Properties of Aerial Photography

- The photograph is the end result of the data acquisition process
- Many factors determine the quality of aerial photography such as:

1. design and quality of lens system
2. *manufacturing the camera*
3. *photographic material*
4. *development process*
5. *weather conditions and sun angle during photo flight*

Classification of aerial photographs

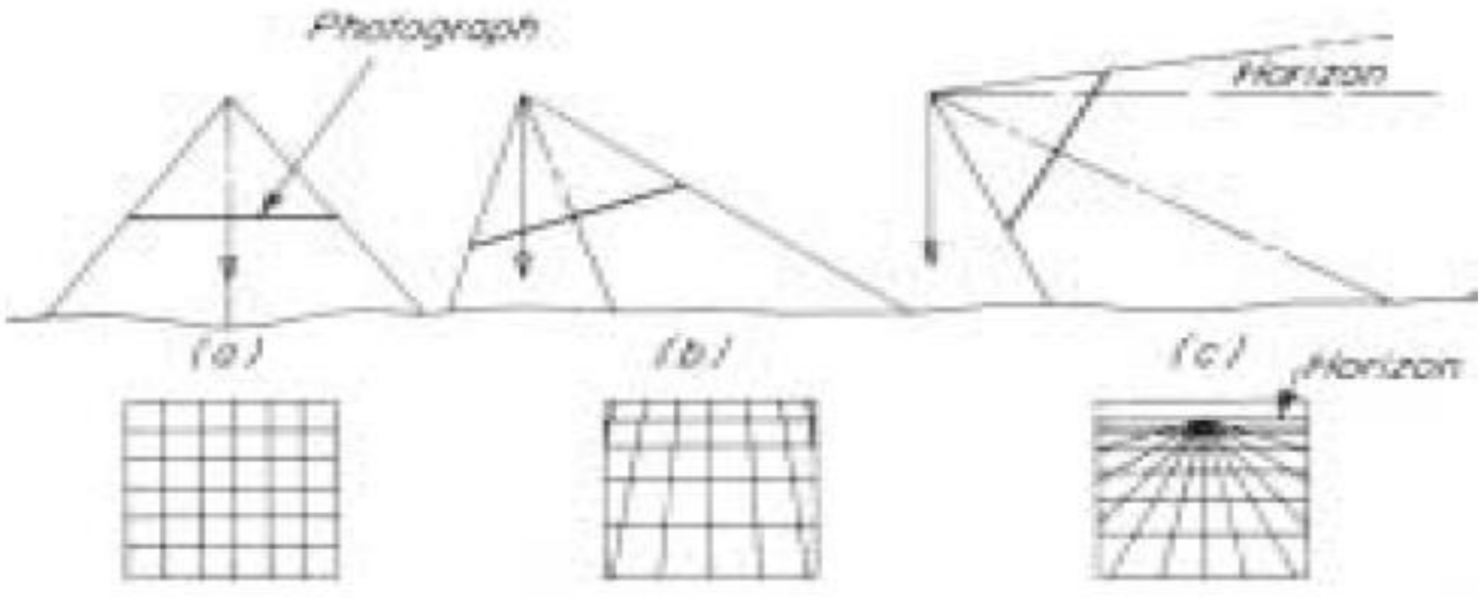
Classified according to

- the orientation of the camera axis,
- the focal length of the camera,
- and the type of emulsion

Orientation of camera axis

- **true vertical photograph** A photograph with the camera axis perfectly vertical (identical to plumb line through exposure center). Such photographs hardly exist in reality.
- **near vertical photograph** A photograph with the camera axis nearly vertical. The deviation from the vertical is called tilt. It must not exceed mechanical limitations of stereoplotter to accomodate it. Gyroscopically controlled mounts provide stability of the camera so that the tilt is usually less than two(2°) to three (3°) degrees.

- **oblique photograph** A photograph with the camera axis intentionally tilted between the vertical and horizontal. A **high oblique** photograph, depicted is tilted so much that the horizon is visible on the photograph. A **low oblique** does not show the horizon



(a) the a true vertical; (b) low oblique and
(c) depicts a high oblique photograph.

Focal Length of the camera

- The angular coverage is a function *of focal length* and *format size*.
- Since the format size is almost exclusively

  9″ × 9″ (23cm x 23cm) the angular coverage depends on the focal length of the camera only.

Table 4.1: Summary of photographs with different angular coverage.

	super-wide	wide-angle	inter-mediate	normal-angle	narrow-angle
focal length [mm]	85.	157.	210.	305.	610.
angular coverage [o]	119.	82.	64.	46.	24.

Emulsion type

The sensitivity range of the emulsion is used to classify photography into:

- **panchromatic black and white** This is most widely used type of emulsion for photogrammetric mapping.
- **Colour** Colour photography is mainly used for interpretation purposes.
- Recently, colour is increasingly being used for mapping applications.
- **infrared black and white**
  Since infrared is less affected by haze it is used in applications where weather conditions may not be as favourable as for mapping missions (e.g. intelligence).
- **false colour** This is particular useful for interpretation, mainly for analyzing vegetation
  (e.g. crop disease) and water pollution.

