AERIAL REMOTE SENSING

UNIT 3

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

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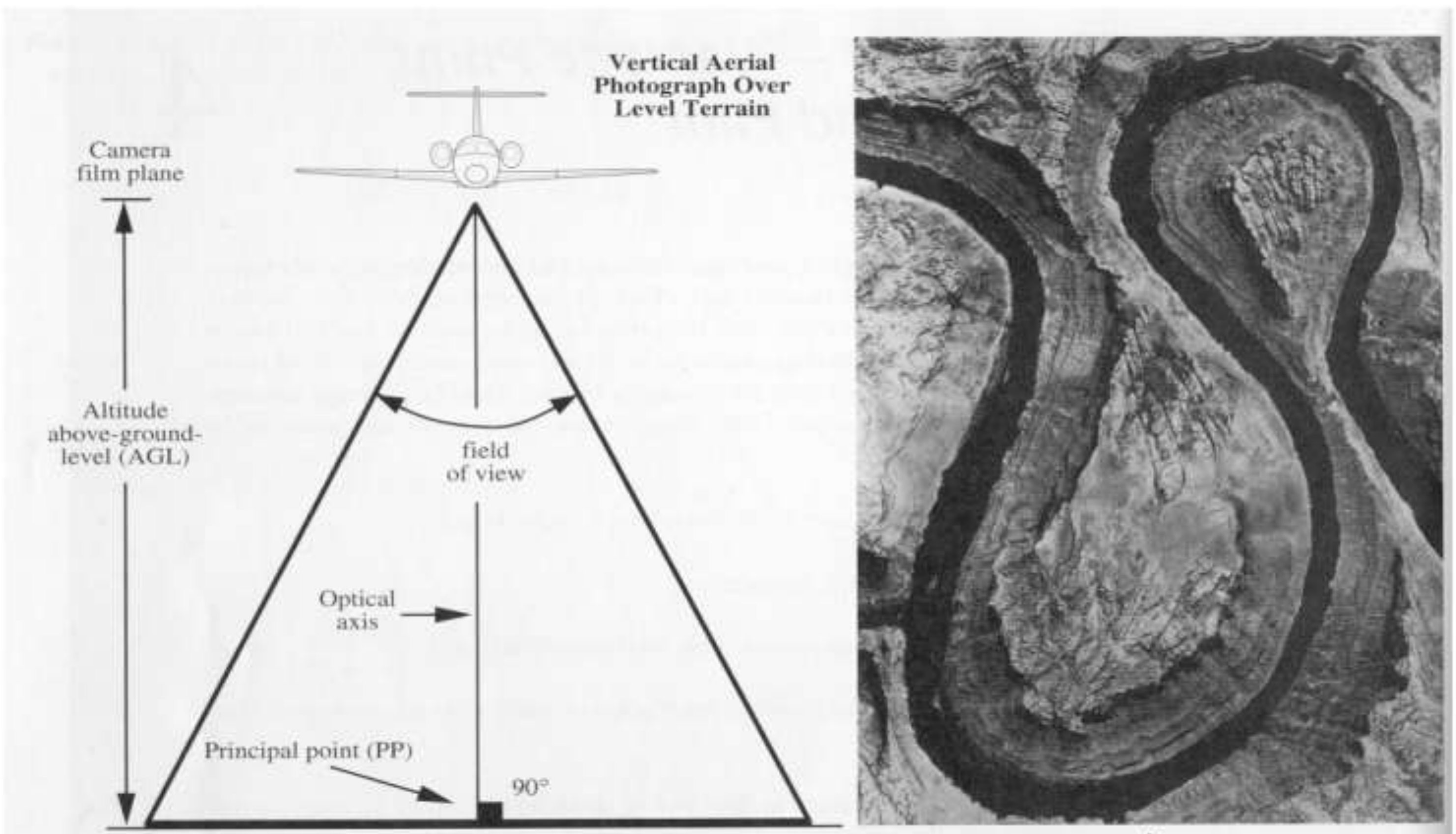
Types of Aerial Photography: On the basis of attitude of the camera axis, lens systems, types of camera and Types of films and filters, aerial photography may be classified

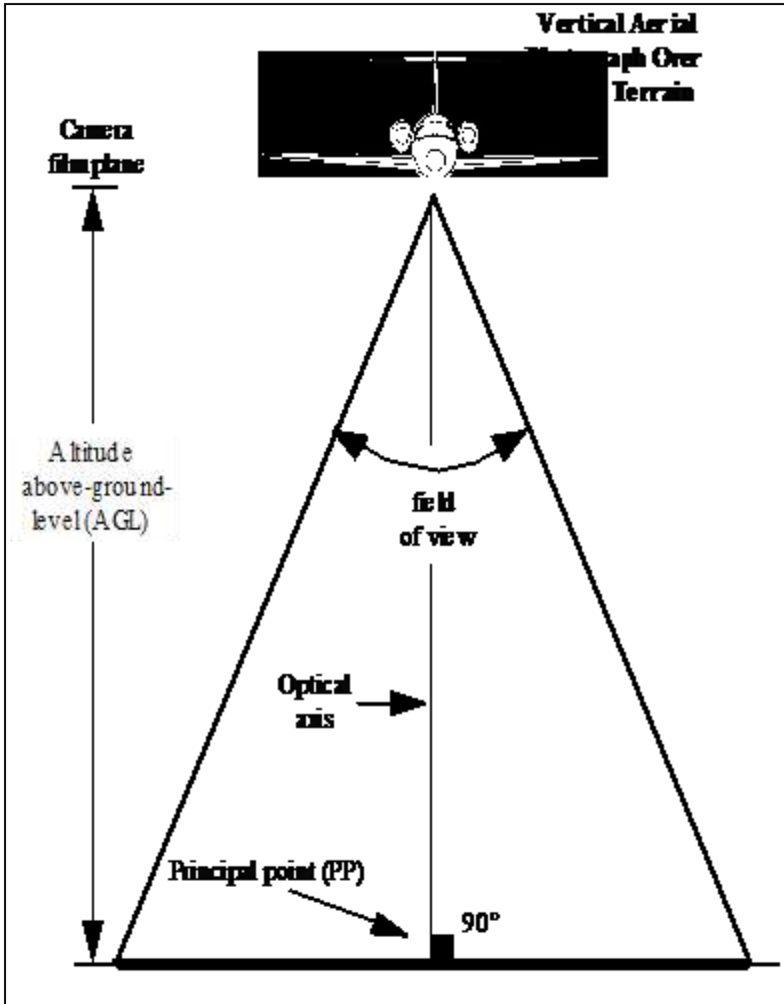
1	According to orientation of camera axis	A) Vertical photography B) Low oblique Photography C) High oblique Photography
2	According to lens system	A) Single lens photography B) Three lens photography (Trimetrogon photography) C) Four lens photography D) Nine lens photography E) Continuous strip photography
3	According to special properties of films, filters or photographic equipment	A) Black and white photography B) Infra-red photography C) Colour photography D) Colour infra-red photography E) Thermal infra-red imagery F) Radar imagery G) Spectrazonal photography
4	Digital aerial photographs (Instead of films, using the CCD arrays	Digital data

According to orientation of camera axis

A)A Vertical photography is one taken with the axis of the camera as vertical as possible at the time of exposure. It is virtually impossible to take absolutely vertical photographs. Deviation of the optic axis from the vertical, which rarely exceeds 1 to 2 degree, results the **tilted photographs**.



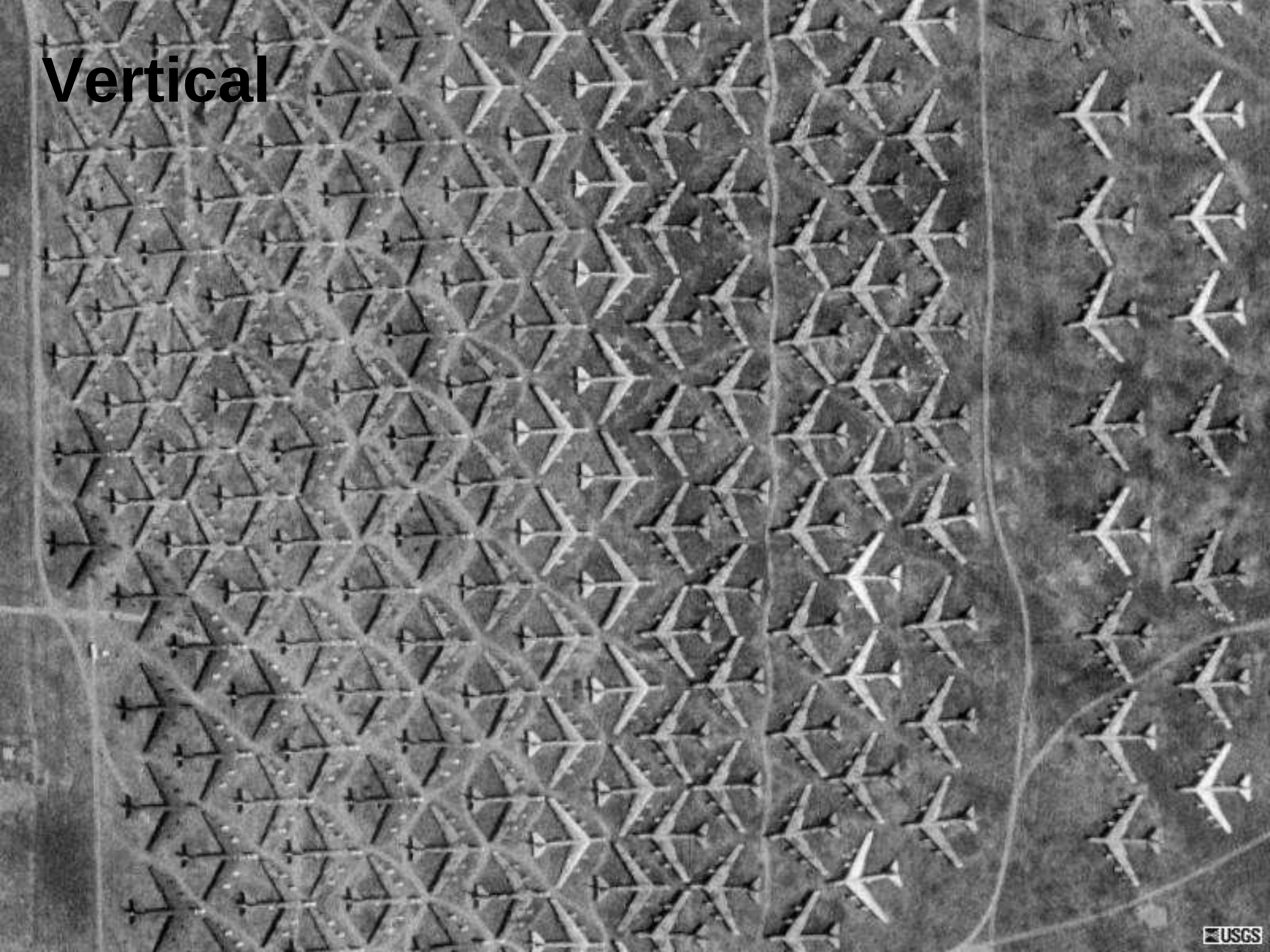
Vertical Aerial Photography



Goosenecks of the San Juan River in Utah

Jensen, 2000

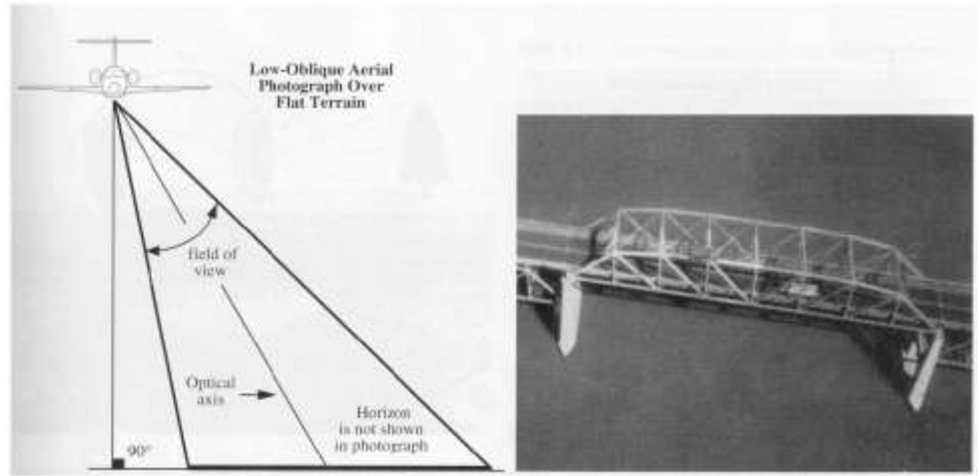
Most are vertical aerial photography


Vertical
USGS

B) An oblique photograph is taken with the axis of the camera intentionally tilted from the vertical.

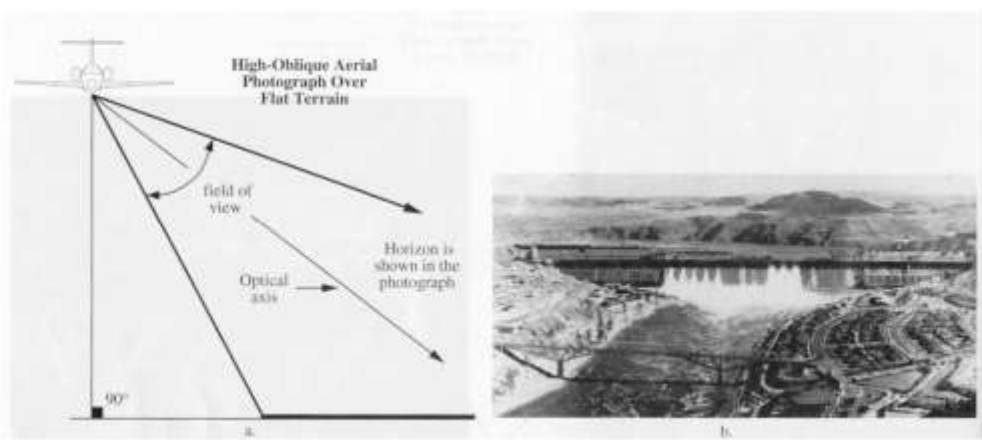
i) Low oblique photography:

In this type of photography, the camera axis is tilted intentionally to a certain low angle, such that the horizon is not photographed. (Max. angle of tilt is 35^o)

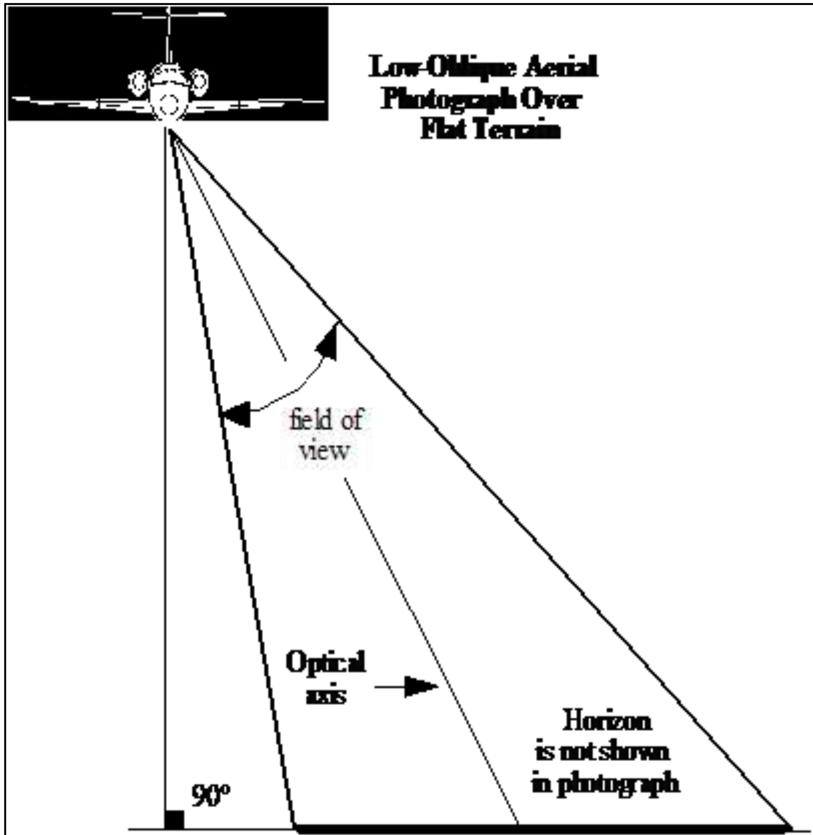


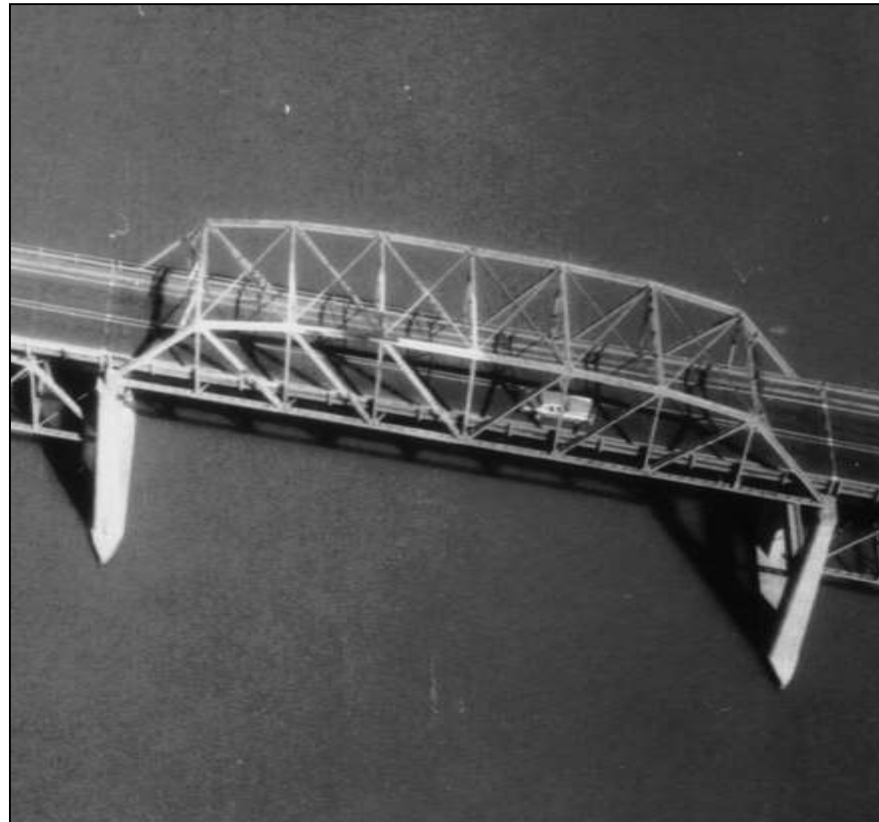
ii) High oblique photography:

