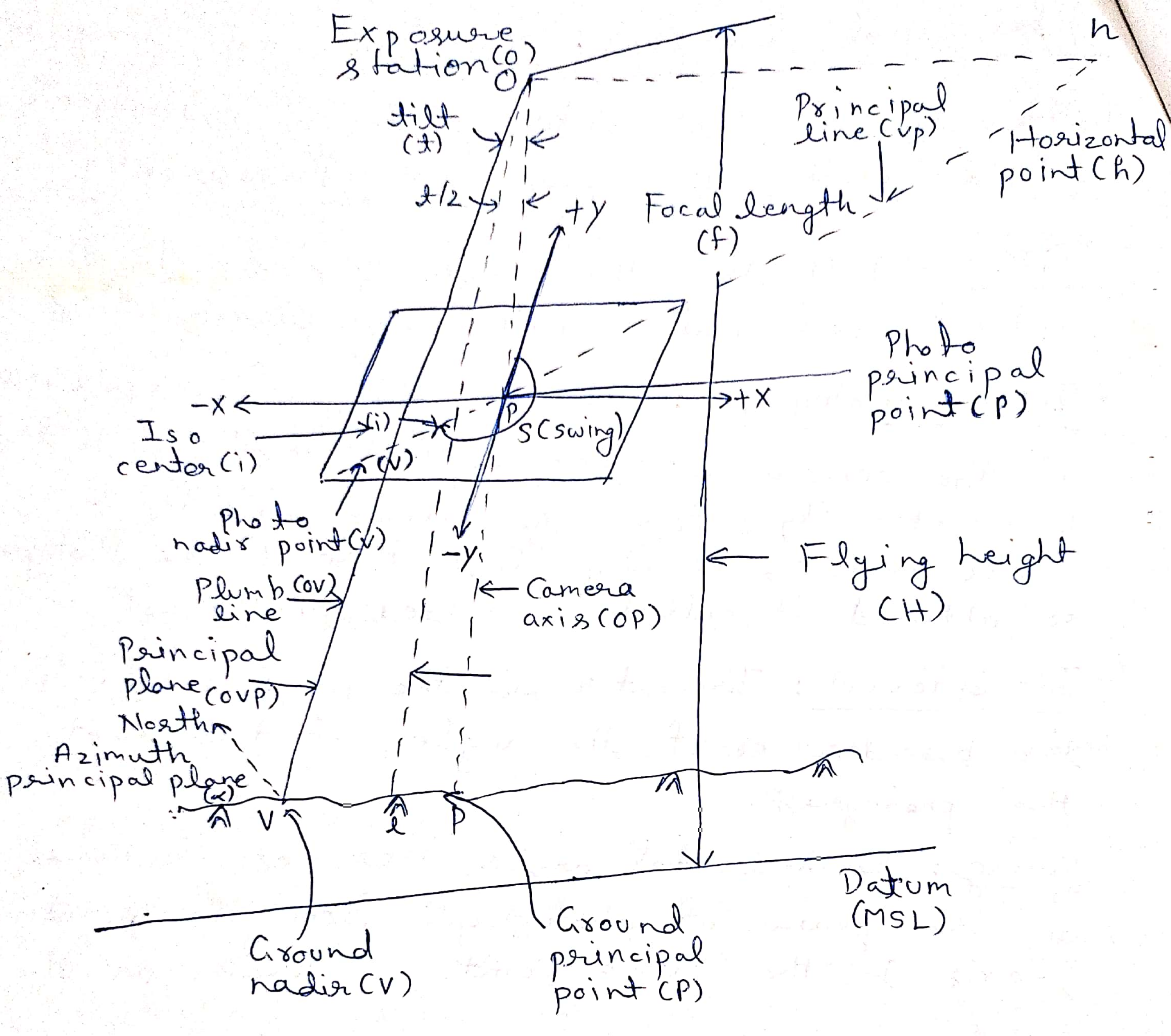
Photo principal point (k) :- It is point on photograph obtained by projecting camera axis to intersect at a point on photograph known as photo principal point (k).

Ground principal point (K) :- Camera axis extended up to ground, the point obtained on ground is called Ground Principal point (K).

Photo nadir point (n) :- It is a point on photograph obtained by dropping vertical line from camera center. That plumb line extended upto ground gives Ground Nadir Point (N).

Horizon point (h) :- It is point of intersection of horizontal line through center of lenses and principal line (np) on photograph.

Principal plane : Plane obtained by exposure station (o), Ground nadir point (N) and ground principal point (P) (i.e. plane NOK)



Exposure station (O)
O
h
tilt (t)
t/2
+y
Principal line (vp)
Horizontal point (h)
Focal length (f)
Photo principal point (p)
-X
+X
Iso center (i)
(i)
(v)
p
S (swing)
Photo nadir point (v)
-y
Plumb line (ov)
Camera axis (OP)
Flying height (H)
Principal plane (ovp)
North
Azimuth principal plane (α)
V
I
P
Ground nadir (V)
Ground principal point (P)
Datum (MSL)

Principal line - Line of intersection of principal plane with photograph plane.

Azimuth (A) :- Clockwise horizontal angle measured about ground nadir point from true north to the principal plane of photograph (ϕ).