Geometric properties of aerial photographs

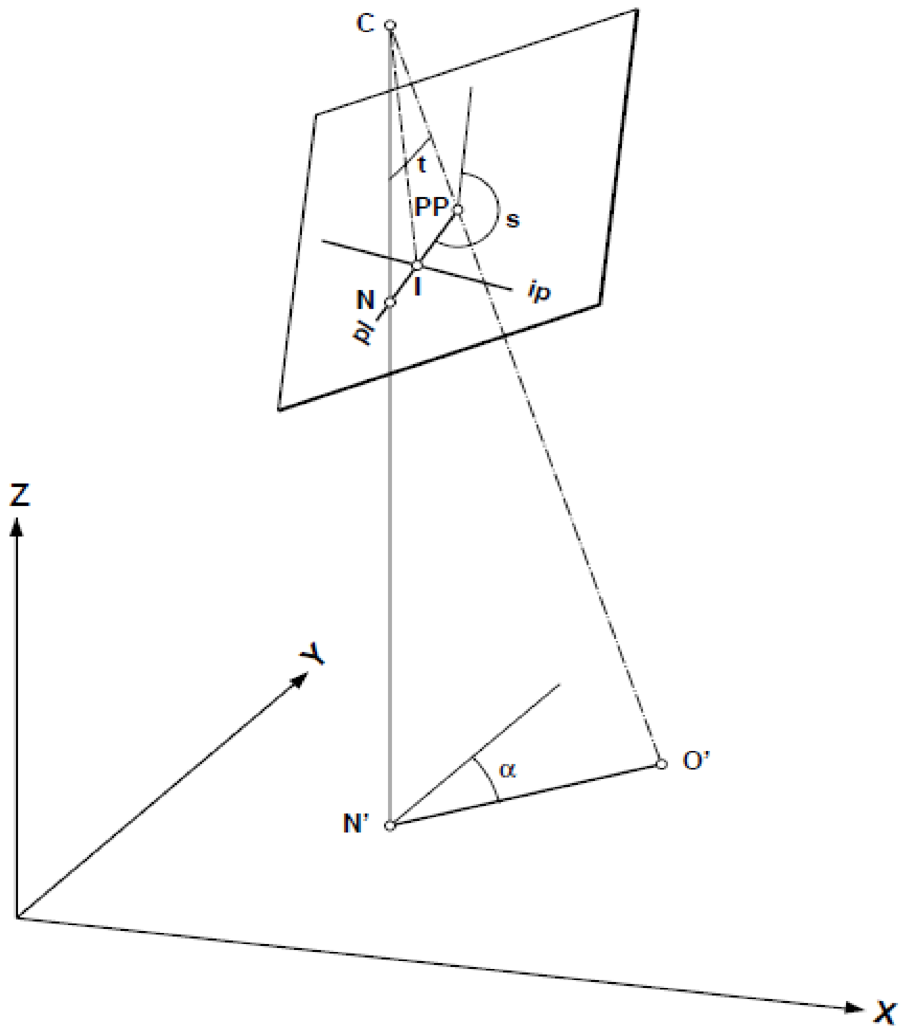
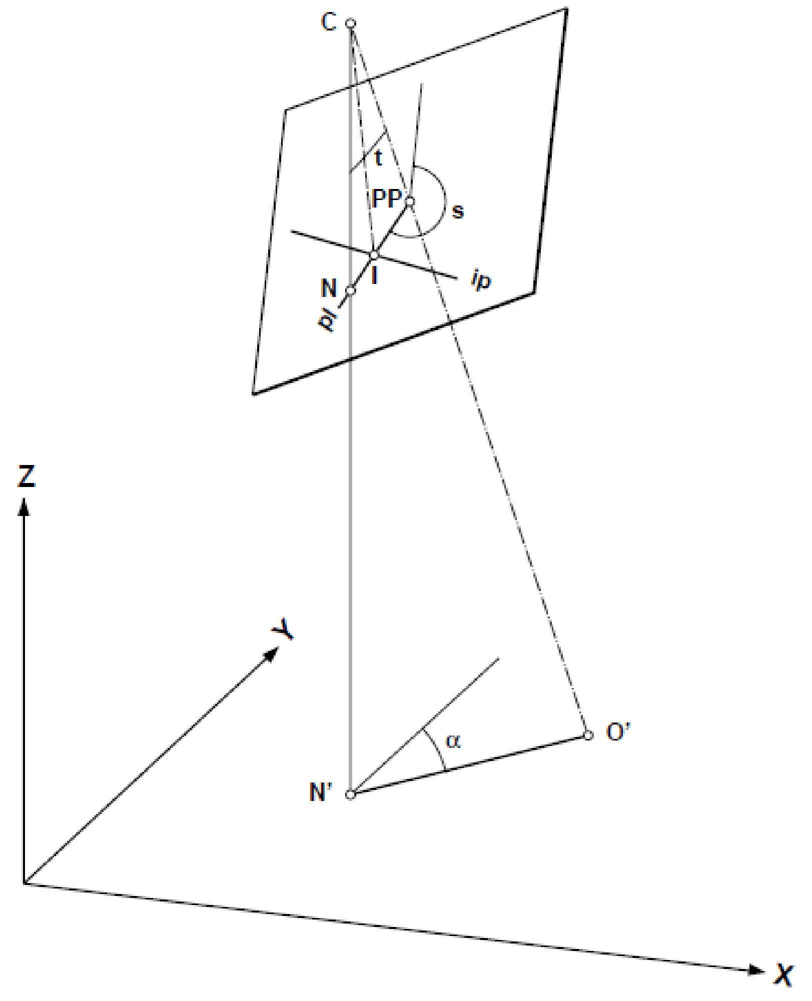


Figure 4.2: Tilted photograph in diapositive position and ground control coordinate system.