Here the camera axis is tilted intentionally to certain greater angle such that horizon is seen on low resulted photograph (max. angle of tilt > 35^o). Such photographs are of importance in military purposes where scenery has to be appreciated with out stereo vision



Low-oblique Aerial Photography

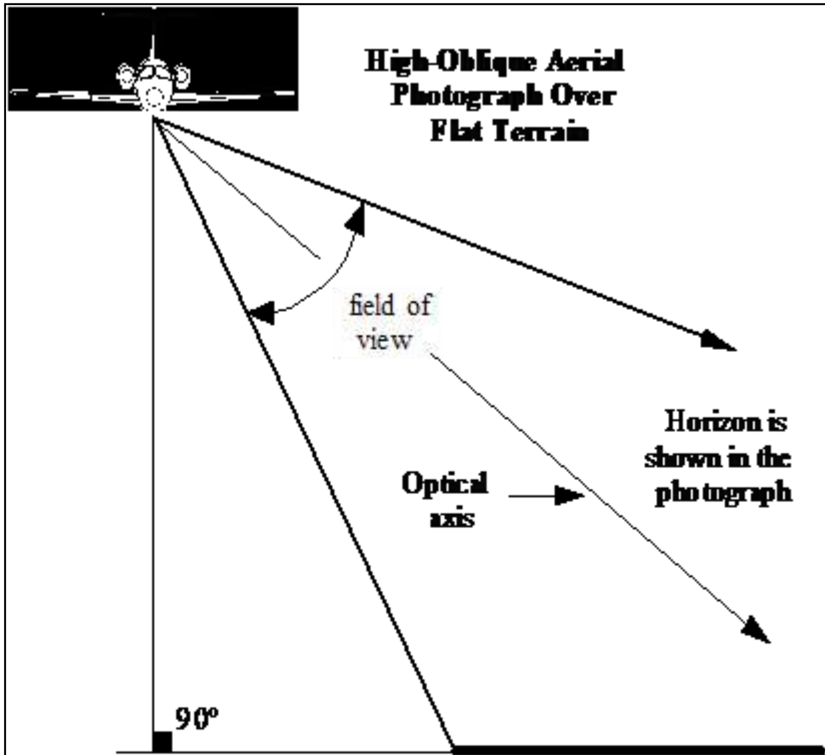




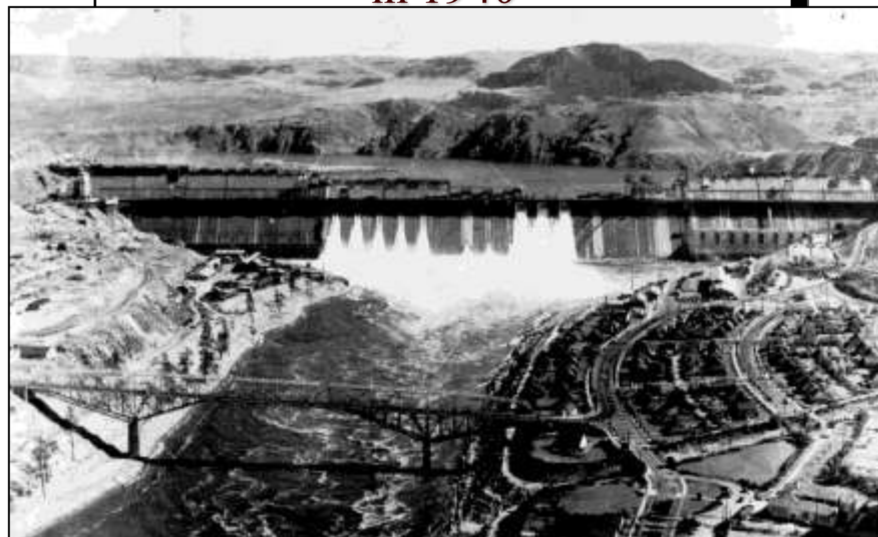
Low-oblique photograph of a bridge on the Congaree River near Columbia, SC.

Jensen, 2000

High-oblique Aerial Photography



High-oblique photograph of the grand Coulee Dam in Washington in 1940

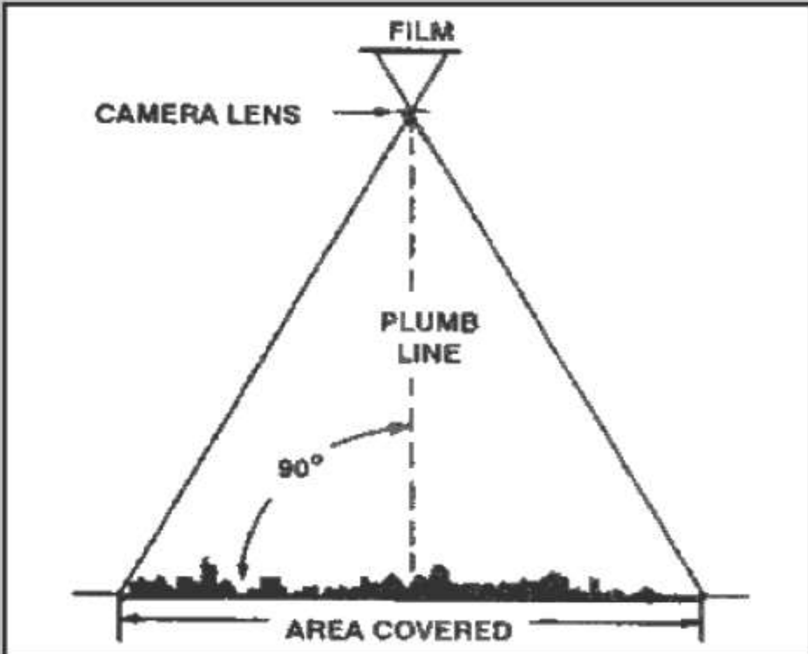


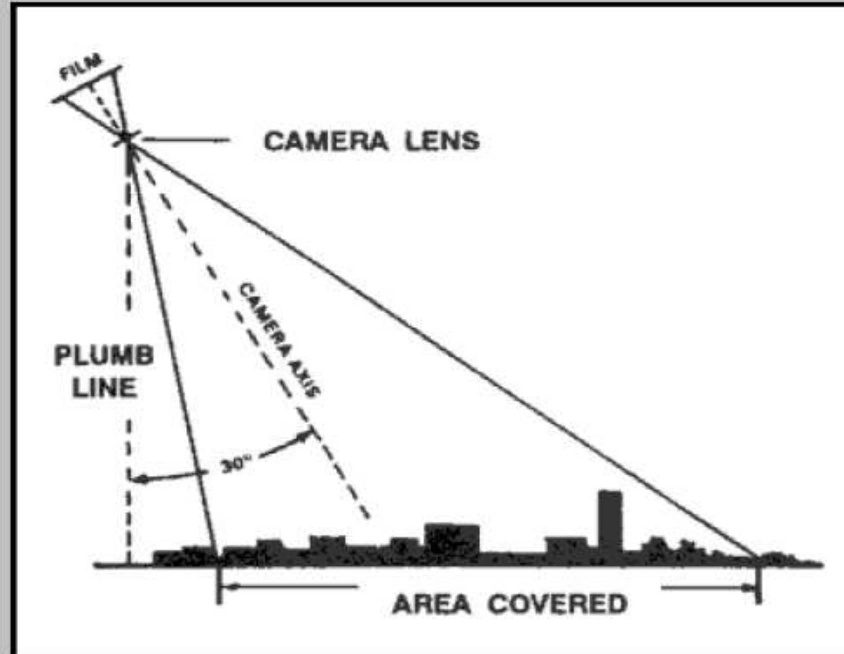
Jensen, 2000

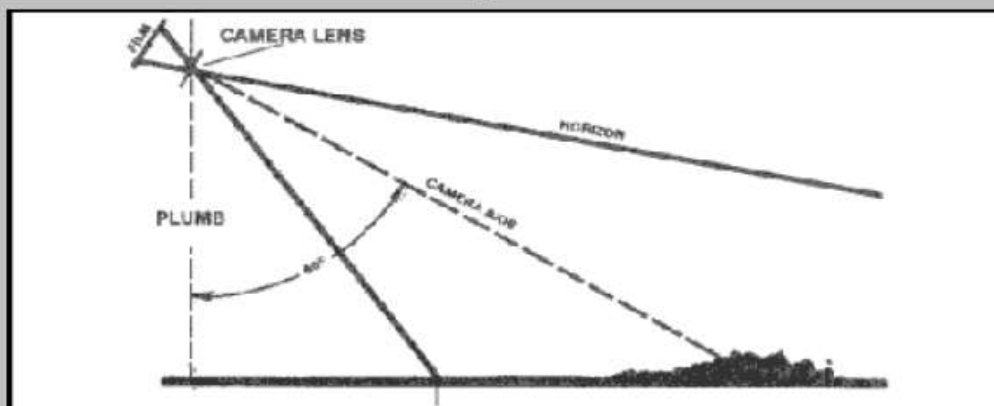
High oblique

Small scale

Large scale







Map-reading.com Robert Davidson

Advantages of vertical over oblique aerial photographs

1. Vertical photographs present approximately uniform scale throughout the photo but not oblique photos.
2. Because of a constant scale throughout a vertical photograph, the determination of directions (i.e., bearing or azimuth) can be performed in the same manner as a map. This is not true for an oblique photo because of the distortions.
3. Because of a constant scale, vertical photographs are easier to interpret than oblique photographs. Furthermore, tall objects (e.g., buildings, trees, hills, etc.) will not mask other objects as much as they would on oblique photos.
4. Vertical photographs are simple to use photogrammetrically as a minimum of mathematical correction is required.
5. Stereoscopic study is also more effective on vertical than on oblique photographs.

Advantages of oblique over vertical aerial photographs

1. An oblique photograph covers much more ground area than a vertical photo taken from the same altitude and with the same focal length.

2. If an area is frequently covered by cloud layer, it may be too low and/or impossible to take vertical photographs, but there may be enough clearance for oblique coverage.

3. Oblique photos have a more natural view because we are accustomed to seeing the ground features obliquely. For example, tall objects such as bridges, buildings, towers, trees, etc. will be more recognizable because the silhouettes of these objects are visible.

4. Objects that are under trees or under other tall objects may not be visible on vertical photos if they are viewed from above. Also some objects, such as ridges, cliffs, caves, etc., may not show on a vertical photograph if they are directly beneath the camera.

5. Determination of feature elevations is more accurate using oblique photograph than vertical aerial photographs.

Because oblique aerial photos are not used for photogrammetric and precision purposes, they may use inexpensive cameras

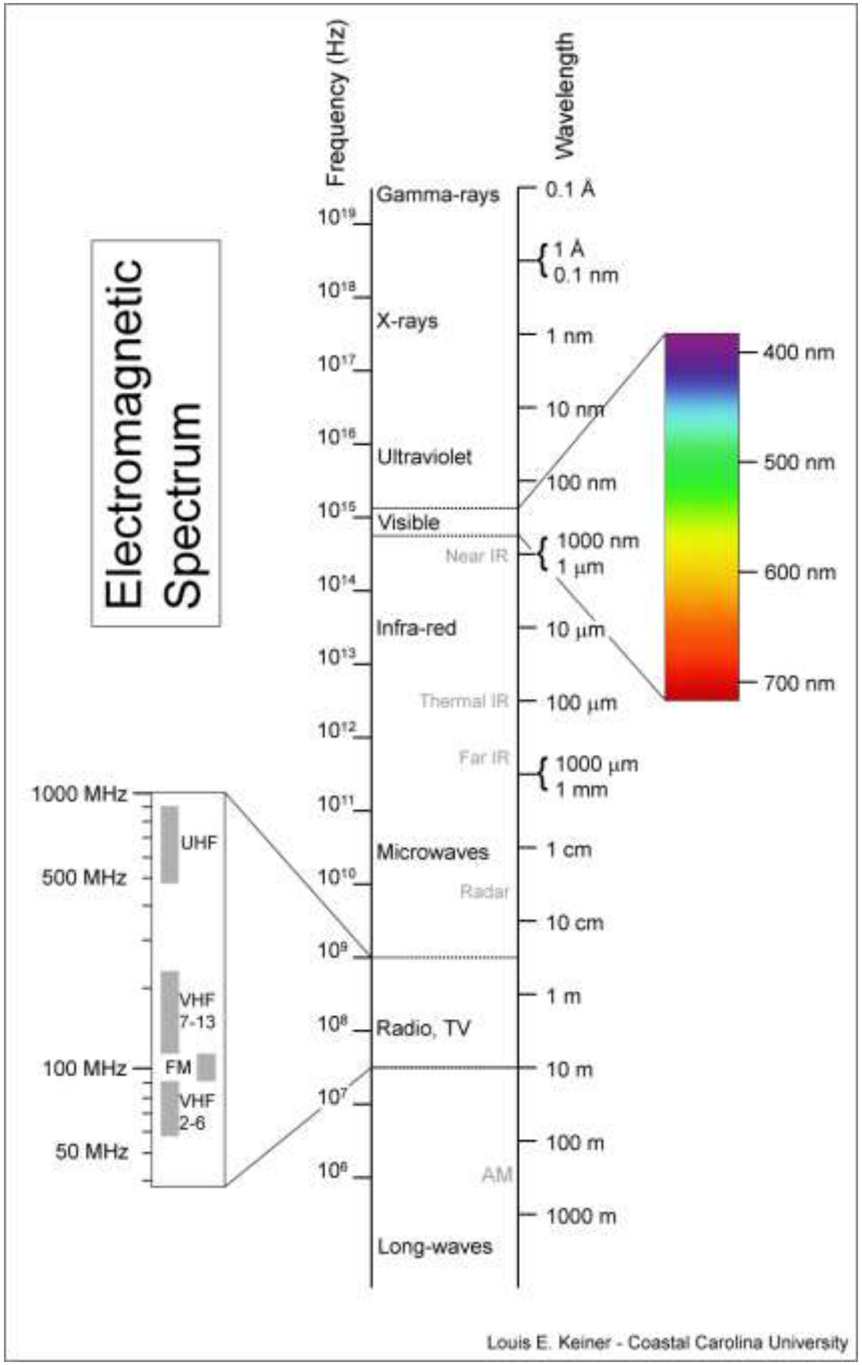
Photography according to Lens System

Now a days single lens photography is most commonly used in most of the aerial photo-interpretation work. Two lens, three lens, four lens or nine lens photography have virtually become obsolete. However, some of the multilens photography, like trimetrogen (three lens), four lens or nine lens photography has been proved to be of significance in war reconnaissance or in aerial photography researchers.

Continuous strip photography: In this photography, the photo negative is made to pass continuously over a narrow slot in the focal plane of the camera.

Photography according to special properties of films, filters or photographic equipments

1	Panchromatic	Records all the reflections of visible spectrum	General photographic interpretation
2	Infra-red	Records only red and infrared part of the spectrum	Water and vegetations discriminations
3	Colour	Records all the reflections of visible spectrum in colour or near natural colours	Mineral prospecting, forestry,
4	Colour Infra-red	Records visible and infra-red in combination resulting in false colours	Plant and crop diseases, land-water-vegetation discriminations
5	Thermal infra-red imagery	Records only thermal infra-red emissions of objects	Temperature variation like geothermal, water pollution
6	Radar imagery	Records reflections of radar waves	Suited for topographic studies, morpho-tectonic studies and general conditions of ground
7	Spectrazonal	Records only the selective part of the spectrum	Different parts of the spectrum suited to different aspects of studies

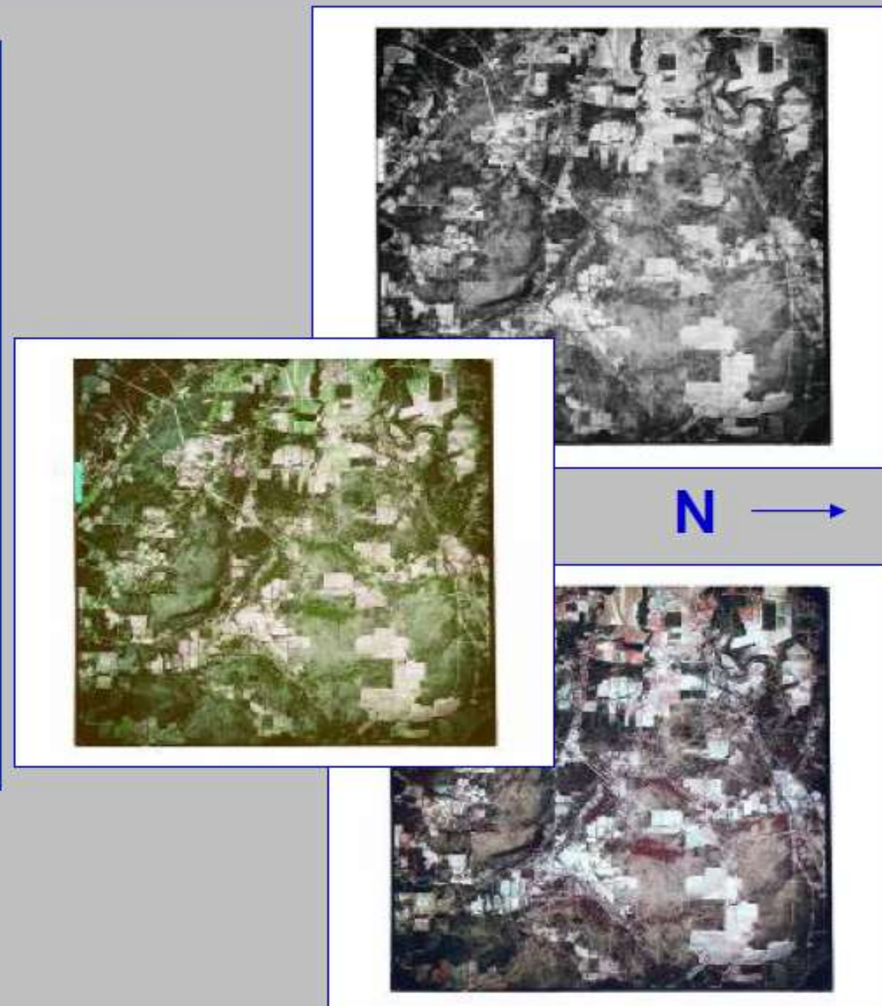


EM Spectrum Regions Used in Remote Sensing

- Ultraviolet – 0.3 to 0.4 µm
- Visible – 0.4 to 0.7 µm
- Near Infrared – 0.7 to 1.3 µm
- Middle Infrared – 1.3 to 2.8 µm
- Thermal Infrared – 2.4 to14 µm
- Microwave – 1 mm to 1 m