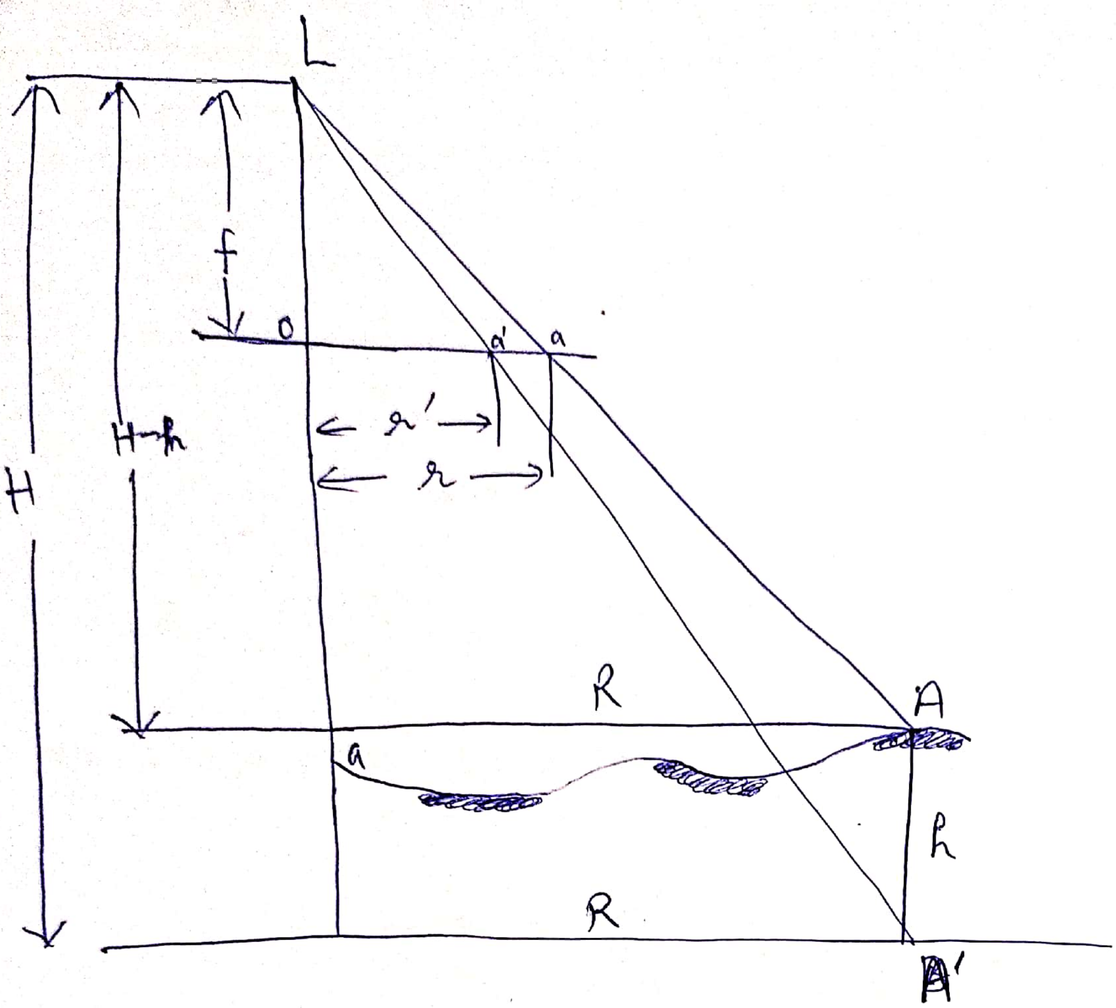
Swing (s) :- Angle measured in plane of photograph from ty axis clockwise to photo nadir point.

Isocenter (i) :- Point on photo where bisection of tilt falls on photo. (dotted line in sketch)

Axis of tilt :- It is line in plane of photograph perpendicular to principal line at the isocenter.

Relief Displacement

Illustration of deformation of an aerial image according to the distance from the nadir point i.e. centre of the image. A vertical object (such as a building for instance) will appear to be lying along a line radial to the image nadir point. This deformation is called relief displacement.



→ L is the pespective centre of the camera system

→ A is the point on ground at an elevation of h with repesct to the datum.

→ a is the image of ground point on photograph.

→ a' is the location of projected point A' on the datum

Fig. indicates that although point A is vertically above point B, their images are not coinciding and are displaced on photographic plane due to relief.

- The displacement of the point 'a' on the photograph from its true posidion, due to height, is called the height or relief displacement or relief distortion (RD).

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Magnitude of Relief Distortion :-

$$\frac{f}{H-h} = \frac{r}{R}$$

$$\frac{f}{H} = \frac{r'}{R}$$

$$r = \frac{Rf}{H-h} \quad \text{and} \quad r' = \frac{Rf}{H}$$

$$R = \frac{r(H-h)}{f} \quad \text{and} \quad R = \frac{r'H}{f}$$

Relief distortion, $d = r - r' = \frac{Rf}{H-h} - \frac{Rf}{H} = \frac{Rfh}{H(H-h)}$

$$d = r - r' = \frac{rh}{H} = \frac{r'h}{H-h}$$

Differentiating d with respect to H gives :