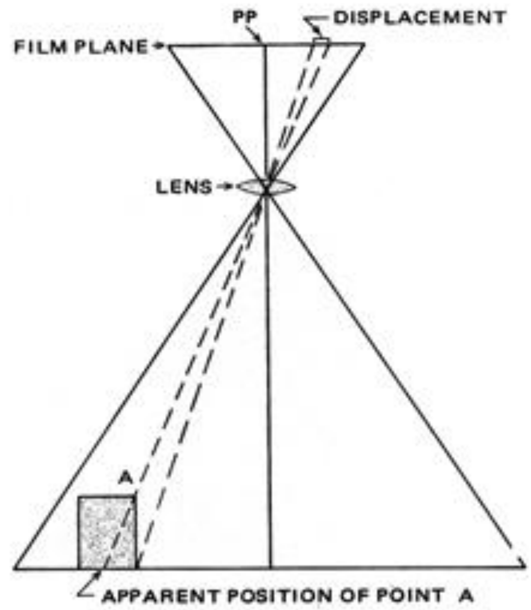
- **perspective center,** *C* *calibrated perspective*
- **focal length, f** *(calibrated focal length)***.**
- **principal point,** ***PP*** *intersection of the camera axis with the camera's focal plane*
- **camera axis *C-PP*** *axis defined by the projection center C and the principal point PP.*

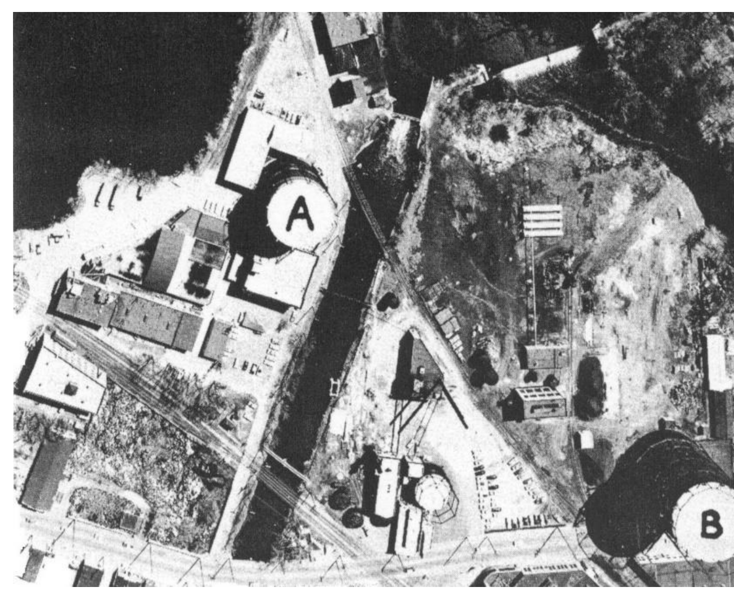
  The camera axis represents the optical axis. It is perpendicular to the image plane



The principle point , PP

- Point directly under camera lens (‘nadir’)
- Elevated objects lean away from PP
- Depressed objects lean toward PP
- Causes image displacement





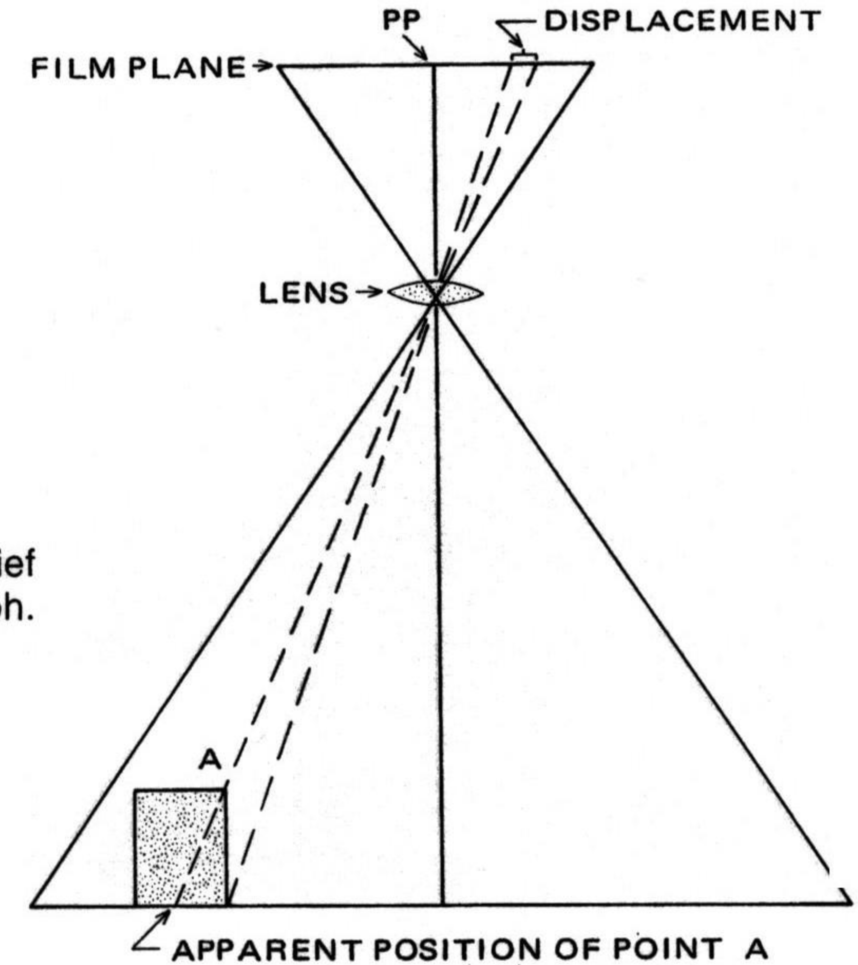
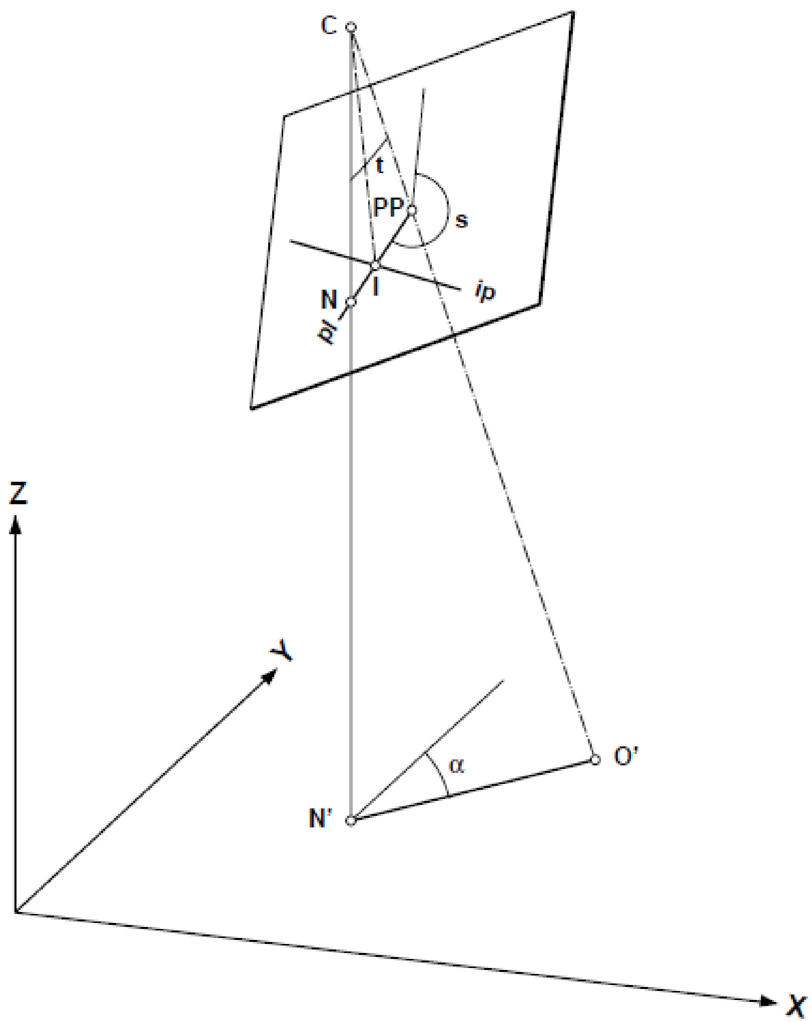