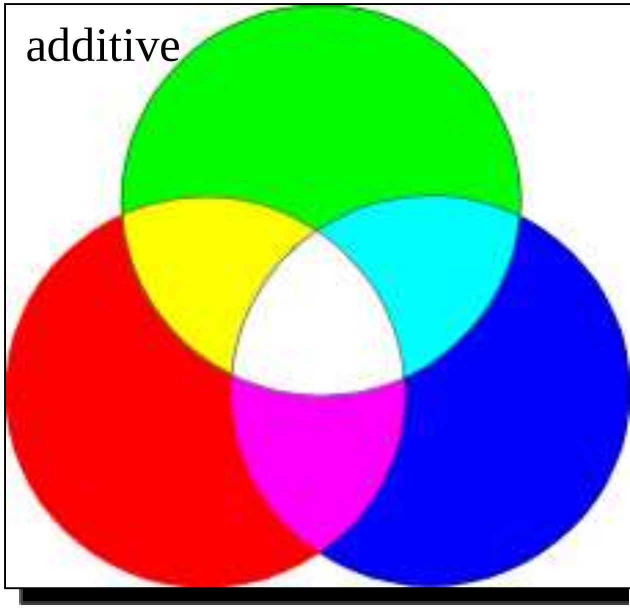
Common Types of Aerial Film

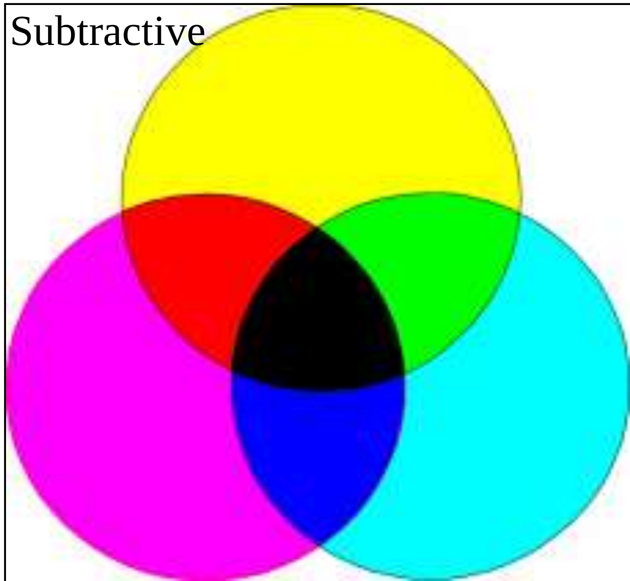
- Panchromatic
  - Sensitive to blue through red wavelengths
- Color
  - Three emulsion layers
- Color Infrared
  - Generally three layers sensitive in green, red, and IR



Color Science

- Additive primary colors :
  - Blue, Green, and Red
- Subtractive primary colors (or complementary colors):
  - Yellow, Magenta, and Cyan
- Filters (subtract or absorb some colors before the light reaches the camera):
  - Red filter (absorbs green and blue, you can see red)
  - Yellow (or minus-blue) filter (absorbs blue, allows green and red to be transmitted, which is yellow)
  - Haze filter (absorbs UV)





Types of photographs

- **Black and white photographs**
  - Panchromatic (**minus-blue** filter used to eliminate UV and blue wavelengths)
  - IR (IR-sensitive film and **IR only** filter used to acquire photographs at 0.7- 1.0 μm)
  - UV (at 0.3-0.4 μm, low contrast and poor spatial resolution due to serious atmospheric scattering)
- **Color photographs**
  - Normal color (**Haze filter** used to absorb UV and create true color 0.4-0.7 μm, or blue, green, red)
  - IR color (**Yellow filter** used to eliminate blue and create IR color (or false-color infrared) of 05-1.0 μm, or green, red, and IR)
  - 4 bands (blue, green, red, and IR)


Normal color

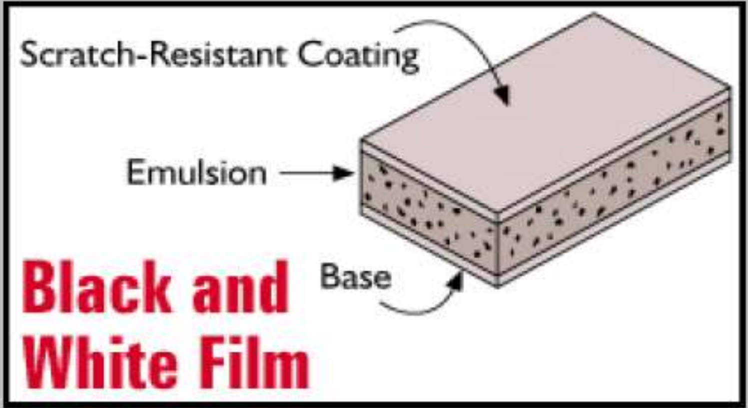

False-color infrared

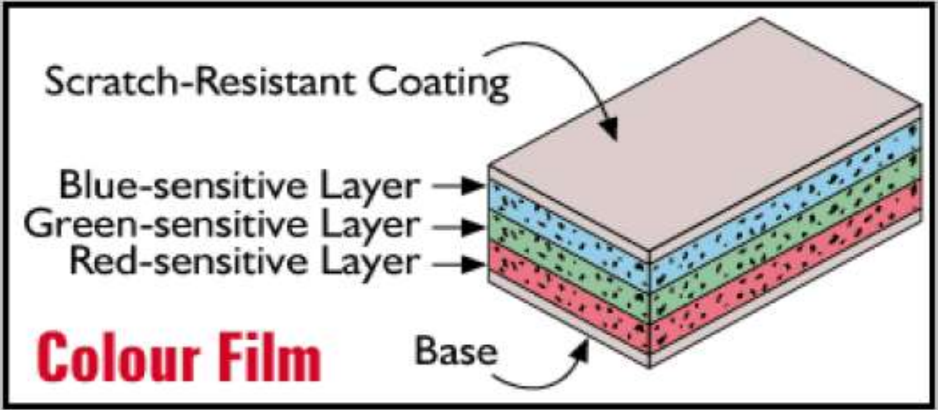
Normal color

False-color infrared

Photographic Film

- Film consists of silver halide emulsions sensitive to particular portions of electromagnetic energy
- Exposure to energy (light) activates the chemicals
- "Black and white" a misnomer





Photographic films

Color films have 3 emulsion layers – filters are used to expose the emulsion layers to different regions of the EM spectrum

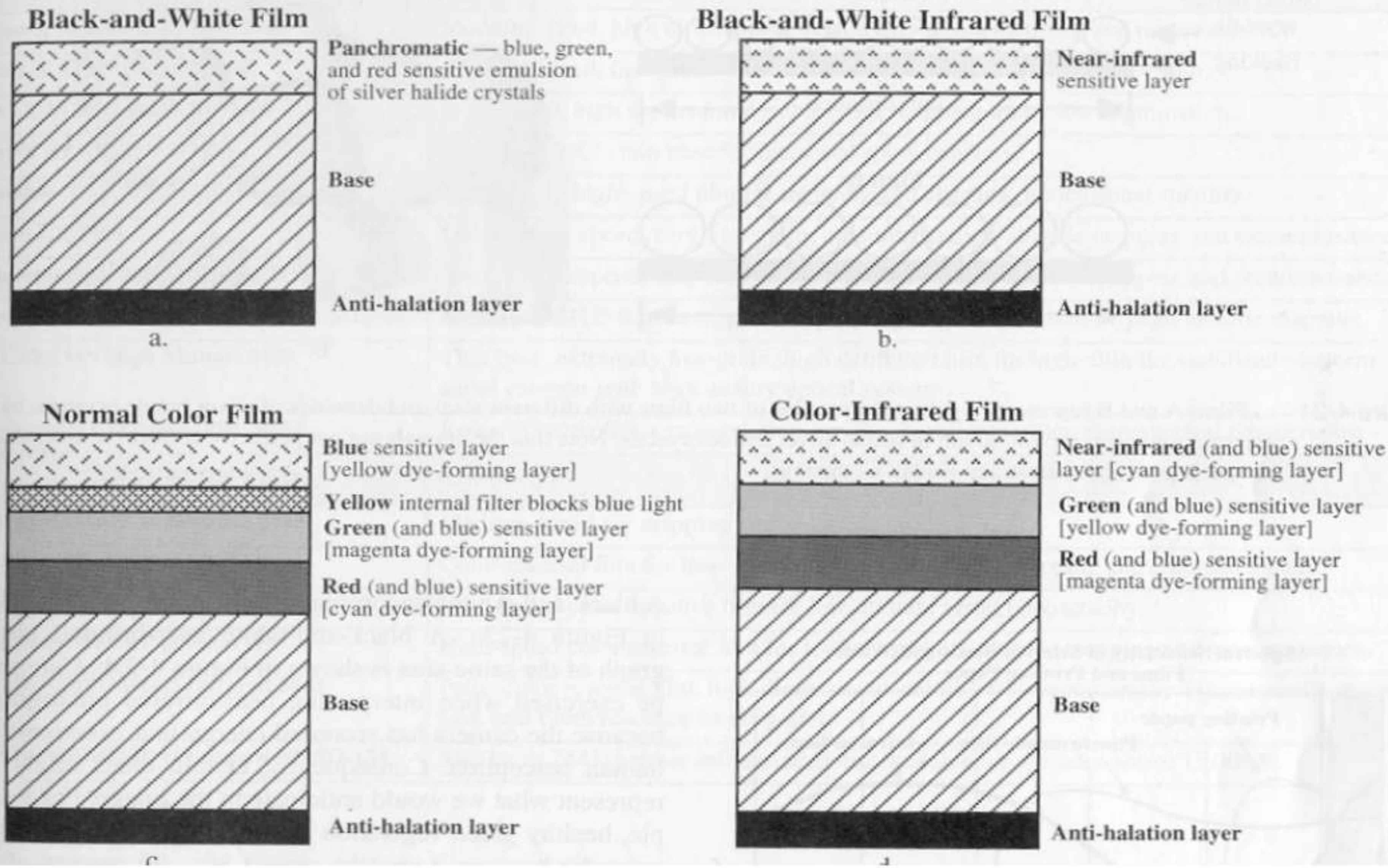
0.4 to 0.5 μm: blue region of the EM spectrum

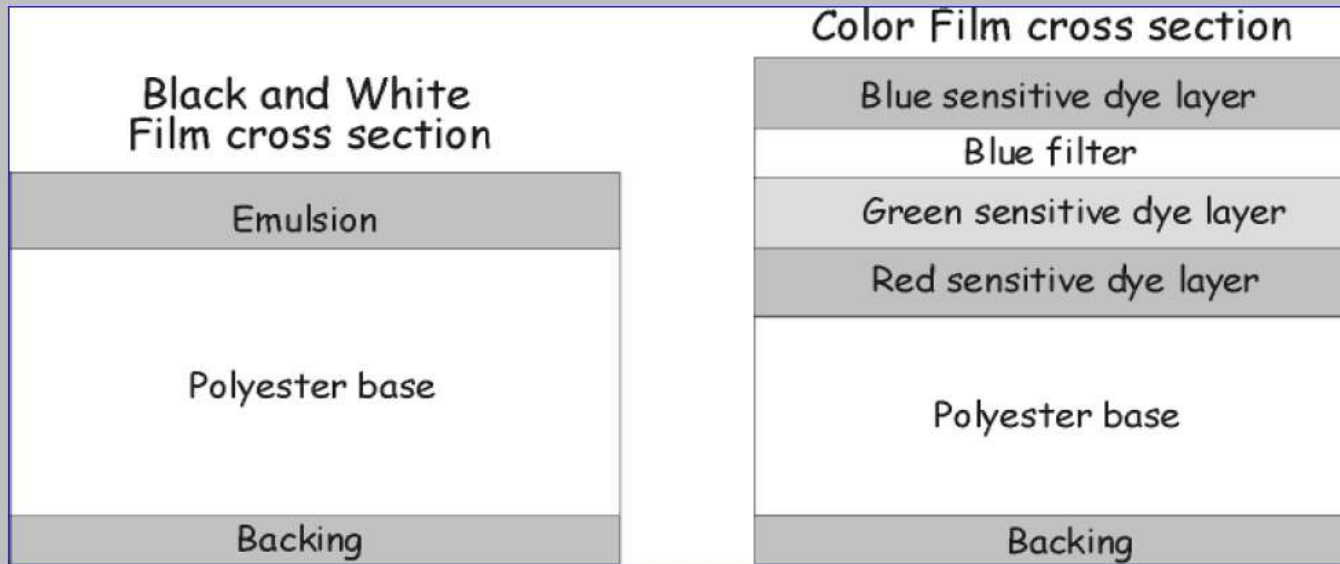
0.5 to 0.6 μm: green region of the EM spectrum

0.6 to 0.7 μm: red region of the EM spectrum

0.7 to 1.1 μm: near infrared region of the EM spectrum

Generalized Cross-Sections of Black-and-White Panchromatic, Black-and-White Infrared, Color, and Color-Infrared Film



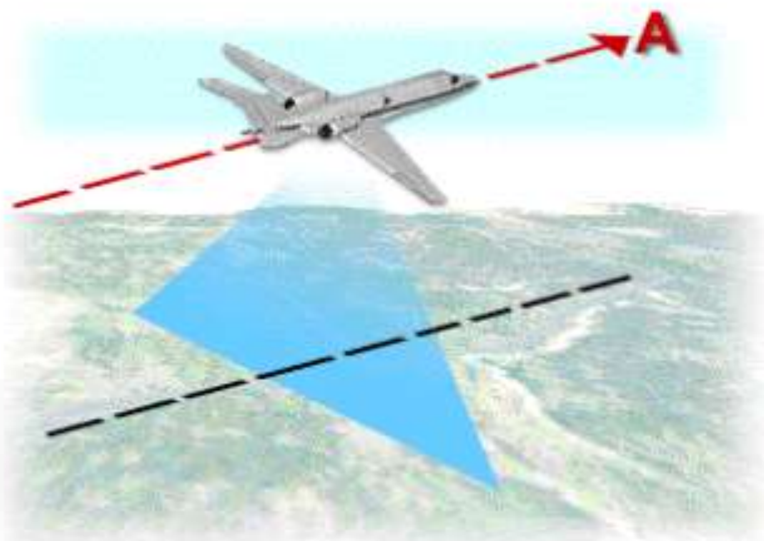

Black and White
Film cross section
Emulsion
Polyester base
Backing
Color Film cross section
Blue sensitive dye layer
Blue filter
Green sensitive dye layer
Red sensitive dye layer
Polyester base
Backing

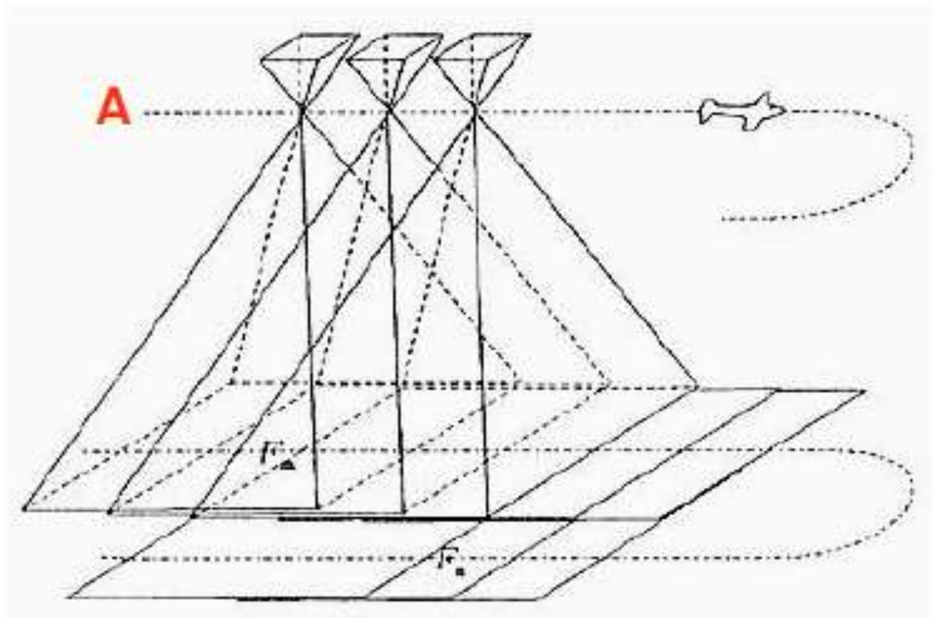
September 18, 2004

January 4, 2004

Flight runs

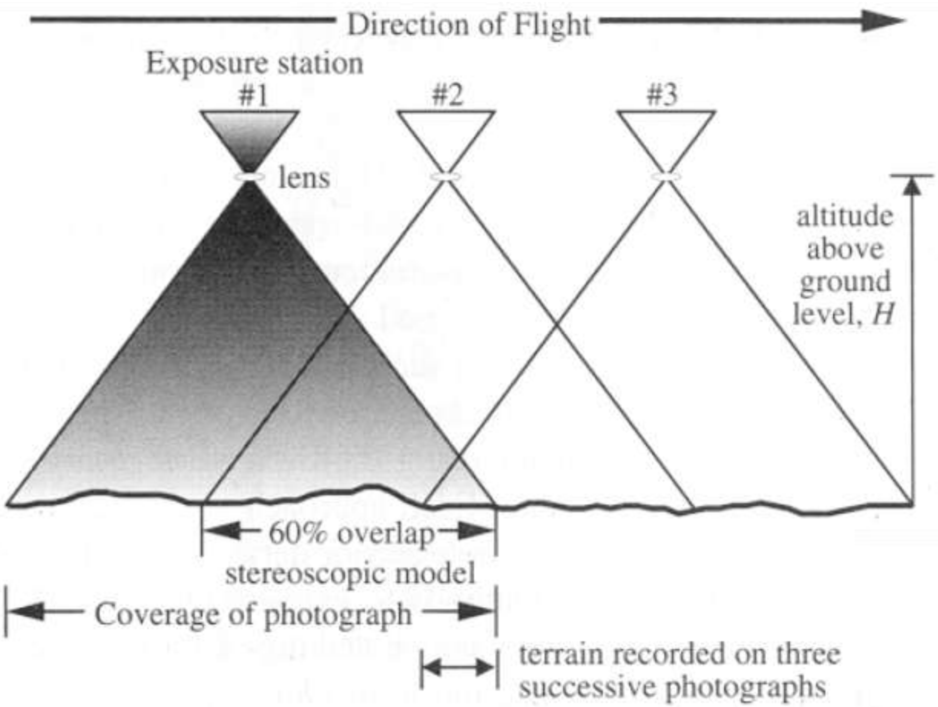
When obtaining vertical aerial photographs, the aircraft normally flies in a series of lines, each called a flight run (A).