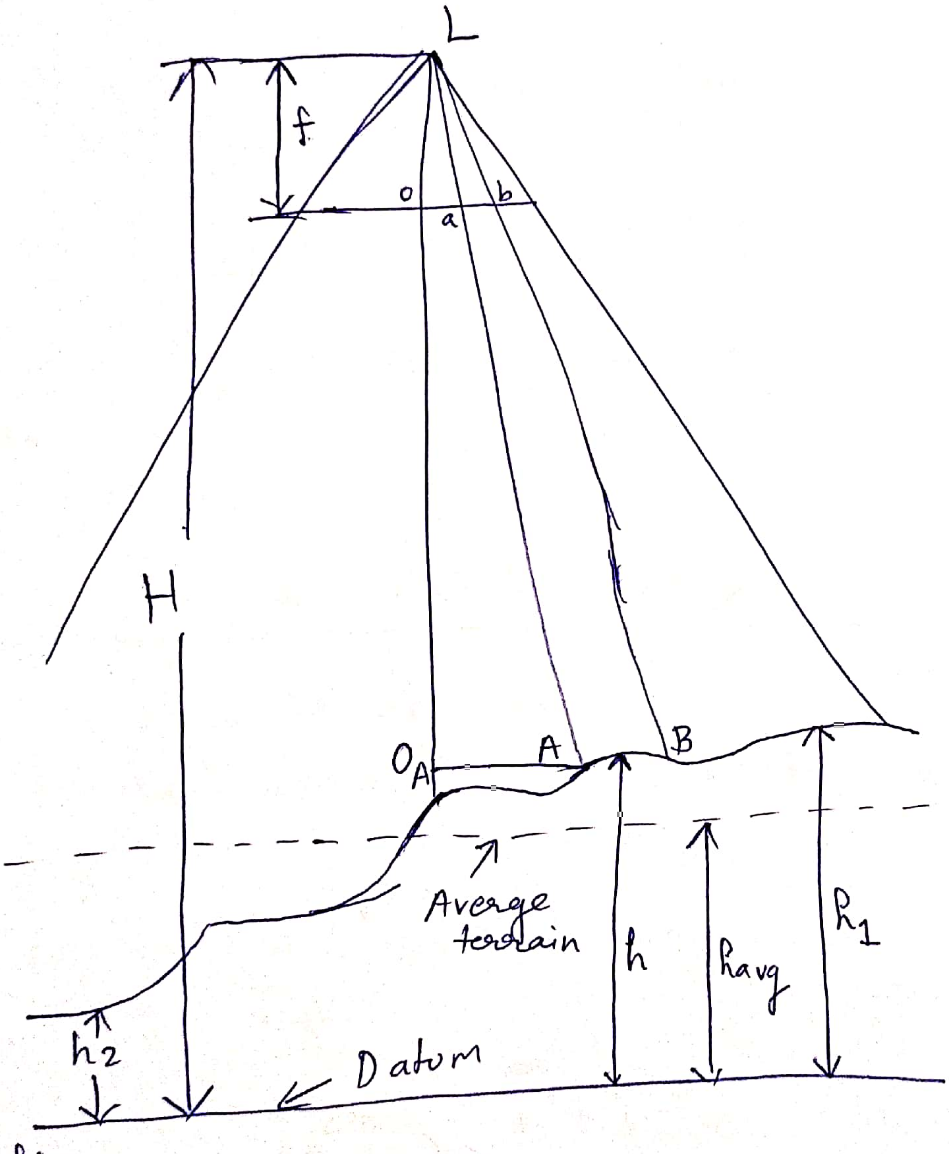
$$\frac{\partial d}{\partial H} = -\frac{rh}{H^2}$$

→ Following observations are made

1. For a given elevation, RD of a point increases as the distance from principal point increases.
2. An increase in H decreases RD of a point.

Scale of Vertical Phototograph

Due to perspective geometry of photographs varies as a function of focal length, flying height, and the reduced level of terrain over a certain reference datum.



In fig.

- L is the exposure station
- f is its focal length
- H is the flying height above datum
- h represents the height of ground point A above datum
- Point 'A' is imaged as 'a' in the photograph
- h_{avg} Average terrain elevation

Savg is the Best single scale to use for a photo or group of photographs.