Figure 3–3. Schematic representation of relief displacement on a single, vertical photograph.

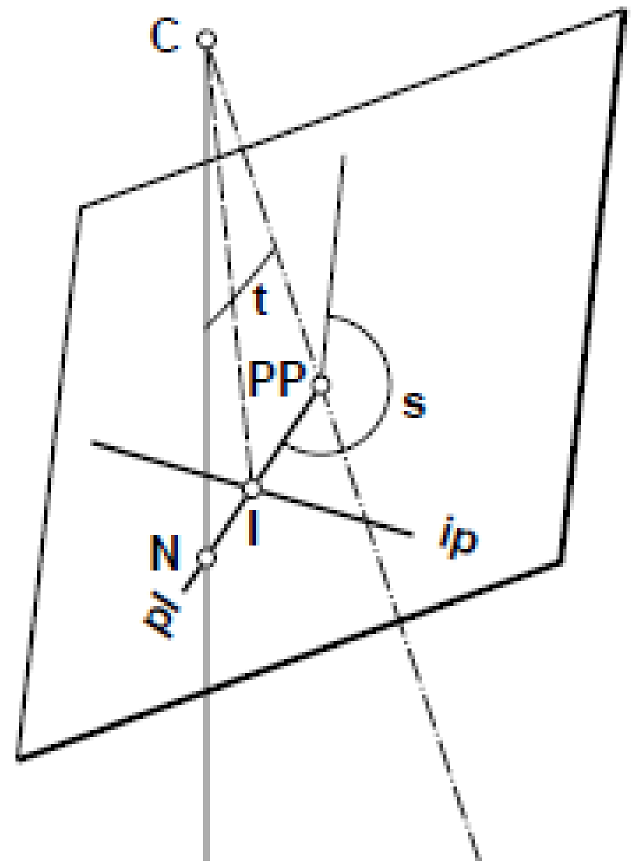


- **nadir point** ***N*** *also called photo nadir point, is the intersection of vertical (plumb line)* from perspective center with photograph.

- **ground nadir point** ***N'*** *intersection of vertical from perspective center with the earth's* surface.

- The line traced on the ground directly beneath the aircraft during acquisition of photography is called the **nadir line**

- **tilt angle *t*** *angle between vertical and camera axis.*



- **swing angle *s*** *is the angle at the principal point measured from the +y-axis counterclockwise* to the nadir *N.*
- **isocenter** *I is the intersection of the bisector of angle t with the photograph. It is on*

the principal line.