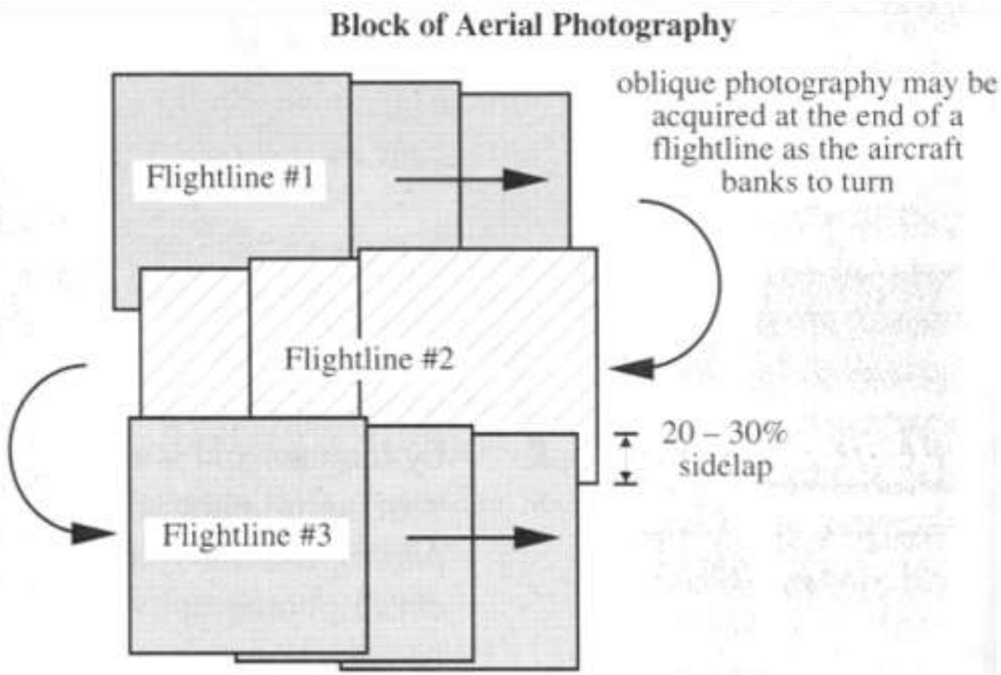


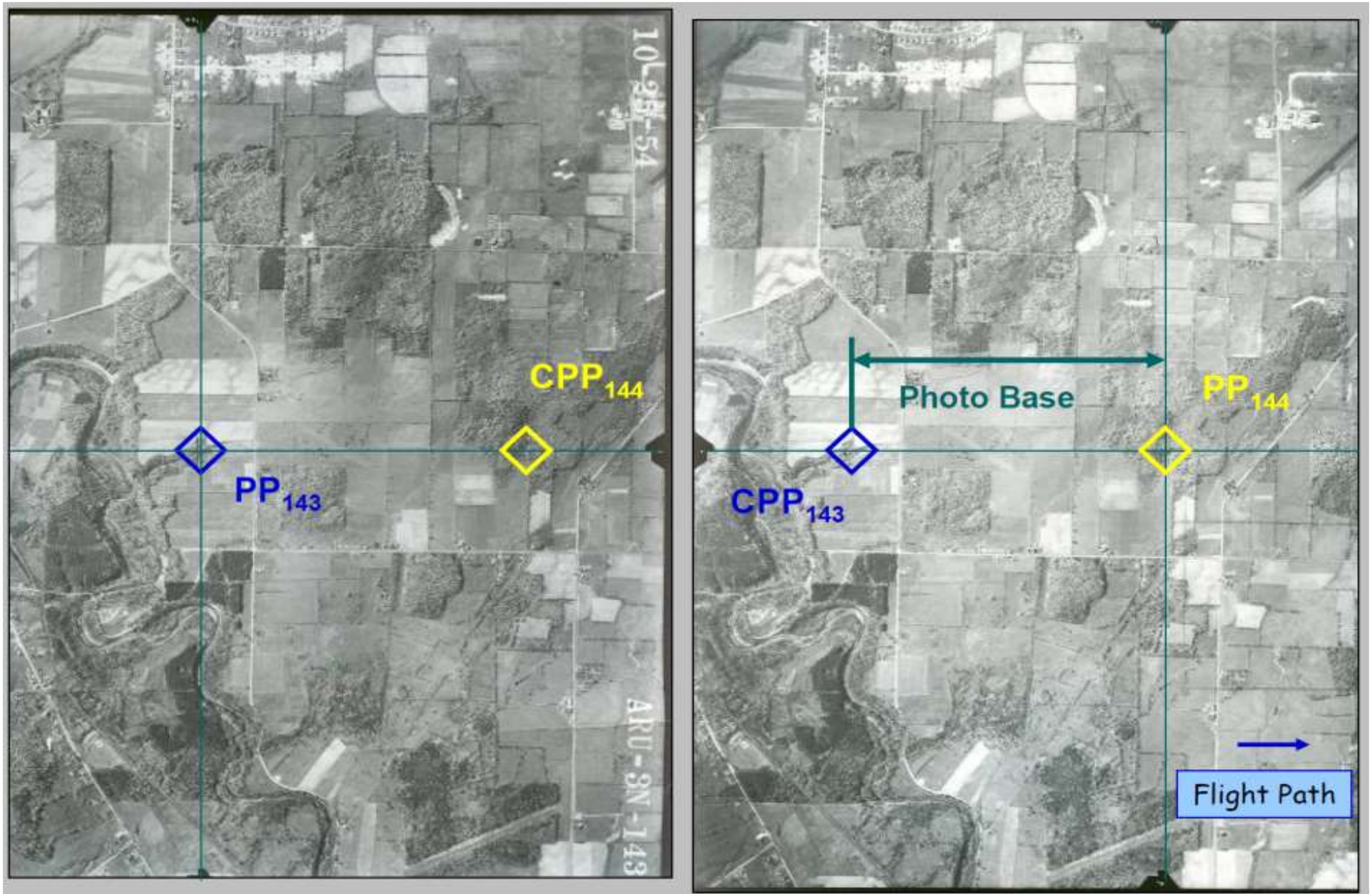


Acquisition of aerial photograph

Flightline of Aerial Photography

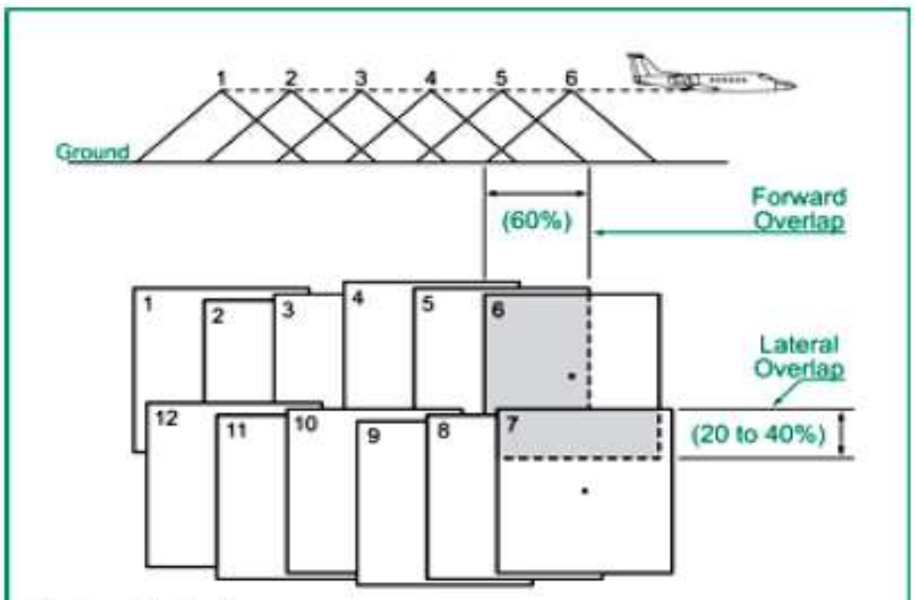




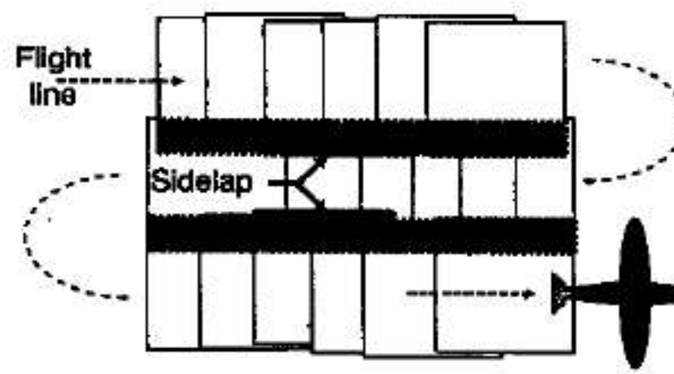

CPP144
PP143
Photo Base
PP144
CPP143
Flight Path

60 % overlap

Photos are taken with a 60 % overlap between next photos. This 60% overlap facilitates stereoscopic viewing.

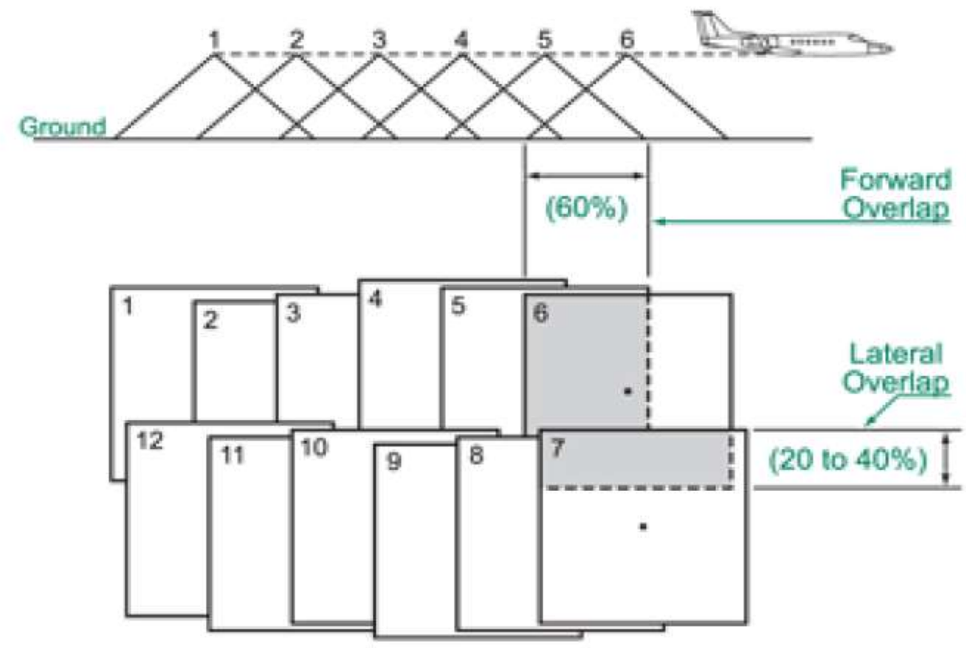


Photographic Overlap

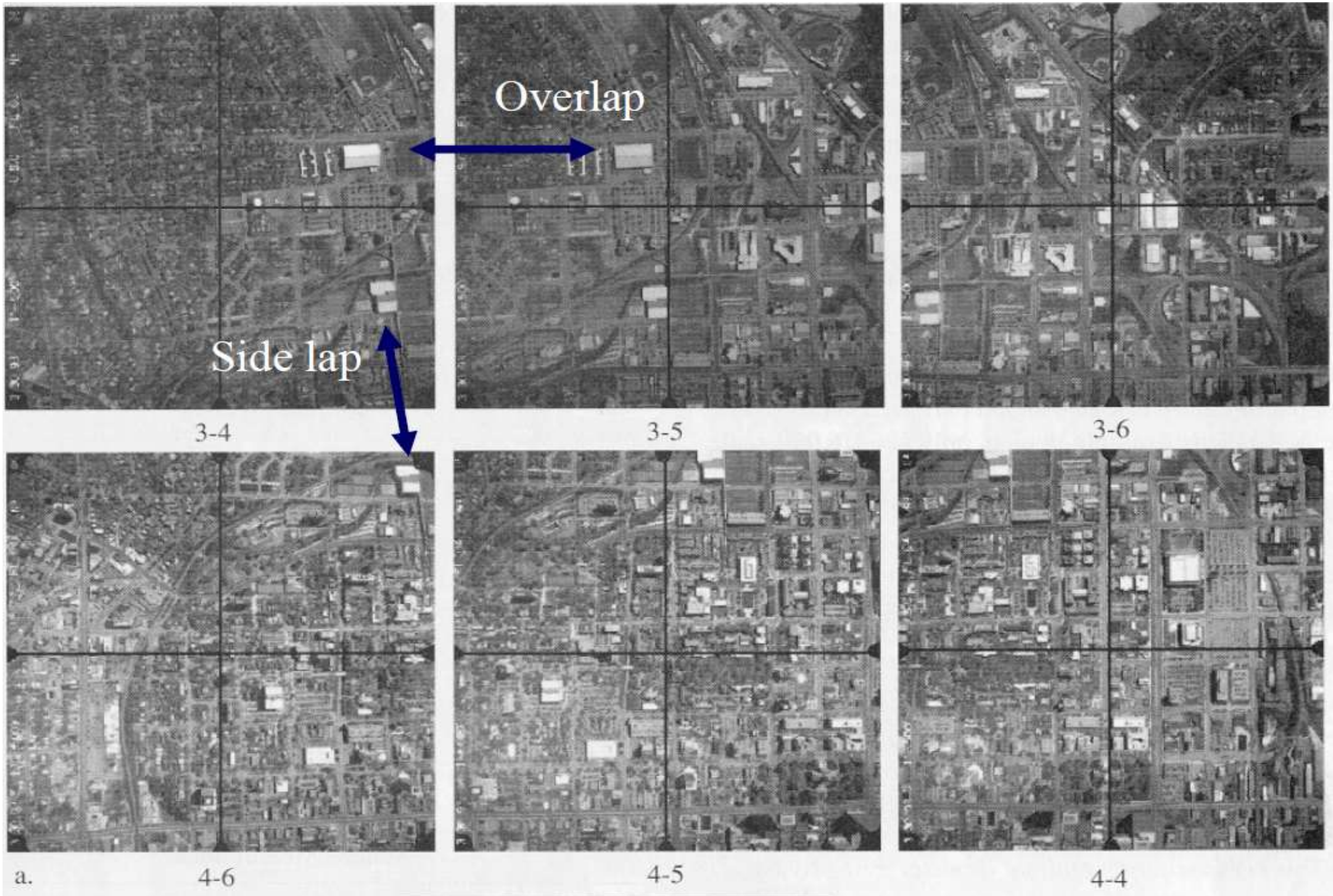


Vertical Photography

- Each frame typically overlaps on sides and end
- Sidelap ensures that there will be no gaps
- Endlap allows for stereo photography



Photographic Overlap



a.

Effective Area

Central portion of a vertical photograph, delimited by bisecting the overlap areas of neighboring photographs

Objects in effective area have less displacement than the same objects in neighboring photographs

Delineates areas to avoid duplication or gaps in interpretation effort between photos

Parts of an Aerial Photograph

- Principal Point (PP)
- Conjugate principal point (CPP)
- Fiducial marks
- Margin information
  - Mission code, exposure number, date

The most of the aerial photographs are not perfectly vertical

There are three different photo centers: the principal point, the nadir, and the Iso-center.

Each one of these centers plays a specific role and is of great importance to the photogrammetrist because different types of distortion and displacement radiate from each of these points.