$$\text{Scale} = \frac{ao}{AO_A} = \frac{f}{H - h_A}$$

$$\text{Datum scale} = S_d = \frac{f}{H}$$

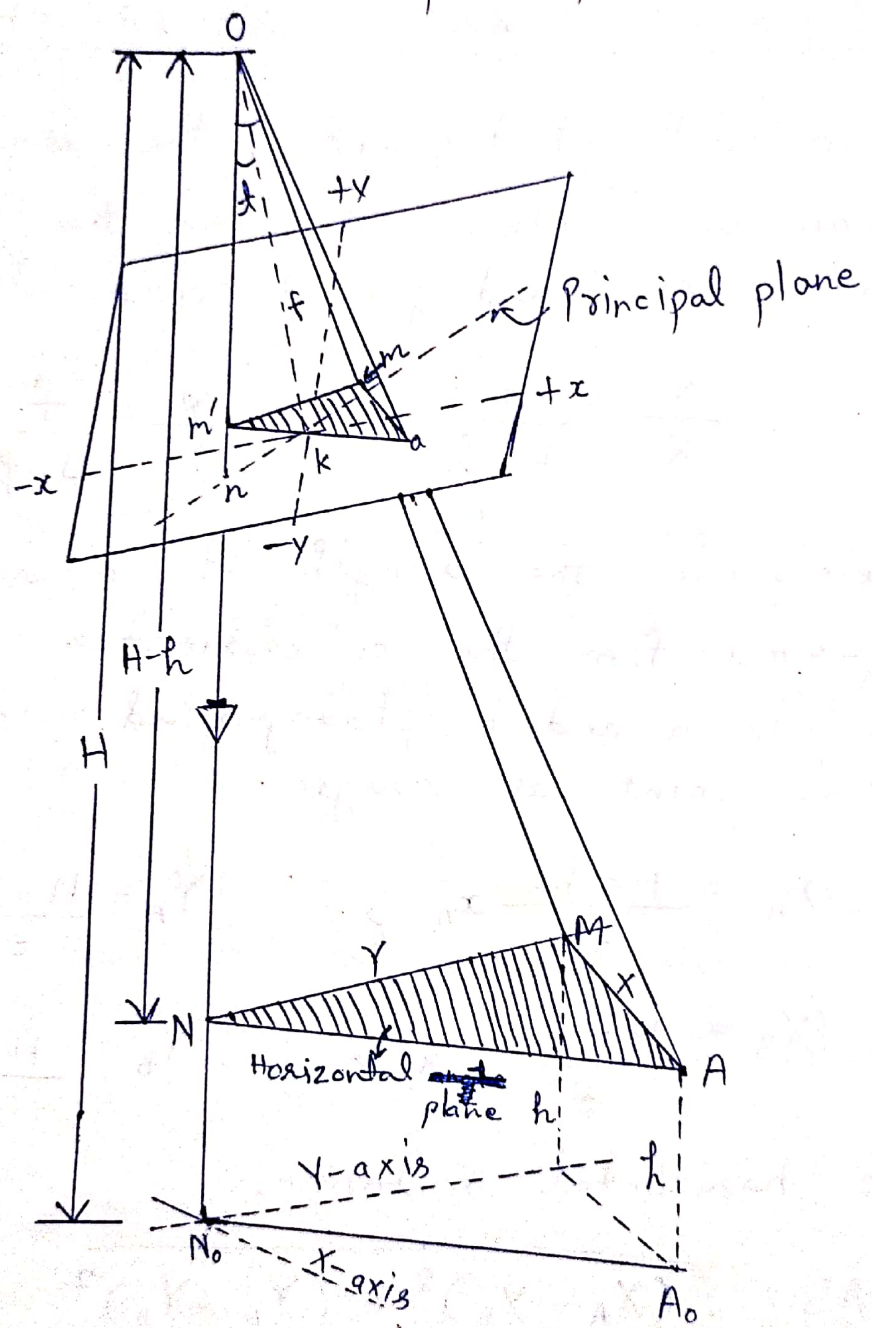
$$\text{Average scale} = S_{avg} = \frac{f}{H - h_{avg}}$$

Scale of photograph from map:

$$\frac{\text{Photo scale}}{\text{Map Scale}} = \frac{\text{Photo distance}}{\text{Map distance}}$$

Scale of Tilted photograph

When the optical axis of the camera is not truly vertical, it results in titled photographs. For an aerial photograph of a flat ground, the downward half of the photograph will have a larger scale than the upward half. To determine the scale from point to point, the position of the points must be known with reference to the principal lines.



Scale of a tilted photograph

Figure shows a tilted photograph in which a is the image of the ground point A, the ground point being at a height h above datum.

The points n, and k are the nadir and principal points and nk is the principal line.

From similar triangles Om'a and ONA.

$$\frac{m'a}{NA} = \frac{Om'}{ON} = \frac{\text{map distance}}{\text{ground distance}}$$ = scale of a point on a tilted photograph

$Om' = On - m'n = f\sec t - mn \sin t$

$ON = ON_o - NN_o = H - h$

$$S = \frac{f\sec t - mn\sin t}{H - h}$$

Ground Co-ordinates

- **Vertical Photograph**

X & Y:

$$\boxed{X = \frac{H-h}{f} \cdot x}$$

$$\boxed{Y = \frac{H-h}{f} \cdot y}$$

- **Distance b/w A – B**

$$L = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

- **Tilted photograph**

X & Y:

$$X = \frac{H-h}{f\sec t - y'\sin t} \cdot x' \qquad (x' = m'n)$$

$$Y = \frac{H-h}{f\sec t - y'\sin t} \cdot y'\cos t$$

→ X & Y are Ground co-ordinates

→ x' & y' are co-ordinate of point with respect

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to axes whose origin is at the nadir point & whose y' axis coincides with the principal line

→ t - tilt of the camera

- Distance b/w A - B

$$L = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

Determine scale of photograph for terrain laying at elevation of 50 m and 200 m. If vertical photograph was taken at altitude of 1200 m. Take focal length of camera as 15 cm

Solution

1) Scale for terrain at 50 m elevation:

$h = 50$ m
$H = 1200$ m
$f = 15$ cm

$\therefore$ Scale of photograph,

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

$$= \frac{15 \text{ cm}}{(1200-50) \text{ m}} = \frac{15 \text{ cm}}{1150 \text{ m}}$$

$$= \frac{1 \text{ cm}}{76.67 \text{ m}}$$

Scale of photograph $= 1 \text{ cm} : 76.67$ m

R.F. (Representative Factor) $= \dfrac{\frac{15}{100} \text{ m}}{(1200-50)} = \dfrac{0.15}{1150} = \dfrac{1}{7666.67}$

2) Scale for terrain at 200 m elevation.