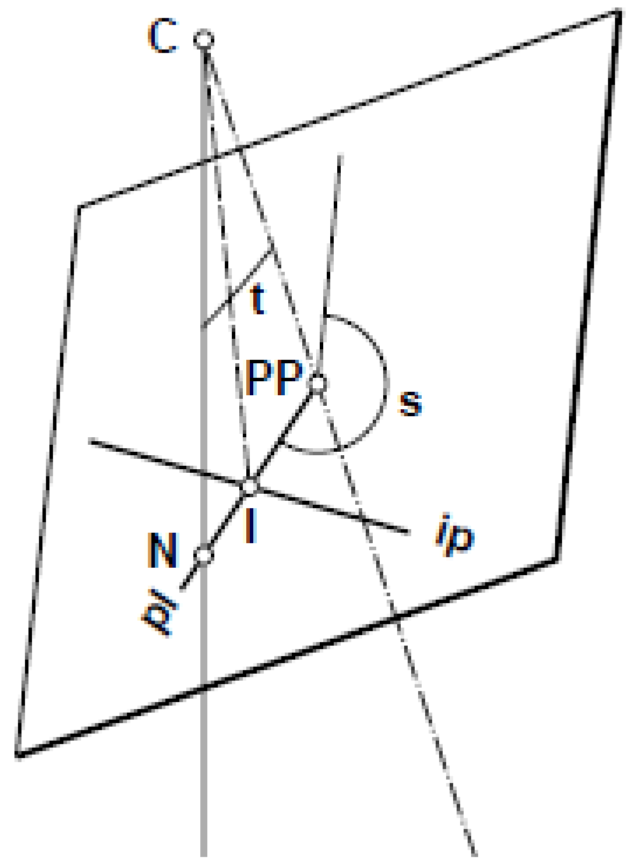


Image and object space

- The photograph is a *perspective (central) projection*
- During the image formation process,
- the physical projection center object side is the center of the entrance pupil
- while the center of the exit pupil is the projection center image side

The two projection centers are separated by the *nodal separation*.
The two projection centers also separate the space into *image space* *and* *object space*

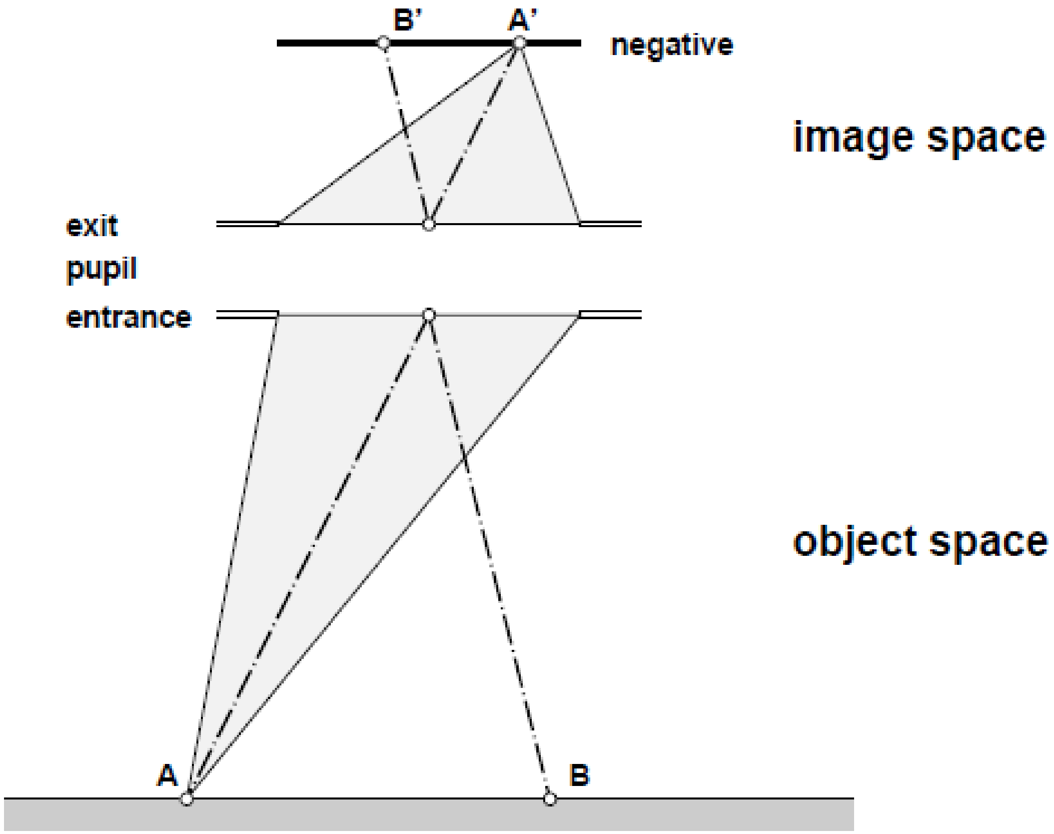


Figure 4.3: The concept of image and object space.