If an aerial photograph is perfectly vertical, the three centers coincide at one point (i.e., the principal point), which is the geometric center of the photograph defined by the intersection of lines drawn between opposite *fiducial marks*

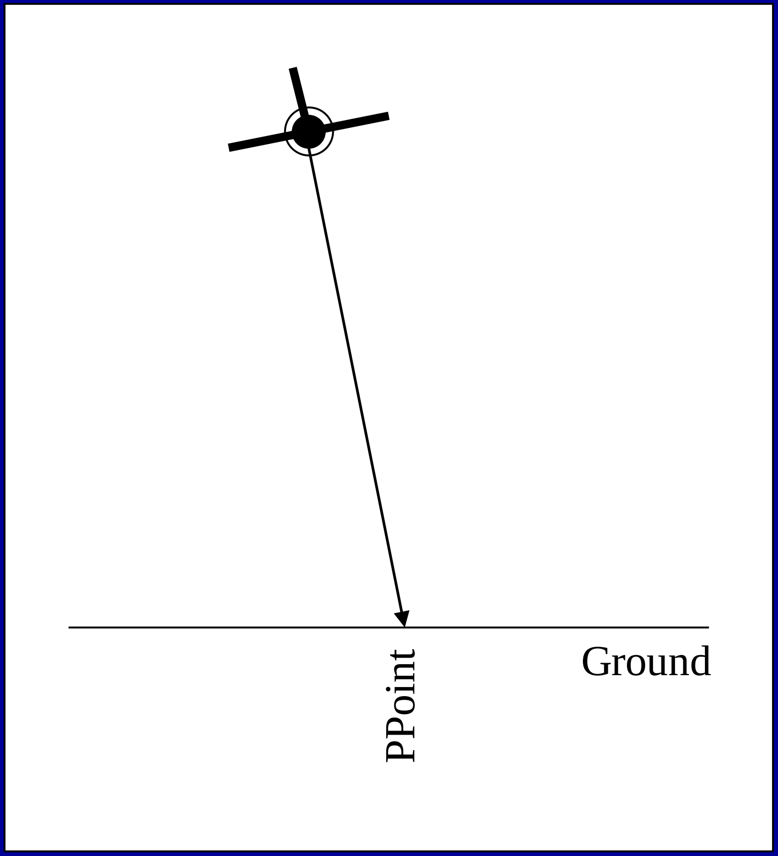
The three photo centers

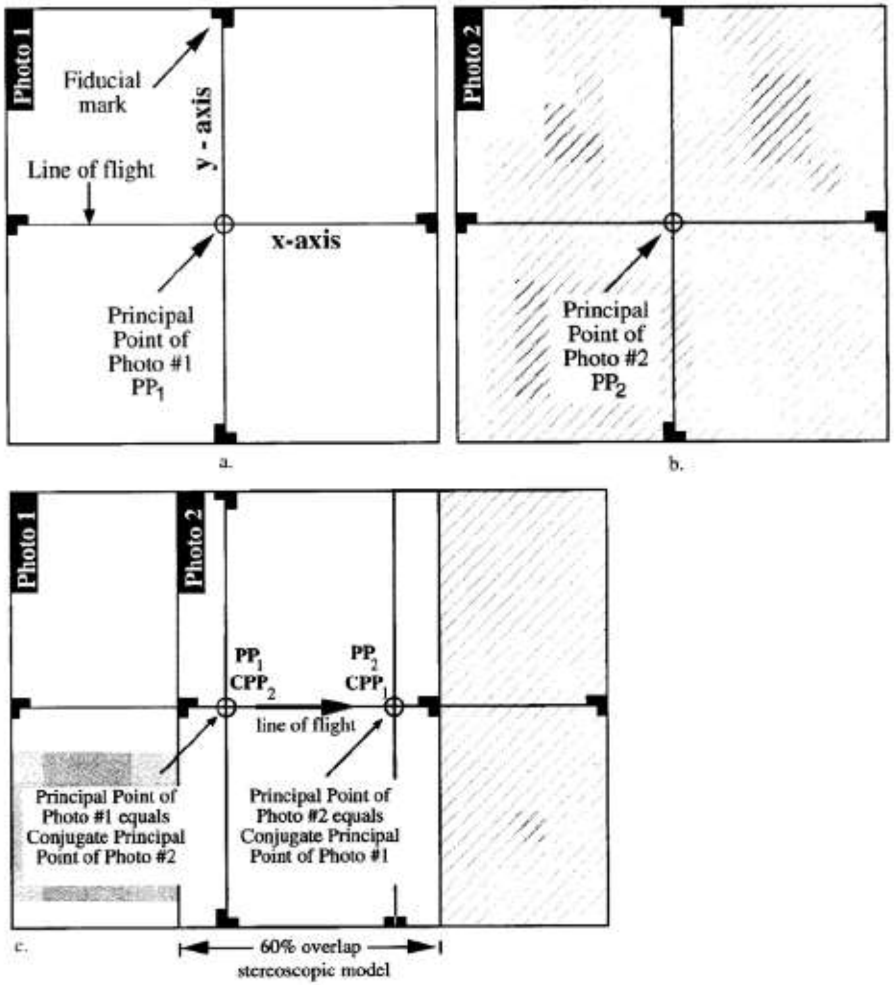
Different types of distortion and displacement radiate from each.

1

Principal point: geometric center of the photograph, and the intersection of the X and Y axes.

Lens distortion is radial from the Principal Point





Principal point

The principal point is the optical or geometric center of the photograph.

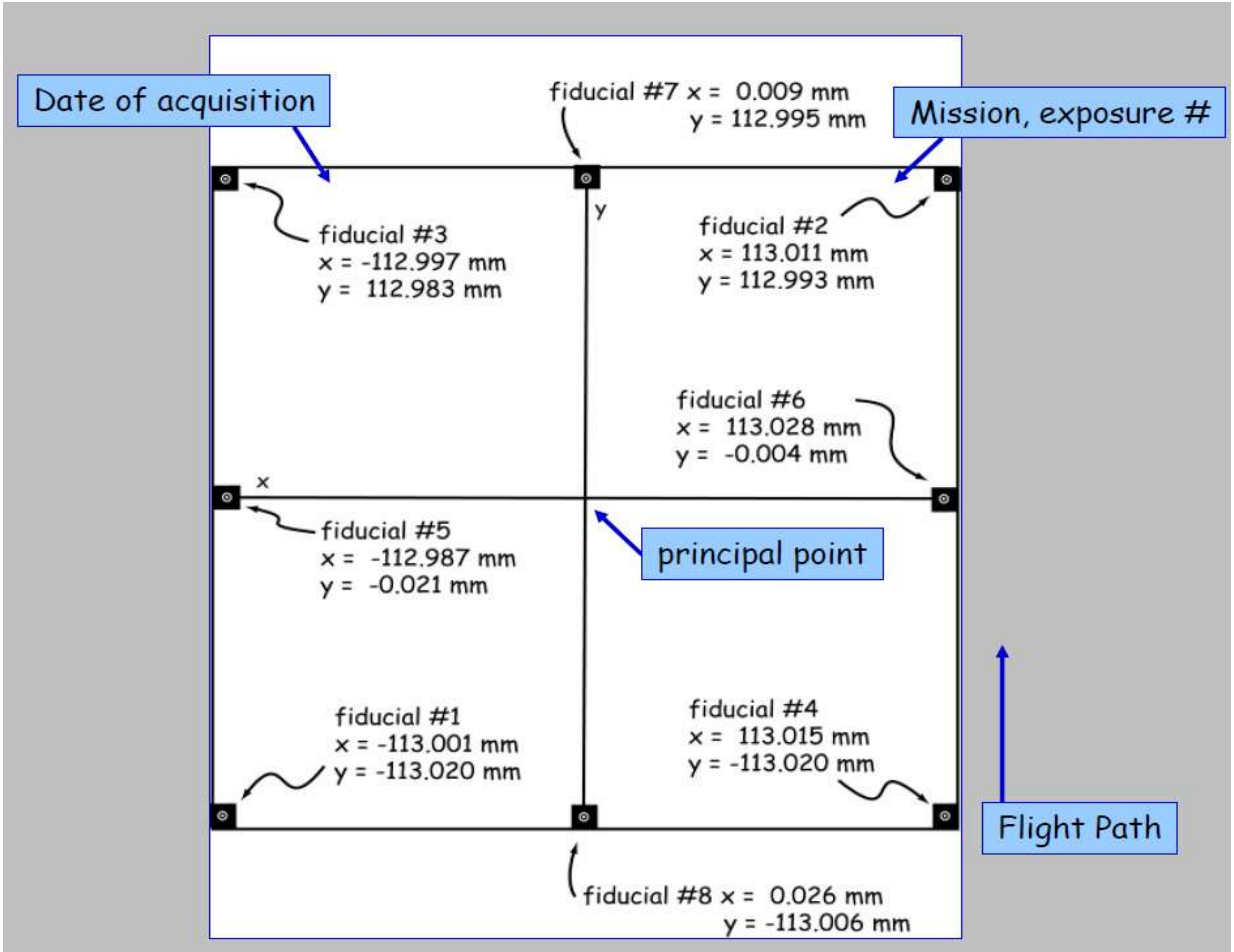
It is the intersection point between the projection of the optical axis (i.e., the perpendicular to the center of the lens) and the ground.

The principal point is assumed to coincide with the intersection of the *x* and *y* axes.

We can locate the principal point (PP) on a single photo by the intersection of lines drawn between opposite side or corner *fiducial marks*.

This PP is then transferred stereoscopically onto the adjacent (left and right) photographs of the same flight line

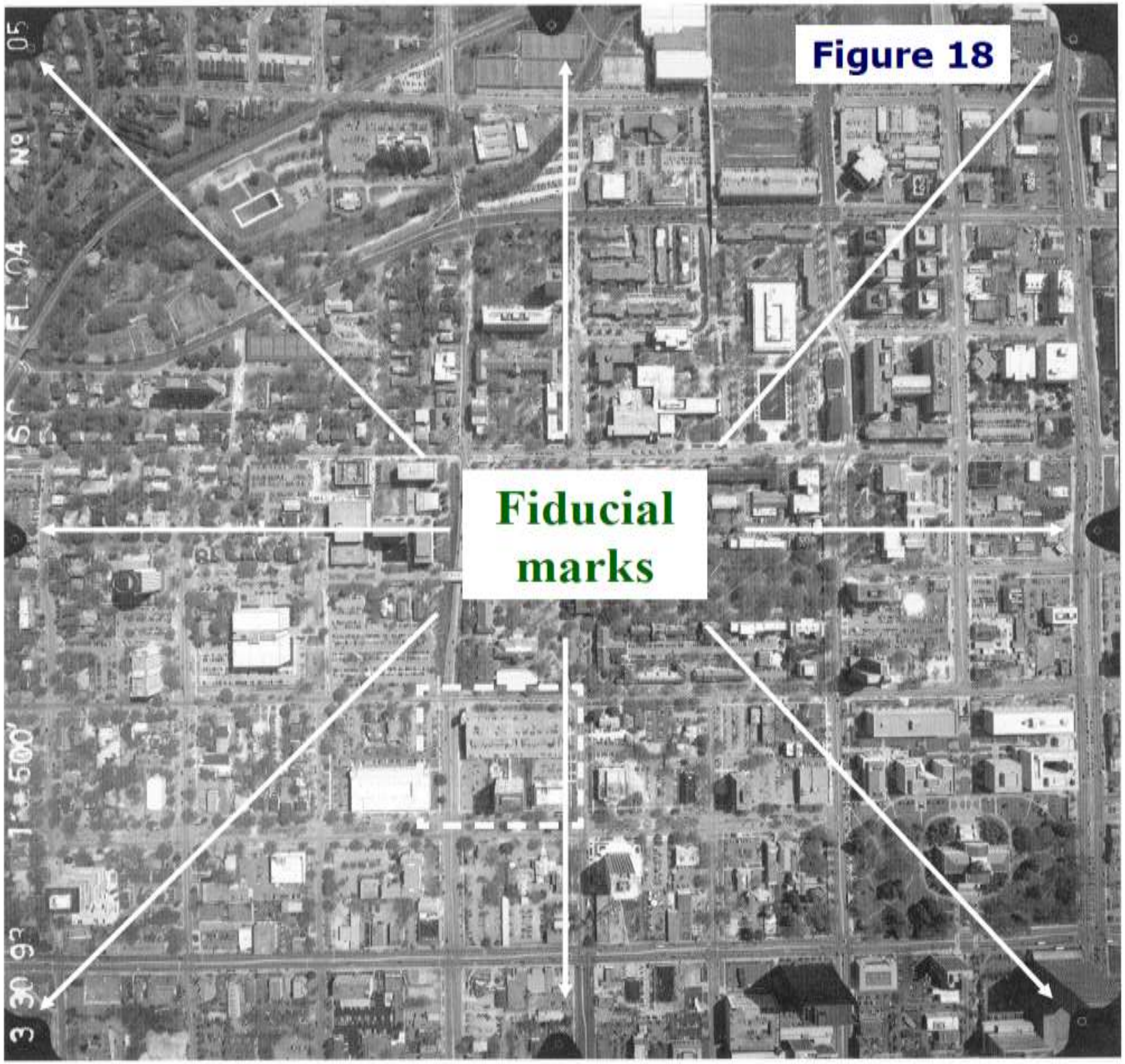
These transferred points are called transferred principal points or **conjugate principal points (CPP).** The line segment joining the principal points and the conjugate principal points constitute the flight line of the aircraft, also called base line or air base

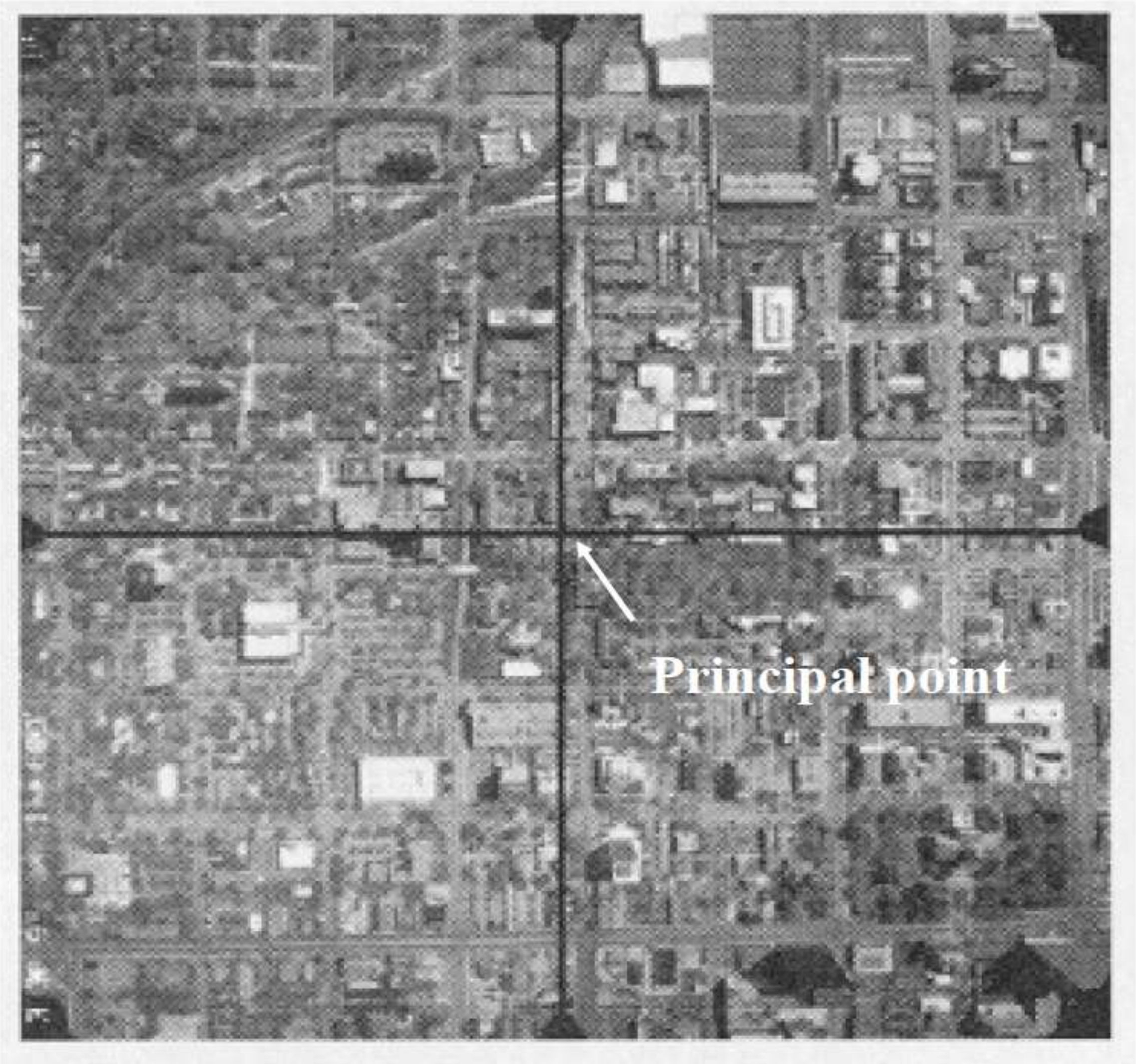


Date of acquisition
fiducial #7 x = 0.009 mm
y = 112.995 mm
Mission, exposure #
y
fiducial #3
x = -112.997 mm
y = 112.983 mm
fiducial #2
x = 113.011 mm
y = 112.993 mm
fiducial #6
x = 113.028 mm
y = -0.004 mm
x
fiducial #5
x = -112.987 mm
y = -0.021 mm
principal point
fiducial #1
x = -113.001 mm
y = -113.020 mm
fiducial #4
x = 113.015 mm
y = -113.020 mm
Flight Path
fiducial #8 x = 0.026 mm
y = -113.006 mm