$h = 200$ m
$H = 1200$ m
$f = 15$ cm

$$\therefore S = \frac{f}{H-h} = \frac{15 \text{ cm}}{(1200-200) \text{ m}}$$

$$= \frac{15 \text{ cm}}{1000 \text{ m}}$$

$$= \frac{1 \text{ cm}}{66.67 \text{ m}}$$

Scale of photograph = 1 cm : 66.67 m

$$R.F. = \frac{15/100}{(1200-200)} = \frac{0.15}{1000} = \frac{1}{6666.67}$$

2. A straight length of a highway AB appears to be 12.5 cm on a vertical air photograph of 15 cm focal length. The corresponding distance of the highway on a 1:50,000 topographical map is 6.25 cm. Assuming the average of elevation of the terrain as 1250 m above m.s.l. Calculate the flying height of the camera above m.s.l.

Solution

$h = 1250$ m

$f = 15$ cm

The relation between the photo scale and map scale is given by:

$$\frac{\text{Photo scale}}{\text{Map Scale}} = \frac{\text{Photo distance}}{\text{Map distance}}$$

Here, Map Scale $= \frac{1}{50,000}$

Let the photo scale $= \frac{1}{n} = S$

$$\frac{1/n}{1/50{,}000} = \frac{12.5}{6.25}$$

$$\therefore \frac{1}{n} = \frac{12.5}{6.25} \times \frac{1}{50{,}000} = \frac{1}{25{,}000}$$

$$\therefore S = \frac{1}{n} = \frac{1}{25{,}000}$$

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

$$\therefore \frac{1}{25{,}000} = \frac{(15/100)\,m}{(H-1250)\,m}$$

$$\therefore H - 1250 = \frac{15}{100} \times 25000$$

$$H - 1250 = 3750$$

$$\boxed{H = 5000\ m}$$

3. Two points A and B having elevation of 400 m and 600 m respectectively above datum appear on the vertical photograph having focal length of 22 cm and flying altitude 2800 m above datum.

The corrected photographic co-ordinates are as follows:

Point	Photographic co-ordinates	
	x (mm)	y (mm)
a	+23.8	+16.4
b	−13.6	−29.7

Determine the length of ground line AB.

$f = 22\ cm = 220\ mm$

The ground co-ordinates are given by :

$$X_A = \frac{H - h_A}{f} \times x_a$$

$$= \frac{(2800 - 400)}{220} \times (23.8) = +259.6\ m$$

$$Y_A = \frac{H - h_A}{f} \times y_A$$

$$= \frac{(2800 - 400)}{220} \times (16.4) = +178.9\ m$$

$$X_B = \frac{H - h_B}{f} \times x_b$$

$$= \frac{(2800 - 600)}{220} \times (-13.6) = -136.0\ m$$

$$Y_B = \frac{H - h_B}{f} \times y_b$$

$$= \frac{(2800 - 600)}{220} \times (-29.7) = -297.0\ m$$

∴ Length of ground line AB.

$$AB = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$$

$$= \sqrt{(259.6 + 136.0)^2 + (178.9 + 297)^2}$$

$$\boxed{AB = 618.85\ m}$$

Q: A tower AB 80 m high appears in a vertical photograph. The flying height of the aircraft above m.s.l. is 3000 m. The distance of the image of the top of the tower from the principal point is 7.25 cm. Compute the displacement of the top of the tower with respect to the image of its bottom if the elevation of the bottom of the tower is 1150.0 m

Soln $h = 80\ m$, $H = 3000\ m$

$r = 7.25\ cm$

$H = 3000 - 1150 = 1850\ m$

$$d = \frac{rh}{H} = \frac{0.0725 \times 80}{1850}$$

$$= 0.0031\ m$$

$$= 0.31\ cm$$

Q. The distance from the principal point to an image on a photograph is 7.50 cm and the elevation of the object above the datum (sea level) is 350 m. What is the relief displacement of the point if the datum scale 1/8000 & the focal length of the camera is 250 mm.

Soln $r = 7.50\ cm$, $h = 350\ m$.

$S_d = 1/8000$, $f = 250\ mm$

$d = ?$

$$S_d = \frac{f}{H} \Rightarrow \frac{1}{8000} = \frac{0.250}{H} \Rightarrow H = 0.250 \times 8000$$

$$= 2000\ m$$

$$d = \frac{r \cdot h}{H} \Rightarrow \frac{0.0750 \times 350}{2000} = 0.0131\ m = 1.3\ cm$$

The distance of an image of a point 230 m above m.s.l. from the principal point is 30.2 mm. Determine the relief displacement, if the flying height is 1500 m.

Soln

$H = 1500$ m

$h = 230$ m

$r = 30.2$ mm

$$d = \frac{r \cdot h}{H} = \frac{30.2 \times 230}{1500}$$

$$= 4.63 \text{ mm}$$

Q. Calculate the height of microwave tower appearing in a vertical photograph. The distance of tower in photograph from principal point is 5.6 cm and relief displacement is 0.45 cm. The datum scale of photograph is 1 : 15000 and focal length of camera is 16 cm.