PHOTO SCALE

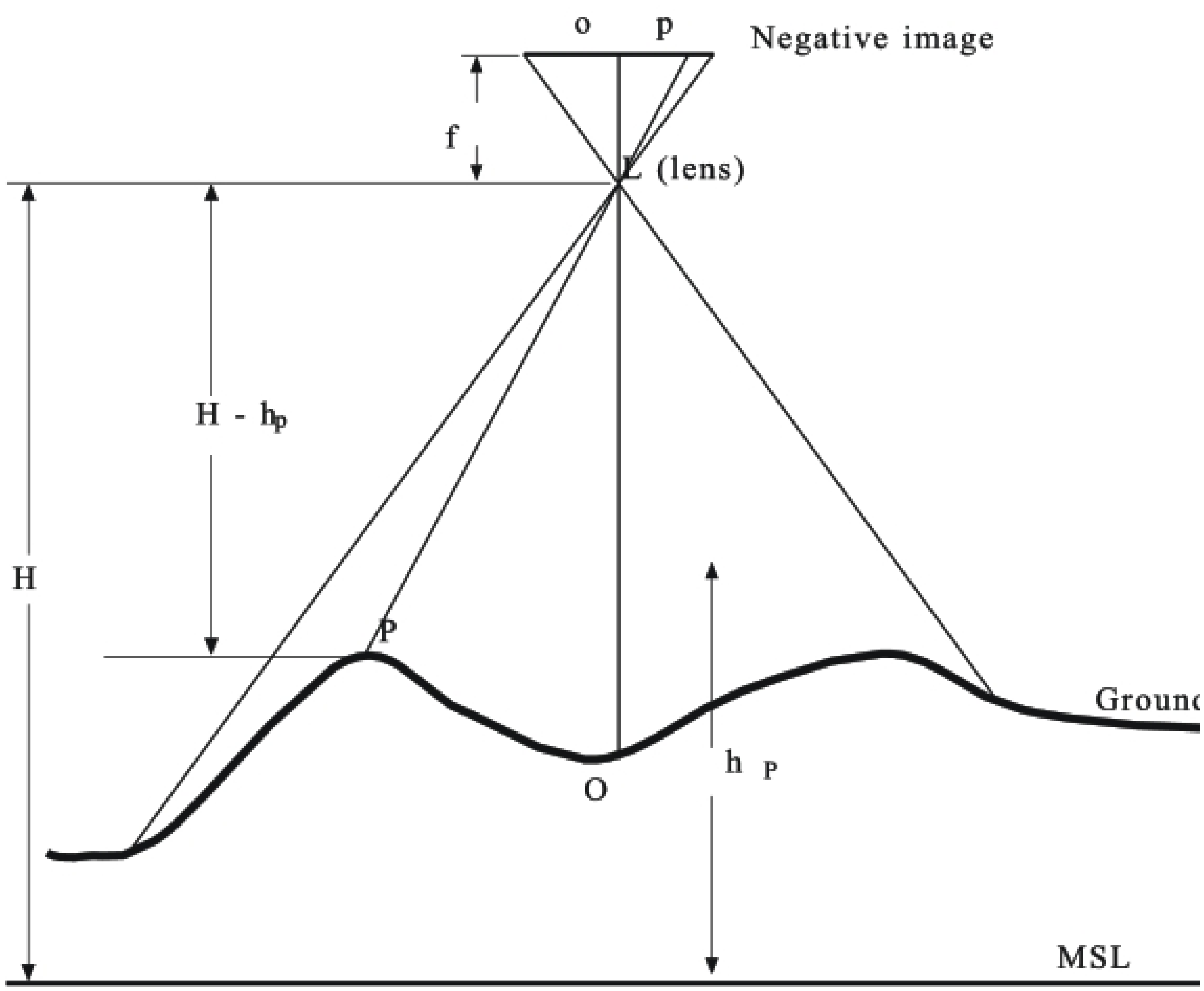


Figure 2.4. Determination of point scale on a vertical aerial photograph.

PSp= f/H-hp = f/Hp

- where:

PS_P is the photo scale at point *P*,

f is the focal length of the camera used to take the photograph, the distance between the lens and the focal plane,

H is the flying height of the aircraft above *MSL*, the distance between *MSL* and the lens,

h_P is the elevation of point *P* above *MSL*, and

$H\text{-}h_P = H_P$ is the flying height of the aircraft above point *P*

Photo scale

- e.g 1mm on a photo represents 25m on the ground, the scale of photo, thus 1mm = 25m (unit equivalent), 1/25000 (representative fraction), 1;25000 (ratio)
- The scale of a near vertical photograph can be approximated by; s = f/H

where s *is the photograph scale number, f the calibrated focal length, and H the flight height above mean ground elevation*

- Note that the flying height *H refers to the*
- average ground elevation. If it is with respect to the datum, then it is called

flight altitude HA, with HA = H + h.

Most commonly:

S=photo scale=

photo distance/ground distance

= d/D

$S = f/H-h$

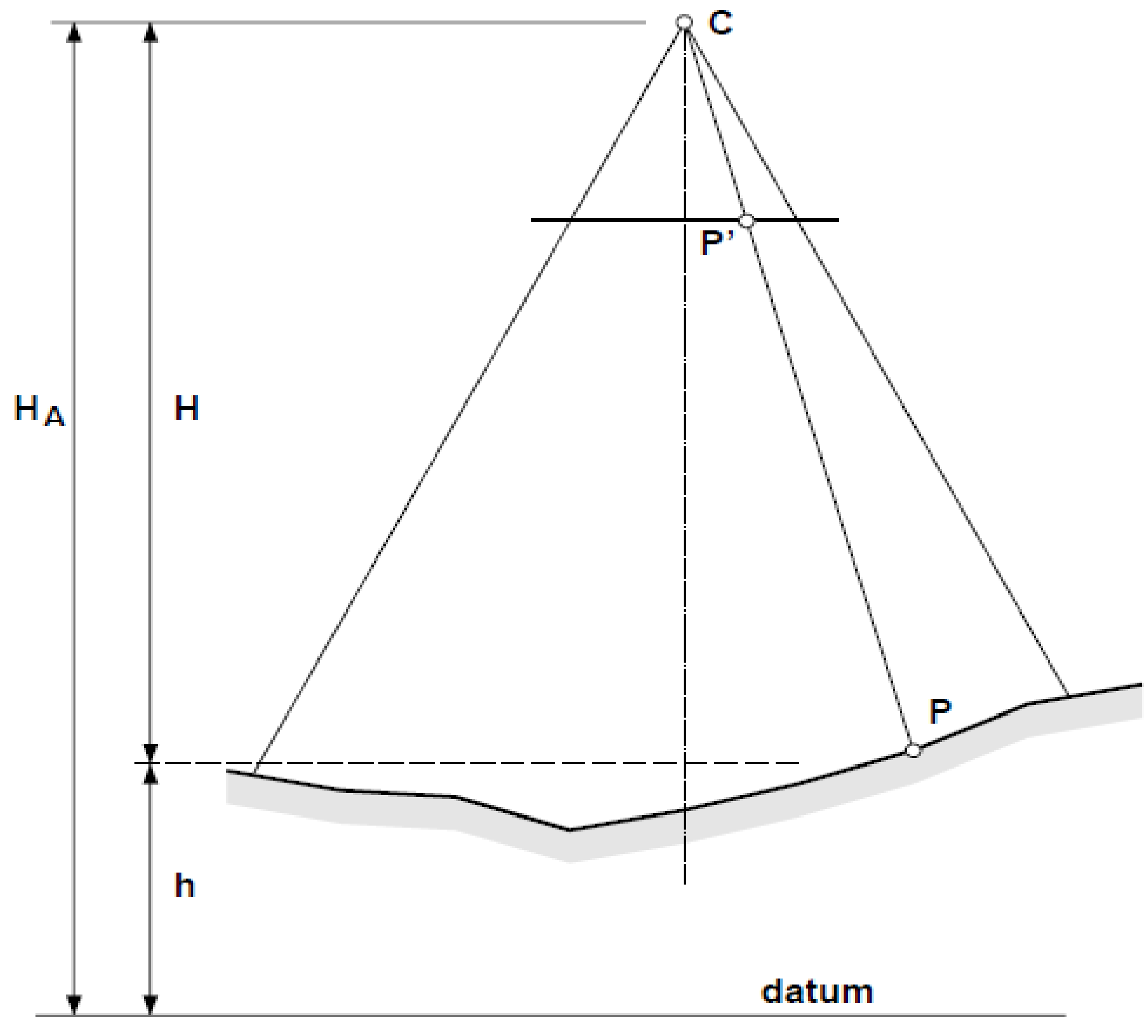


Figure 4.4: Flight height, flight altitude and scale of aerial photograph.

- photograph scale varies from point to point
- the scale for point P can easily be determined as the ratio of image distance *CP' to object distance CP by*

- where *xP , yP are the photo-coordinates, XP , YP, ZP the ground coordinates of* point P, and *XC, YC, ZC the coordinates of the projection center C in the ground* coordinate system

$$m_P = \frac{CP'}{CP} \tag{4.2}$$

$$CP\prime = \sqrt{x_P^2 + y_P^2 + c^2} \tag{4.3}$$

$$CP = \sqrt{(X_P - X_C)^2 + (Y_P - Y_C)^2 + (Z_P - Z_C)^2} \tag{4.4}$$

- **Example**
- A 305-mm focal length camera was used to take photographs from 4000 m above MSL. Find the scale of a point that is 800 m above MSL and the scale of a point that is at the MSL.
- Solution…….