$f = 6''$

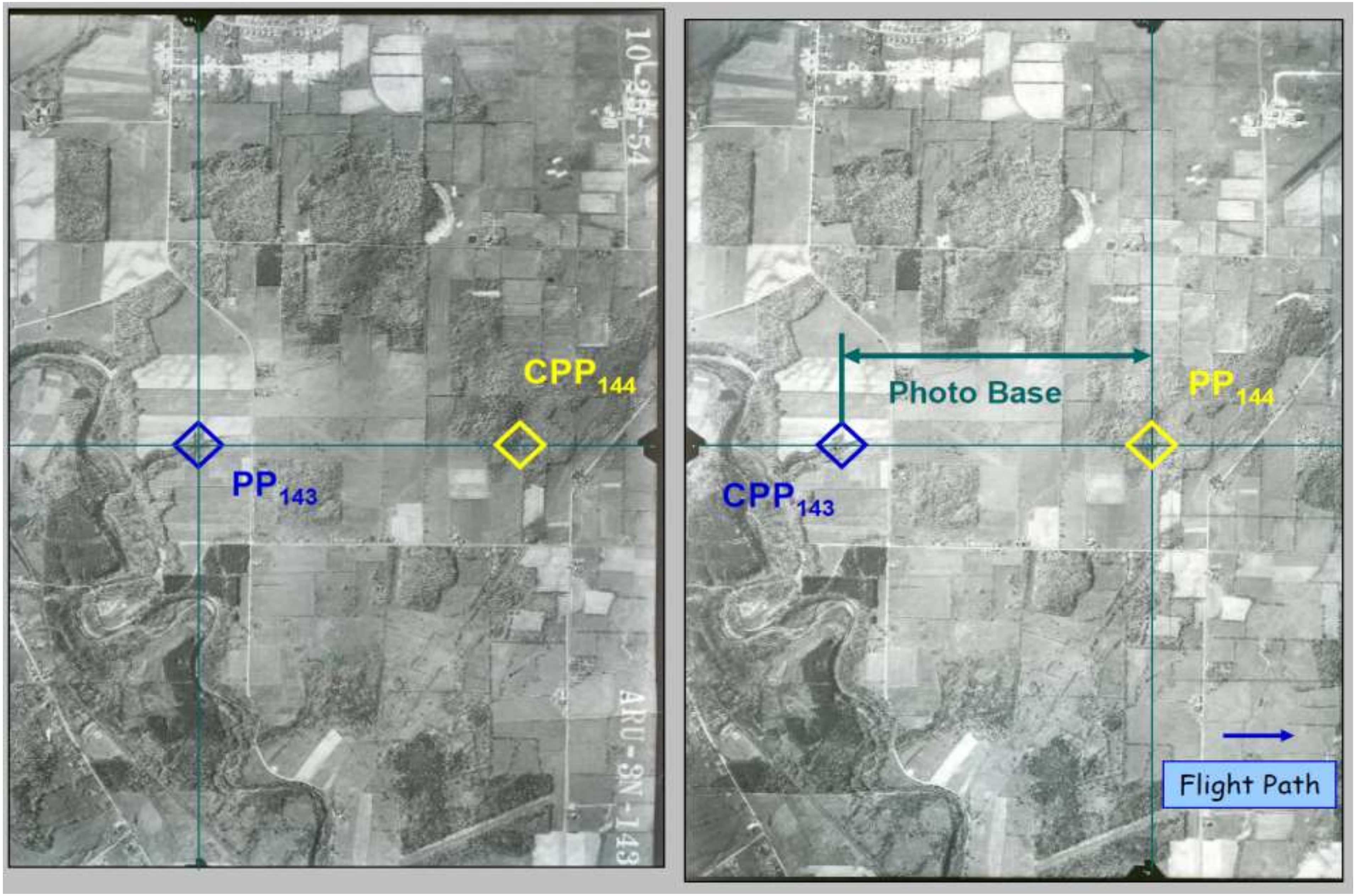
Ancillary data





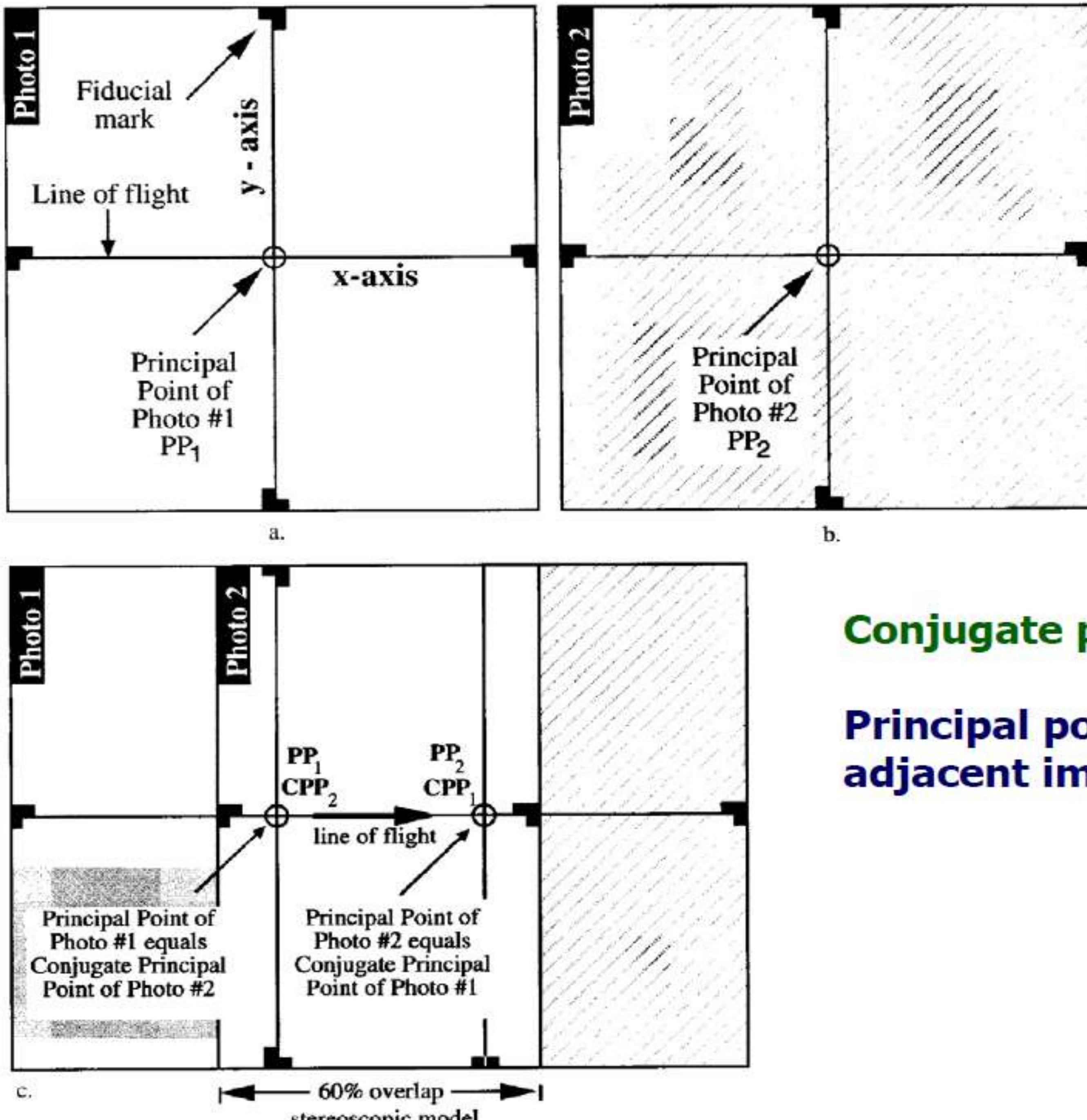
Principal point
- the intersection of the lines connecting two sets of fiducial marks
- represents the point on the ground where the camera was pointing when the photograph was taken

Figure 19



CPP_{144}
PP_{143}
Photo Base
PP_{144}
CPP_{143}
Flight Path

Figure 20



Conjugate principal point

Principal point from an adjacent image

Nadir Point

The nadir point is also called *vertical point* or *plumb point*

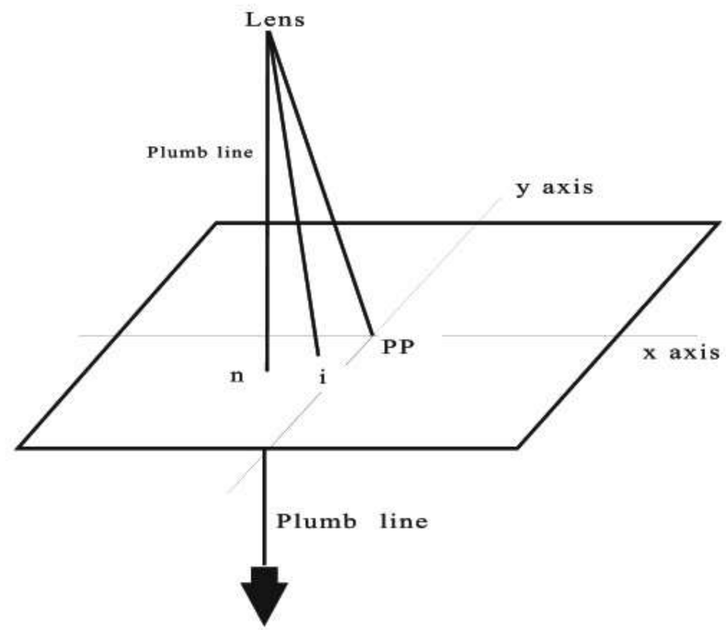
It is the intersection point between the plumb line directly beneath the camera center at the time of exposure and the ground.

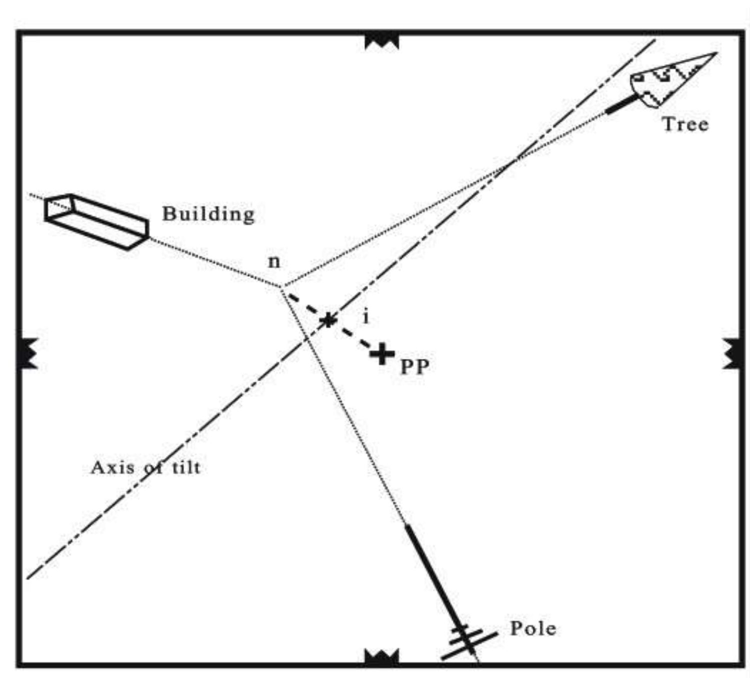
The nadir is important because relief displacement is radial from this point

Unlike the principal point, there are no marks on the photograph to locate the nadir point.

Locating the nadir on a tilted aerial photograph usually requires sophisticated stereoscopic plotting techniques involving expensive instruments and ground control information.

However, in certain situations, the nadir is easily located. The nadir point is at the intersection of lines extended from the top to bottom of tall and perfectly vertical objects.





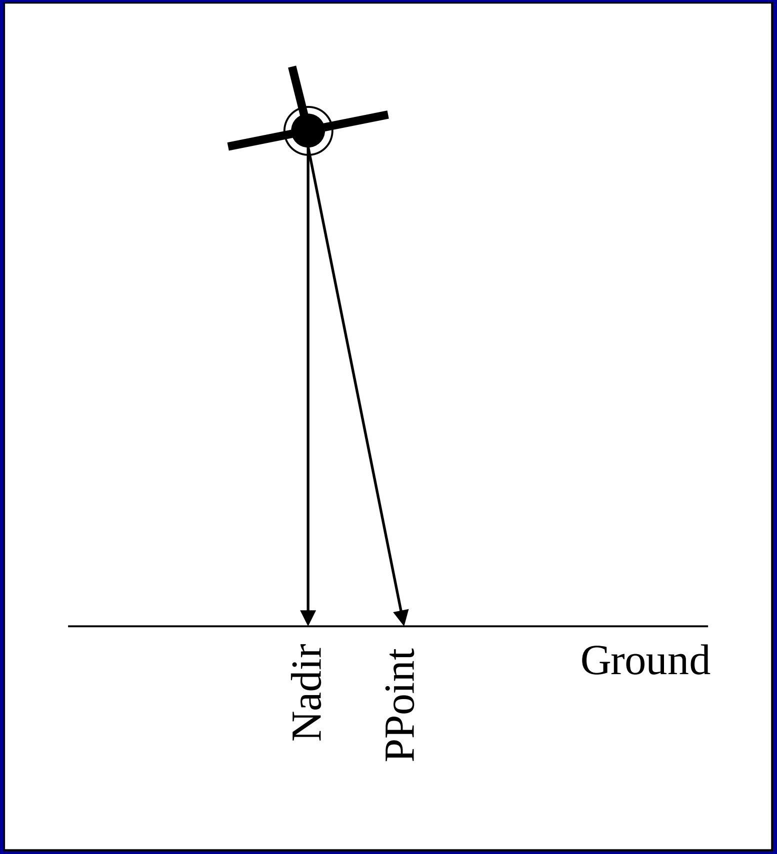
The three photo centers

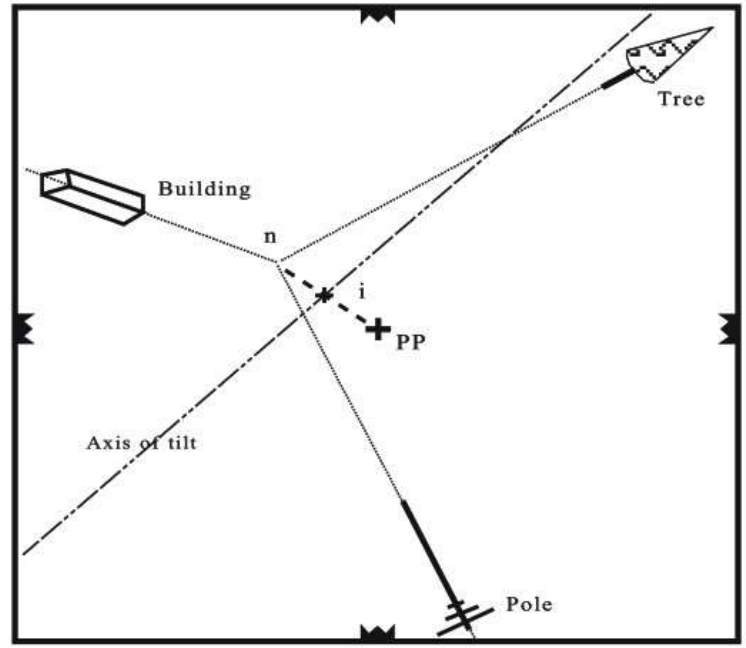
2

Nadir: **The point vertically beneath the camera at the time the photograph was taken.**

Topographic displacement is radial from the nadir

Usually difficult to locate on a single aerial photograph





Isocentre

The isocenter is the point halfway between the principal point and the nadir and on the line segment joining these two points on the photograph.

It is a point intersected by the bisector of the angle between the plumb line and the optical axis.

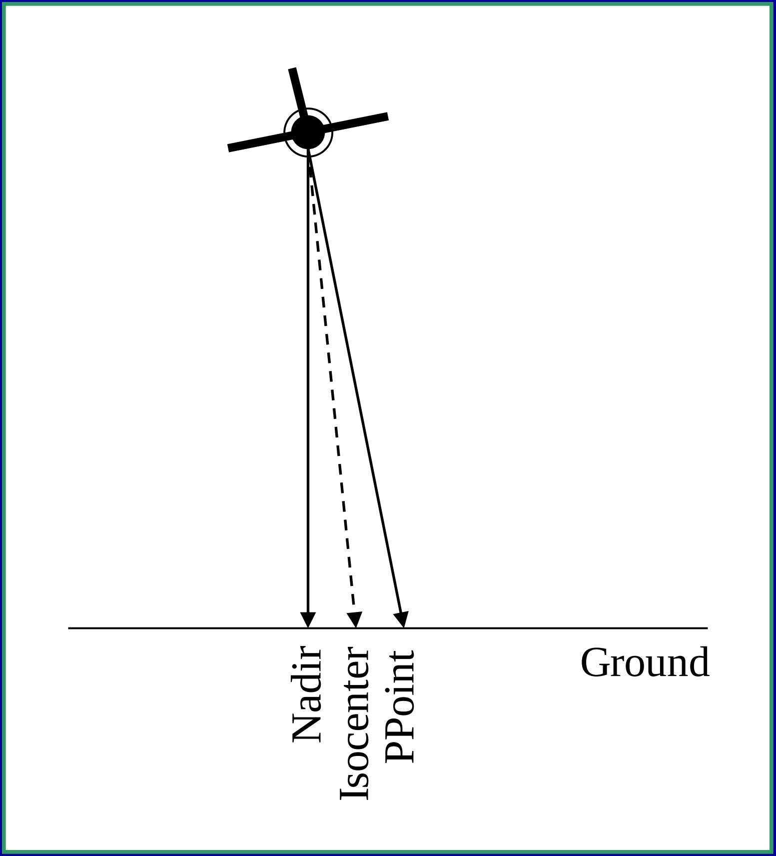
The isocentre is the point from which tilt displacement radiates.