Soln

$f = 16$ cm

$$S_d = \frac{1}{15000}$$

$r = 5.6$ cm

$d = 0.45$ cm

Datum scale, $S_d = \dfrac{f}{H}$

$$\frac{1}{15000} = \frac{(16/100)}{H} \quad \therefore \boxed{H = 2400 \text{ m}}$$

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

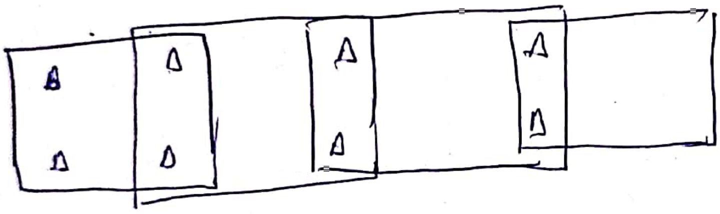
$$0.45 = \frac{5.6 \times h}{2400} \quad \therefore \boxed{h = 192.85 \text{ m}}$$

Ground control for aerial photogrammetry

Field surveying for photogrammetric control is generally a two-step process.

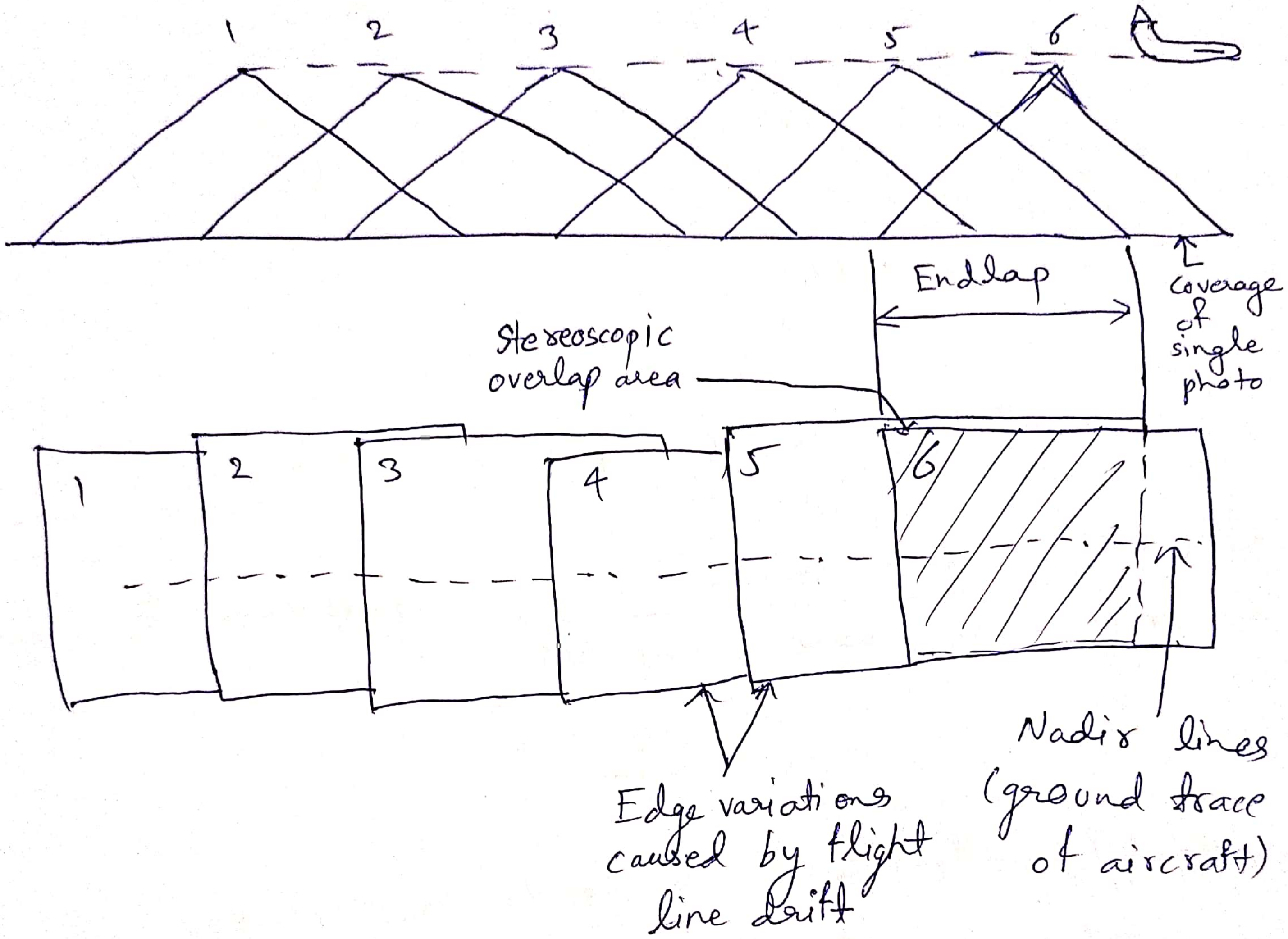
→ The first step consists of establishing a network of basic control in the project area. It can be established by GPS techniques.

→ The second step involves establishing photo control by means of surveys originating from the basic control network.