$$PS_A = \frac{0.305\,m}{(4000 - 800)\,m} = 1:10490$$

$$PS_B = \frac{0.305\,m}{4000\,m} = 1:13110$$

Relief displacement

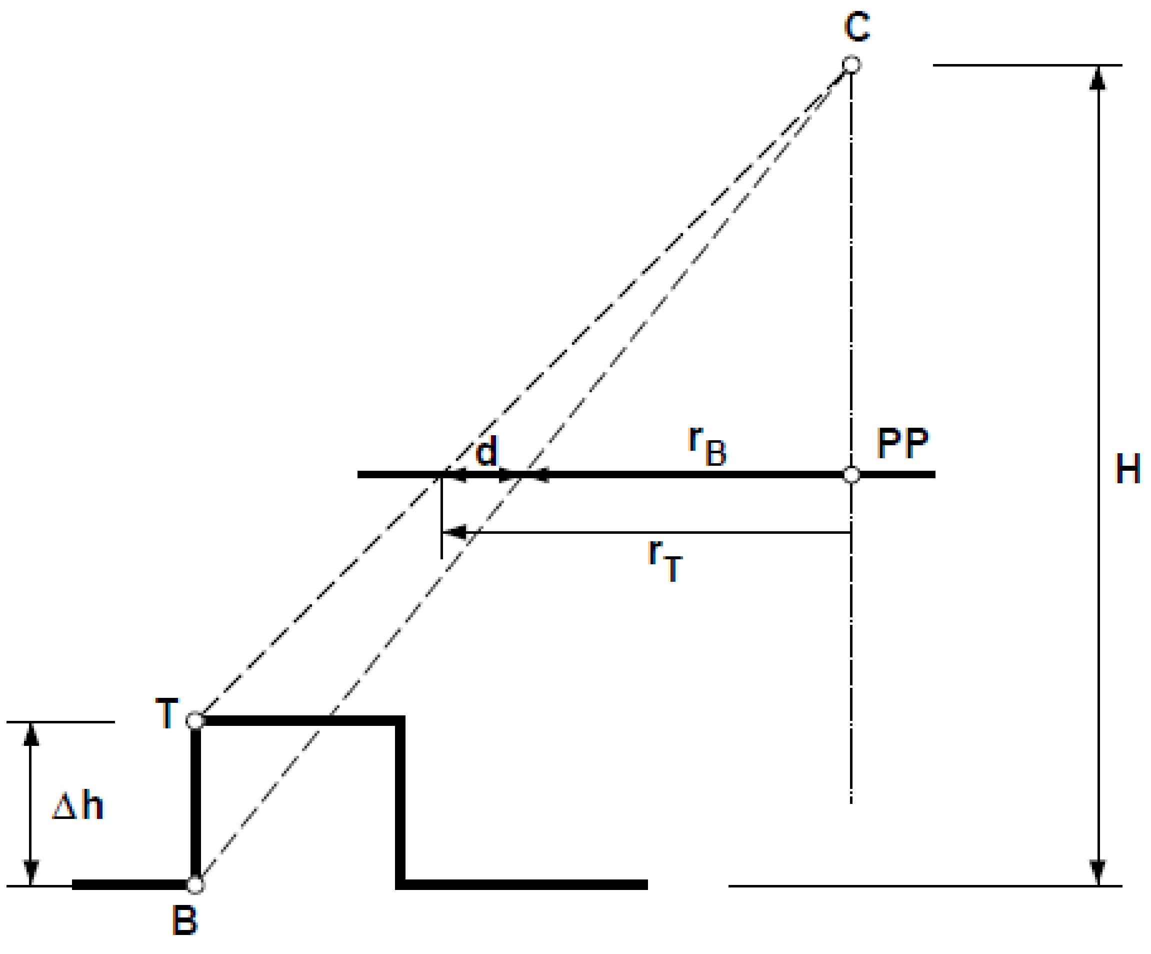


Figure 4.5: Relief displacement.

Relief displacement

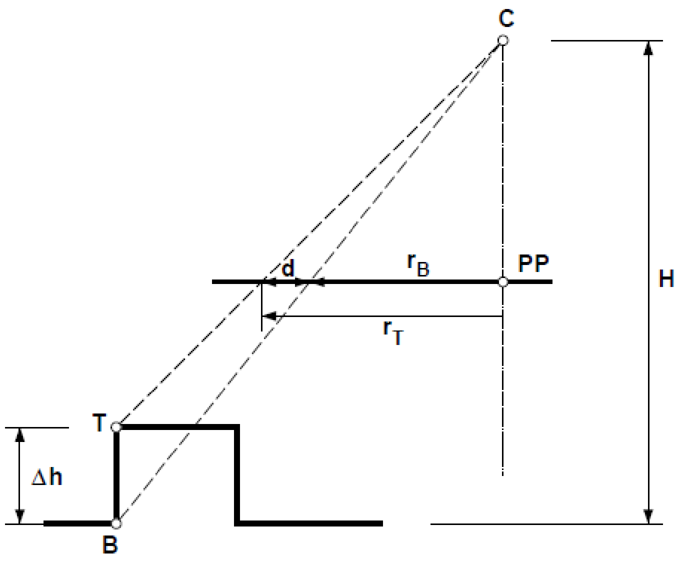


Figure 4.5: Relief displacement.

- d= relief displacement
- r= radial distance on the photograph from the principal point to the displaced image point
- h= height above datum of the object point
- H= flying height above the same datum chosen to reference h

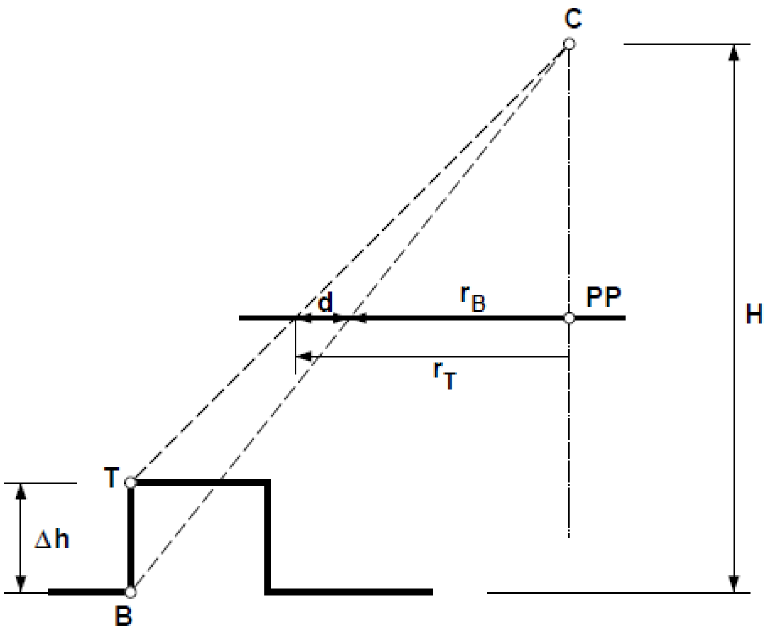


Figure 4.5: Relief displacement.

- *T is on top of a building and point B at the bottom*
- On a map, both points have identical *X, Y coordinates; however, on the photograph they are imaged at different positions,*

  namely in *T′ and B′*
- The distance ***d*** *between the two photo points is called* *relief displacement* *because it is caused by the elevation difference Δh between T and B.*
- *In essence, an increase in elevation of a feature causes its position on the photograph to be displaced radially outward from the principle point.*
- Generally, vertical features appear to lean away from the center of the photograph.

- The magnitude of relief displacement for a true vertical photograph can be determined by the following equation

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

where $r = \sqrt{x_T^2 + y_T^2}$, $r' = \sqrt{x_B^2 + y_B^2}$,

- And Δh the elevation difference of two points on a vertical photo.

- Thus,
- To determine the elevation h of a vertical object

- h=dH/r

Ground Coordinates from measurements on a Vertical Photo

- The ground coordinates of a general point are given by the following expressions

$$X = H\text{-}h/f *x \qquad Y= H\text{-}h/f *y$$

Where X and Y are the ground coordinates of a point; x and y are the corresponding photo coordinates.