The three photo centers

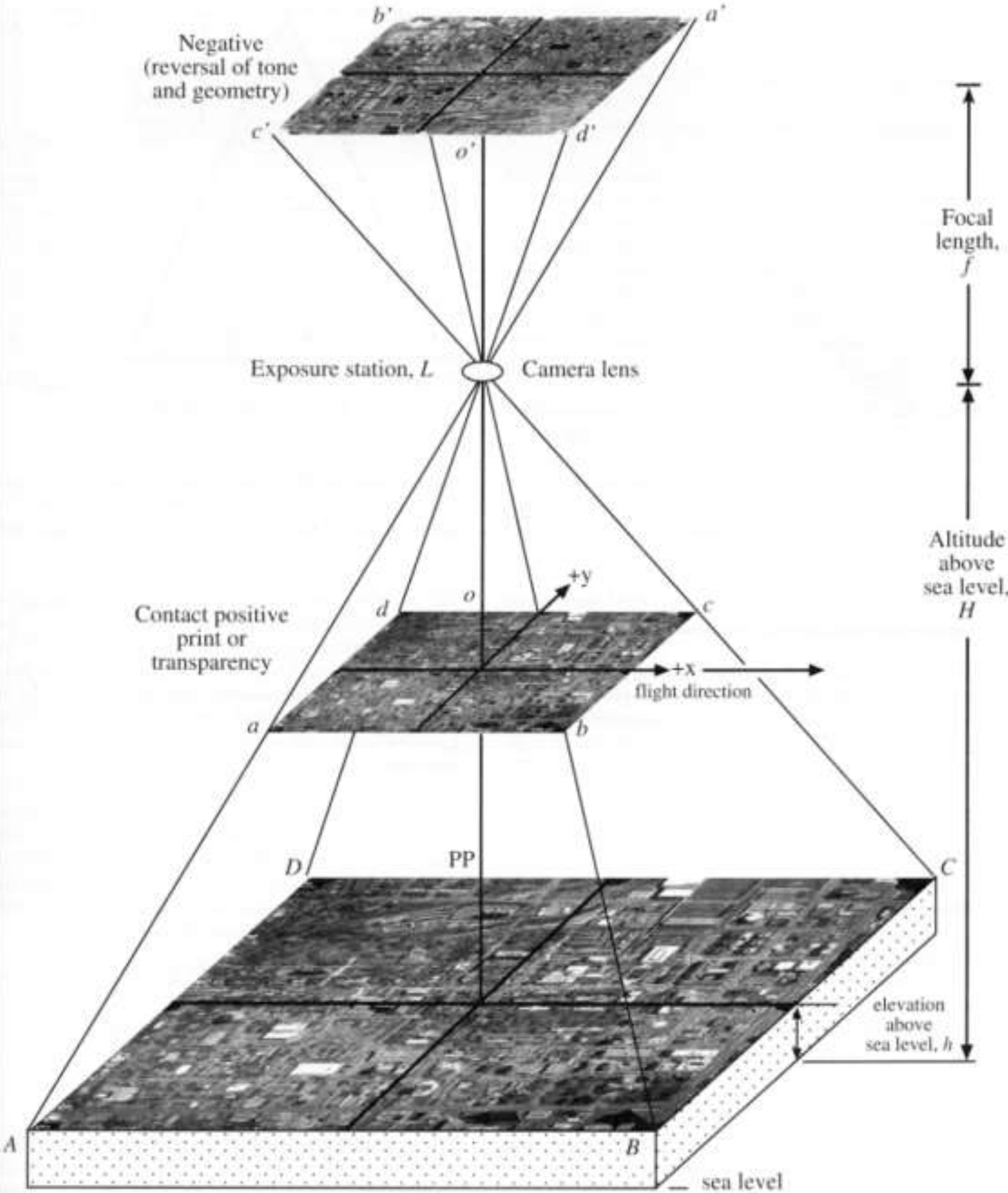
3

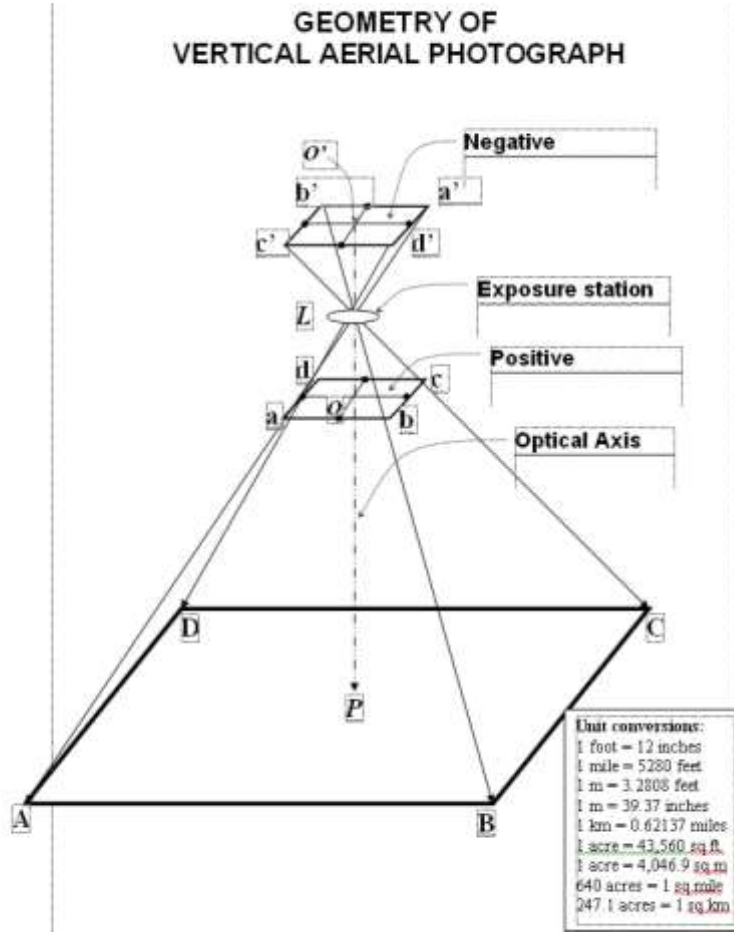
Isocenter: **The point that falls on a line halfway between the Principal Point and the Nadir.**

Tilt displacement radiates from the isocenter

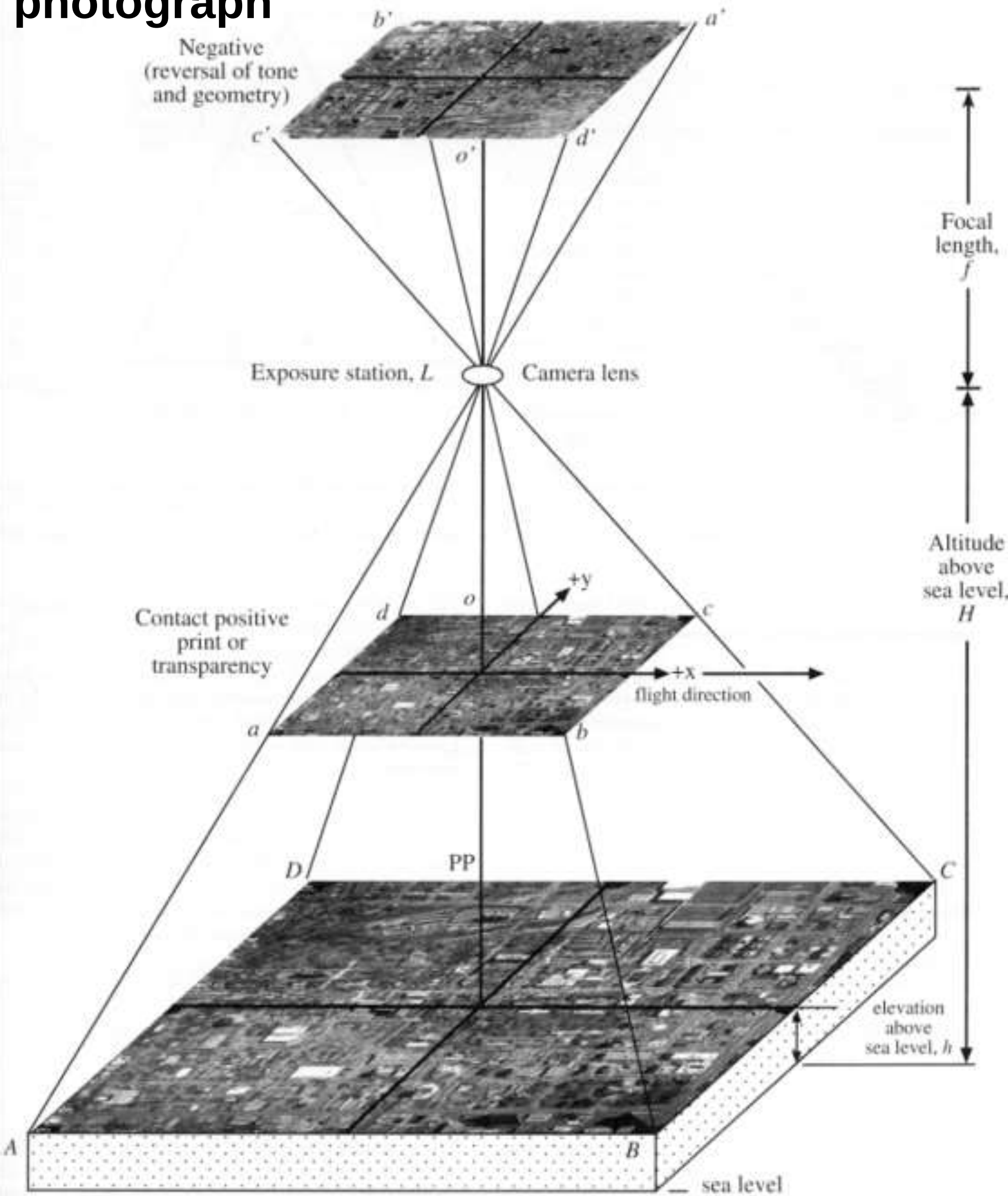


Geometry of a vertical aerial photograph





Geometry of a vertical aerial photograph



➔Incoming light rays from objects on the ground pass through the camera lens before they are imaged on the film in the focal plane.

➔The distance between the lens and the focal plane is termed ***focal length***

➔The *x* coordinate axis is arbitrarily assigned to the imaginary flight line direction on the photograph and the *y*-axis is assigned to a line that is perpendicular to the *x*-axis

➔These two axes usually correspond to the lines connecting the opposite ***fiducial marks*** recorded on each side of the print (i.e., positive image)

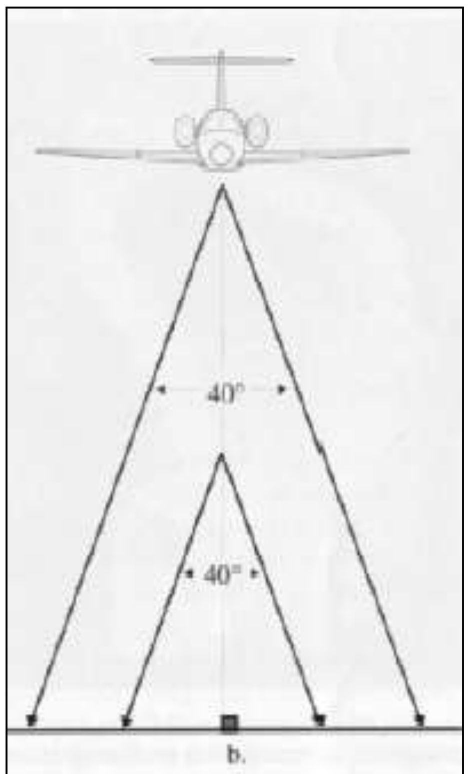
Field of View – The region which is collected in the photograph is often referred to as the camera system's field of view (FOV

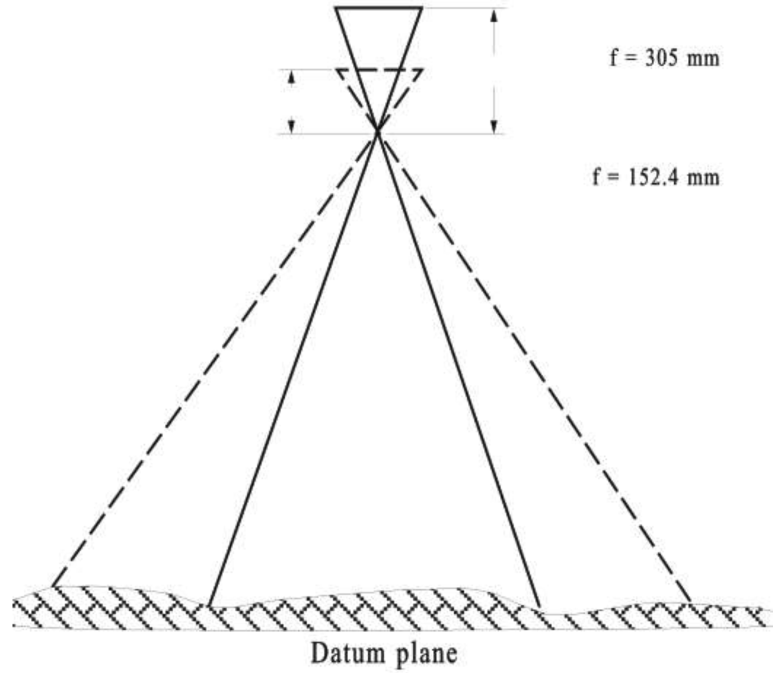
Relationship between aircraft altitude and ground coverage

➔Changing the focal length of the camera lens will alter the angular coverage of the system – as the focal length gets smaller, the angular coverage increases

➔As the angular cover increases (focal length decreases), the FOV increases

➔Changing the aircraft altitude will alter the ground coverage of the system





Relationship between aircraft altitude and ground coverage – two ways to change FOV

a. Changing the focal length of the camera lens will alter the angular coverage of the system – as the focal length gets smaller, the angular coverage increases

b. As the angular cover increases (focal length decreases), the FOV increases

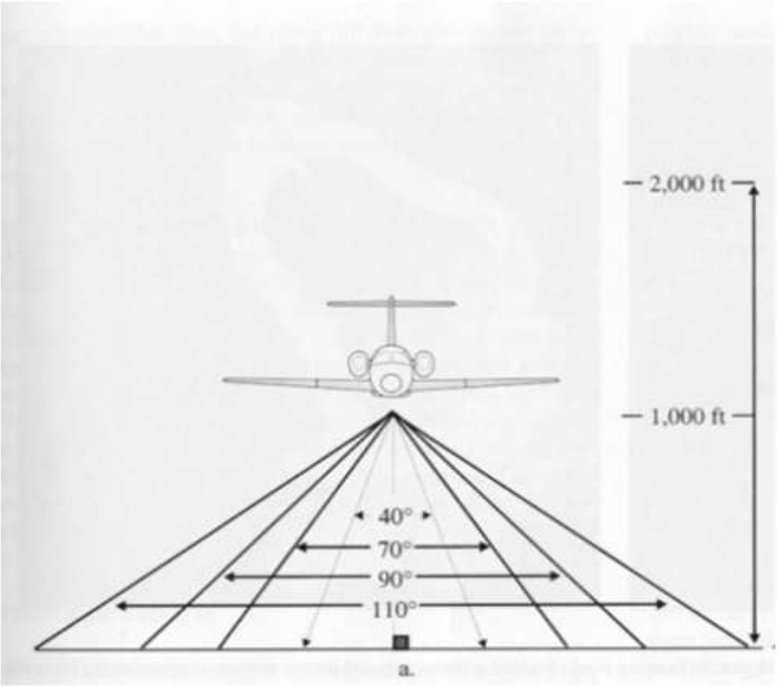
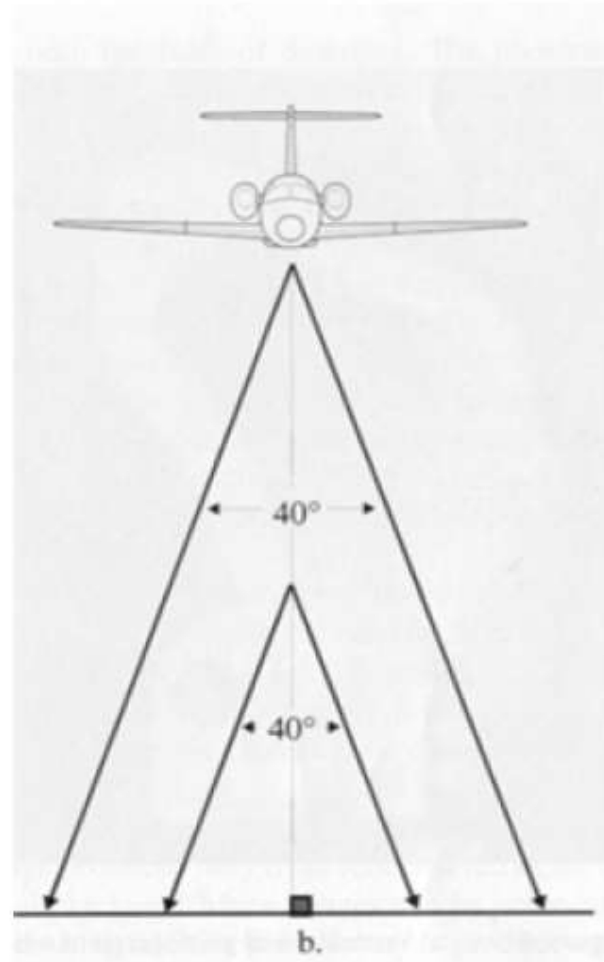


Figure 23

Relationship between aircraft altitude and ground coverage – two ways to change FOV

Changing the aircraft altitude will alter the ground coverage of the system



Main parts of Frame Aerial Cameras

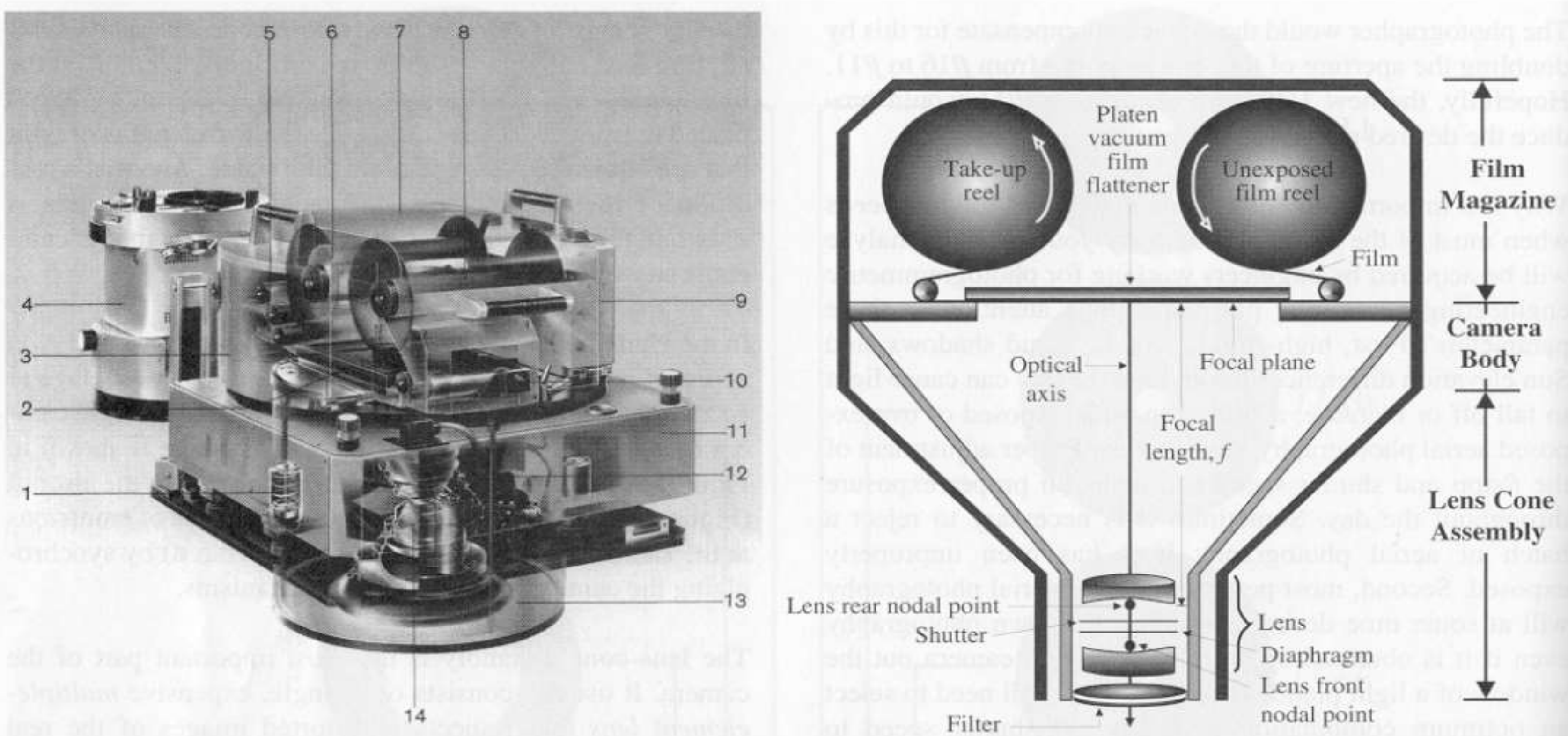
The three basic components or assemblies of a frame aerial camera such as magazine, camera body and lens cone assembly.