Overlaps

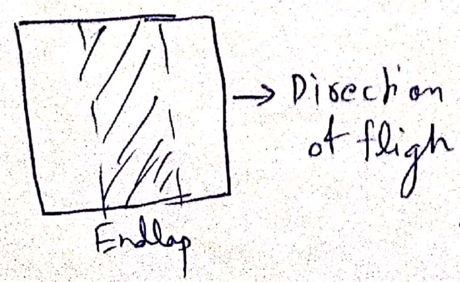
Overlaps :-

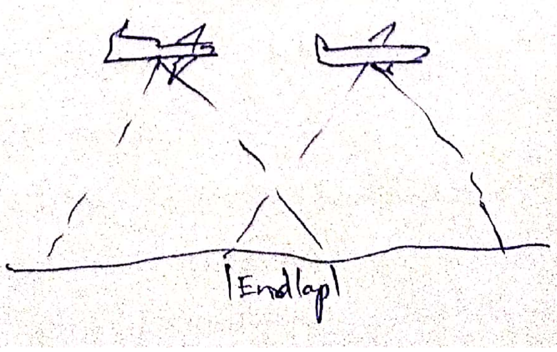


It is of two types :

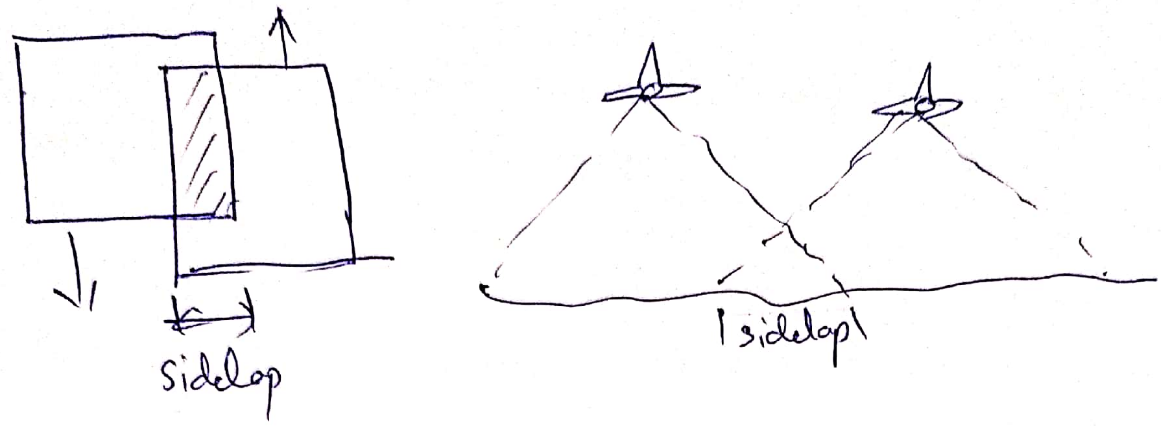
1. Endlap
2. Side lap

1. <u>Endlap</u>





2. Sidelap



Number of photographs required to cover the area A

$$\text{No.'s of photograph} = \frac{\text{Total area to be photographed}}{\text{Net ground area covered by each photo}}$$

$$= \frac{A}{a}$$

The size of each photograph = $l \times w$ (net area of photograph)

$$= (1-P_l)\, l \times (1-P_w)\, w$$

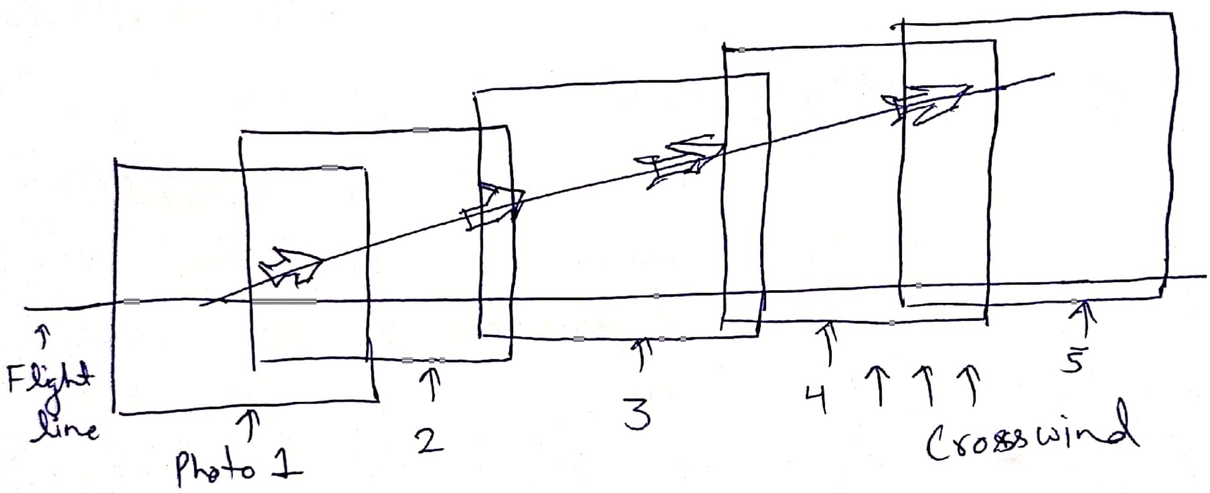
Ground area covered by each photograph, $a = s(1-P_l)\, l \times s(1-P_w)\, w$

where, A = Total area to be photographed
l = length of photo in direction of flight
w = width of photo normal to direction
s = scale of photograph (f/H)
L = net ground distance corresponding to 'l'
W = Net ground width corresponding to w
a = net ground area covered by each photo
P_l = % Overlap in direction of flight (length)
P_w = % overlap in side (width)

Crab & Drift

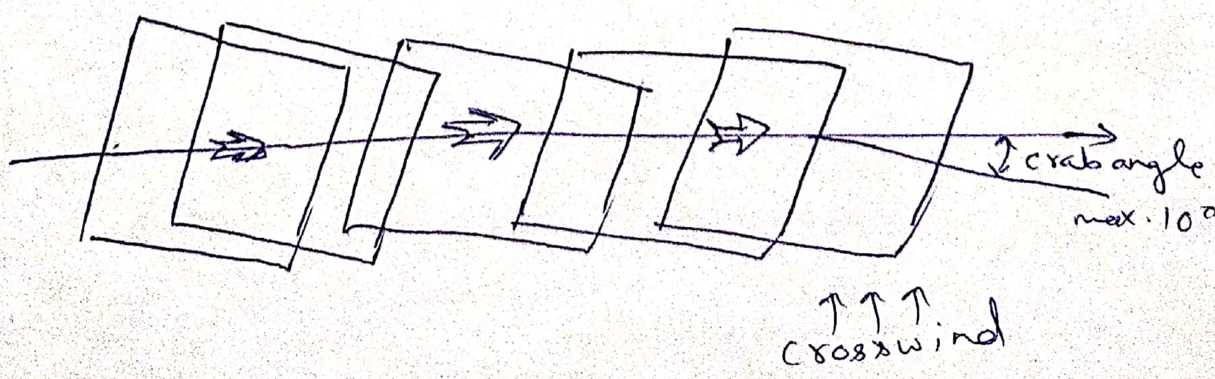
Drift -

It is assumed that there should be no wind when aerial survey is performed. If there is wind the aircraft will move bodily & fly in a direction inclined at an angle to the flight line and this angle is known as drift angle.



Crab

When the camera is not square with the direction of flight at the exposure time, an angle is formed between the flight line and the edges of photographs. This angle is known as crab angle. This effect is known as crab.



Interval between Exposure

$$T = \frac{3600L}{V}$$

T = Time interval between exposure in (second)
L = Dist. covered along the flight line (km) (Air Base)
V = Velocity of the aircraft (km/h)

Flight planning

The parameters of flight planning are -

- → Altitude of flight (H)
- → Focal length of camera (f)
- → size of photograph
- → Size of area or land to be photographed
- → Alignment of flight line & parallel flight line
- → Lateral overlap
- → No. of photo in each flight line and overlap
- → Scale of flight map
- → Ground speed of airplane
- → Time interval of successive photographs.

Photomaps & Mosaics

The individual aerial photo which contains different informations is called photomaps.

Assembly of individual aerial photographs is known as moasic,

Stereoscope

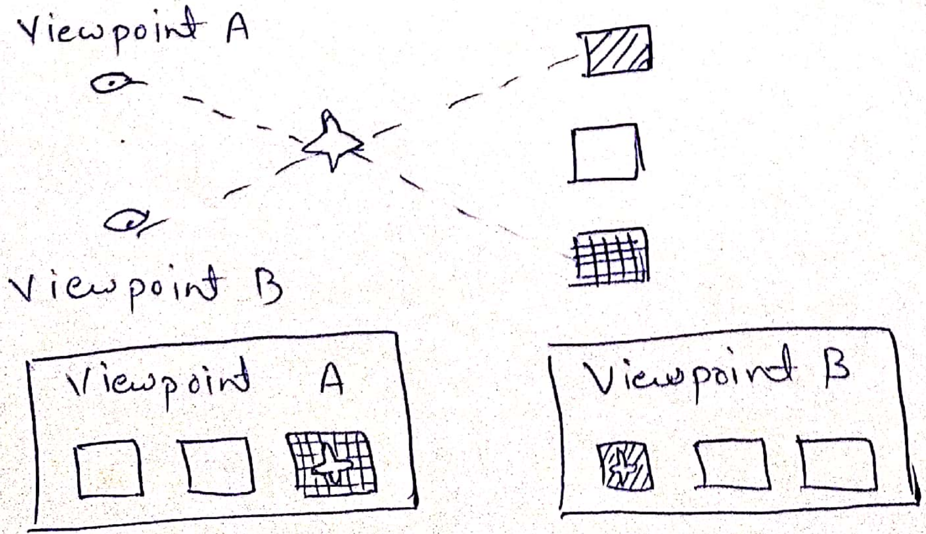
Two seperate photo viewed in stereoscope the image of the left photograph viewed by left eye and the image of right photograph viewed by right eye is fused together in brain to provide a 3-dimensional view. This is called stereoscopic fusion.

Parallax

In normal binocular vision, the apparent movement of a point viewed first with one eye and then with the other is known as parallax.

Parallax is displacement of two images in successive photographs.

Parallax is a displacement or difference in the apparent position of an object viewed along two different lines of sight, and is measured by the angle or semi-angle of inclination between these two lines.



Parallax bar

Parallax bar is also termed as stereometer. It is used to measure the difference of parallax between any two point more accurately and precisely.