The camera magazine houses the reels which hold exposed and unexposed film and it also contains the film-advancing and film flattening mechanisms.

The camera body is a one-piece casting which usually houses the drive mechanism. The drive mechanism operates the camera through its cycle. The cycle consists of 1) advancing the film, 2) flattening the film, 3) cocking the shutter and 4) tripping the shutter. The power for the drive mechanism is most commonly provided by an electric motor. The camera body also contains carrying handles, mounting brackets and electrical connection.

The lens cone assembly contains a number of parts and several functions. Contained within this assembly are the lens, shutter and diaphragm.

Aerial metric camera



a. b.

Invention of Digital Cameras

- Throughout most of the 20th century, aerial camera systems used film to record information
- This changed in 1986, when Kodak invented the first charged couple device that was capable of sensing and recording an entire photographic image
  - The first digital camera recorded 1.4 million picture elements (pixels) in a 5 by 7 inch format
- Now, digital aerial camera systems are quite common

Digital Aerial Camera System from Vexcel Corp.

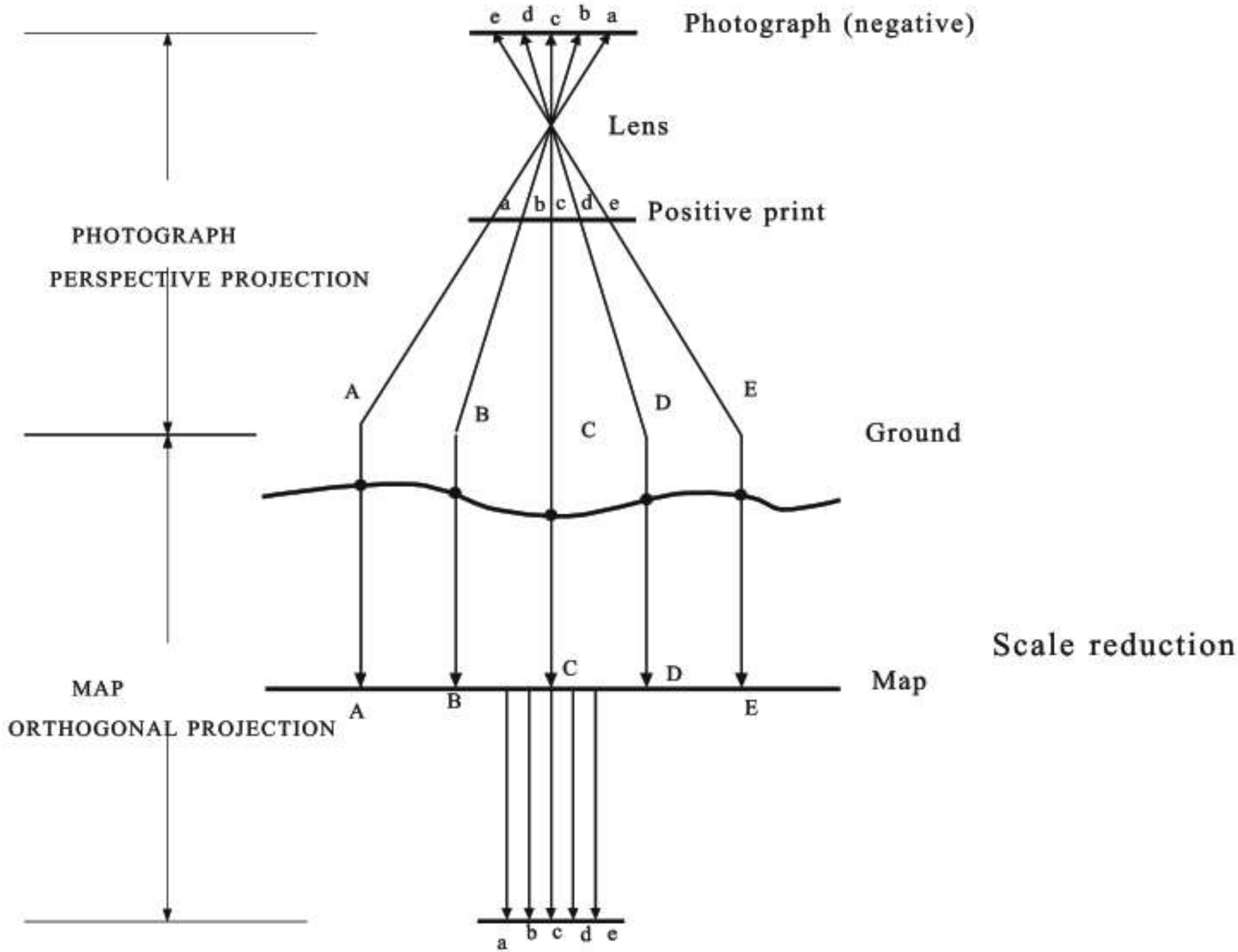
DISTORTION AND DISPLACEMENT

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.

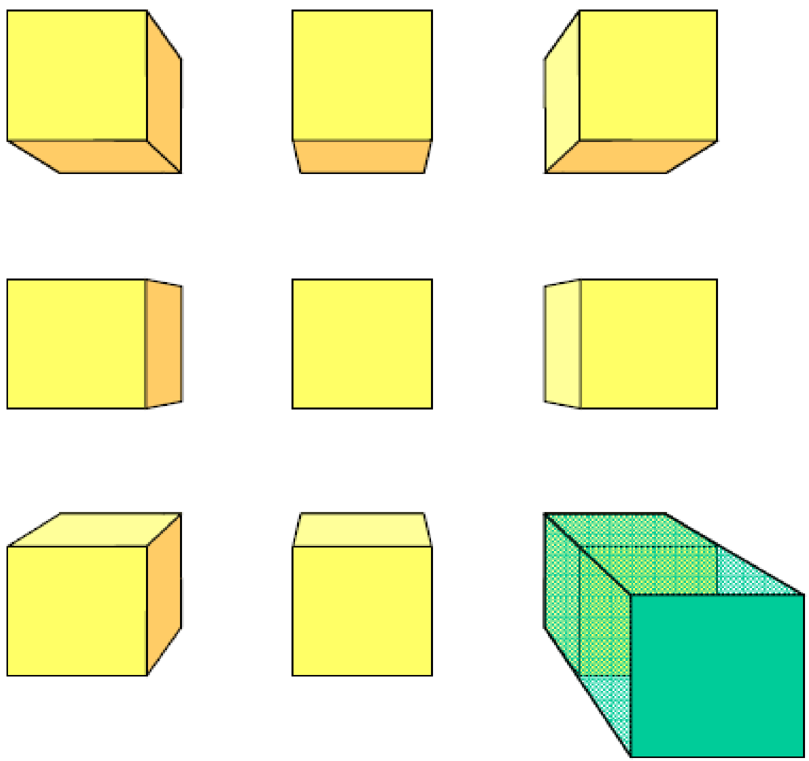


e d c b a
Photograph (negative)
Lens
a b c d e
Positive print
PHOTOGRAPH
PERSPECTIVE PROJECTION
A
B
C
D
E
Ground
Scale reduction
C
D
Map
MAP
A
B
E
ORTHOGONAL PROJECTION
a b c d e

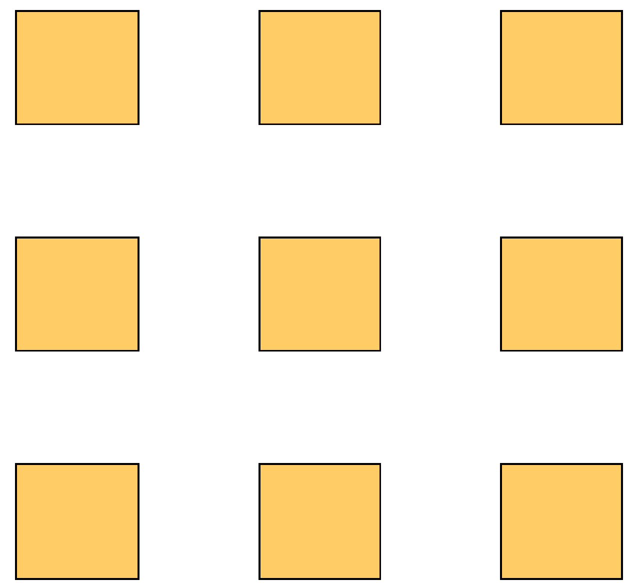
Central Perspective

Imagine nine high-rise buildings wiewed from above

Central Projection (photo):



Orthogonal Projection (map):



- Radial displacement
- Scale differences

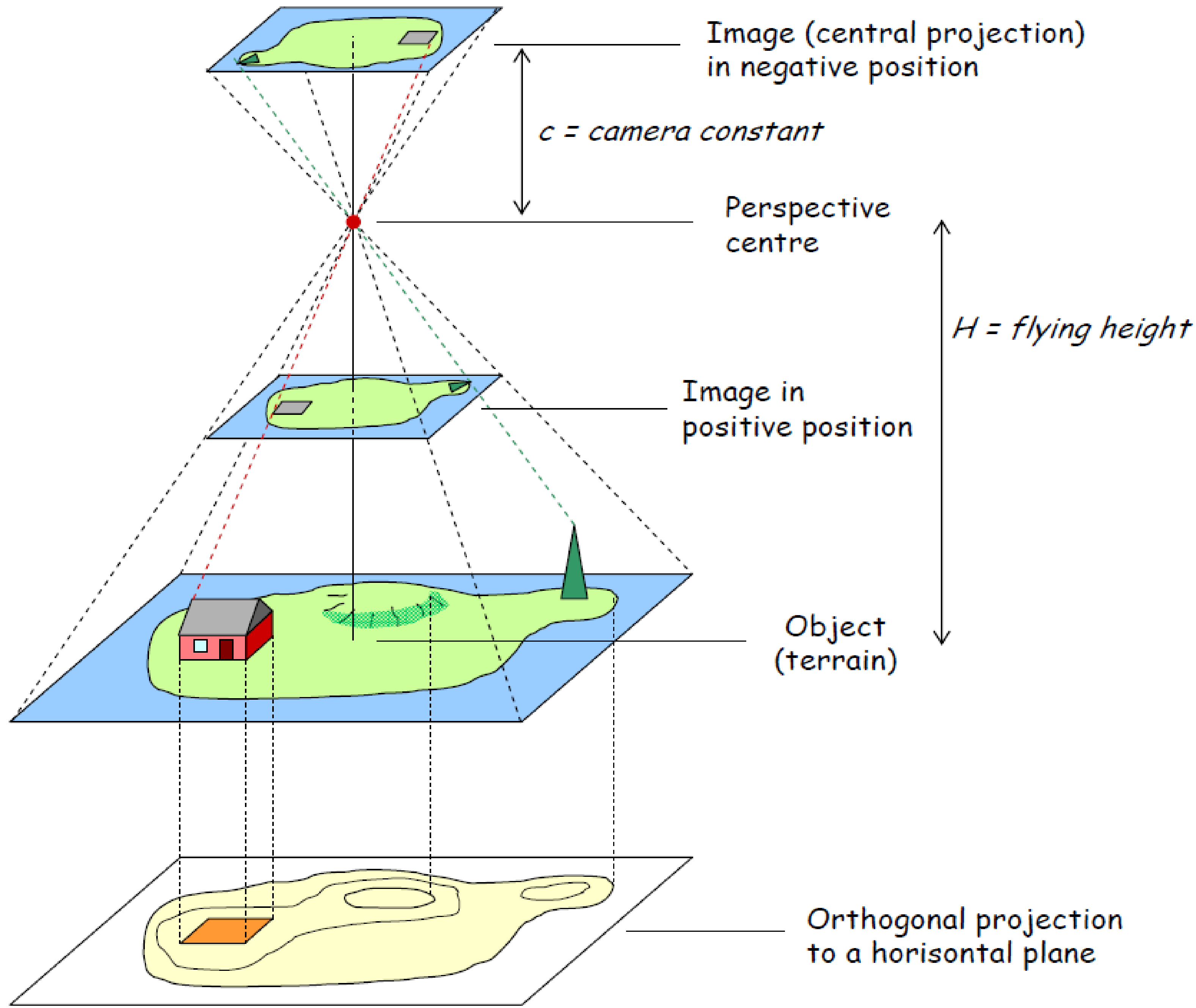
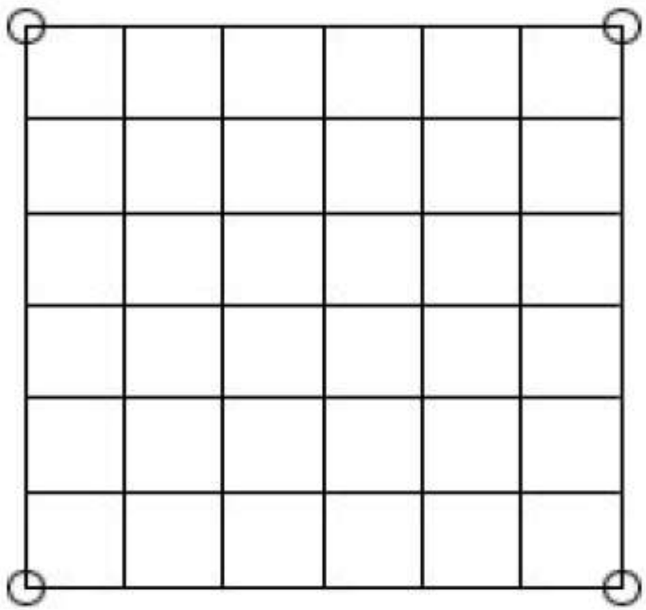
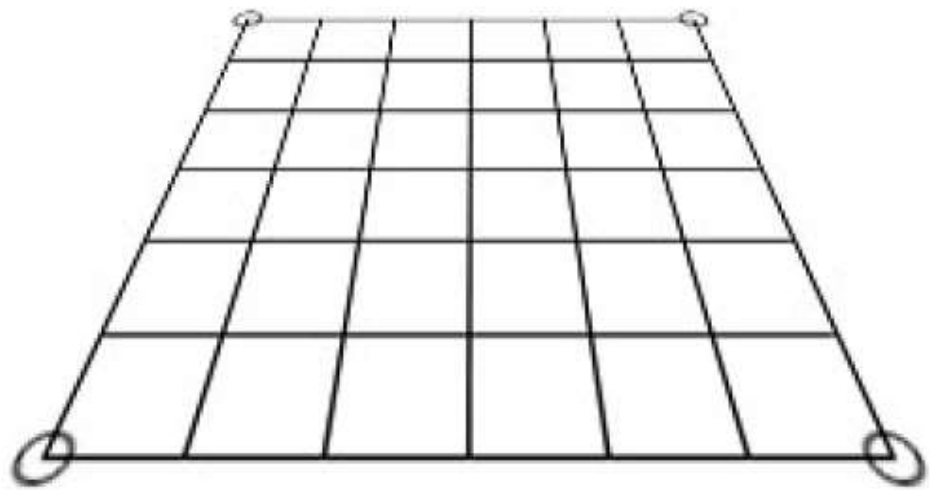


Image (central projection)
in negative position
c = camera constant
Perspective
centre
H = flying height
Image in
positive position
Object
(terrain)
Orthogonal projection
to a horisontal plane

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.

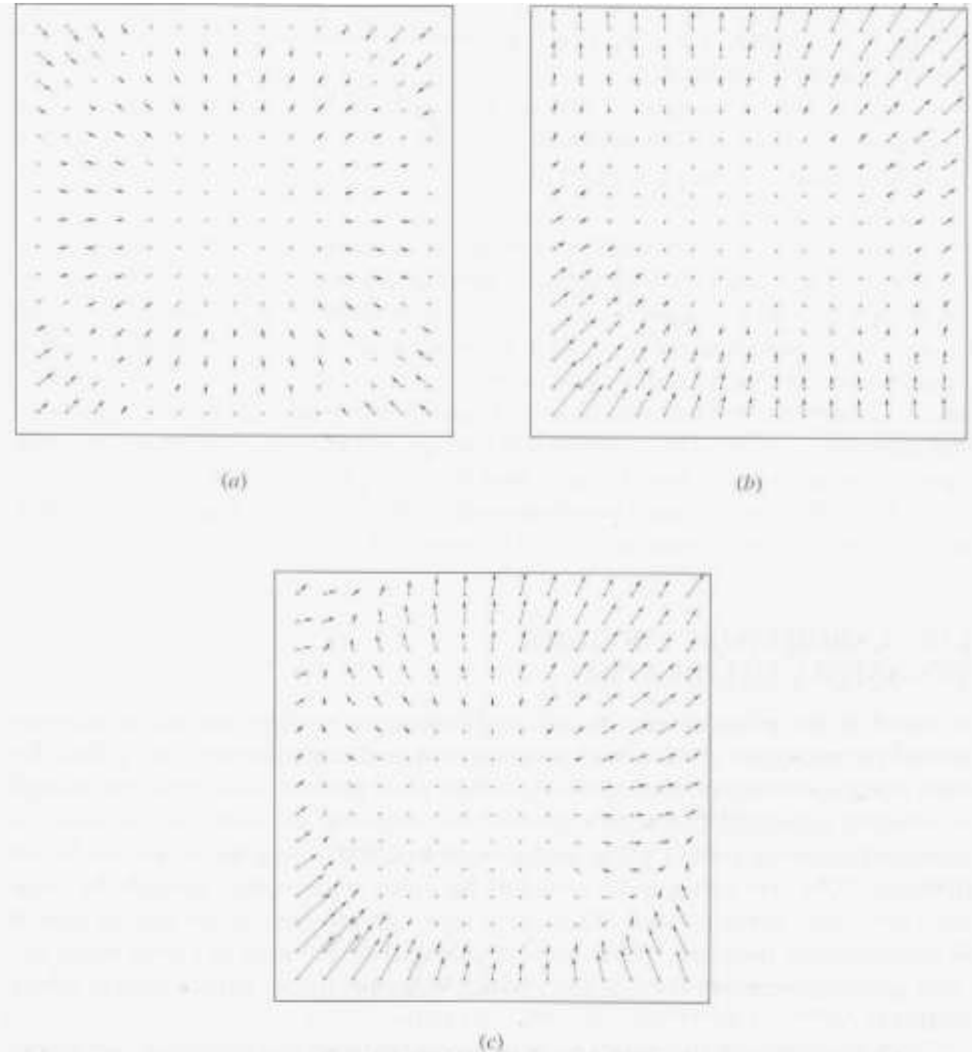
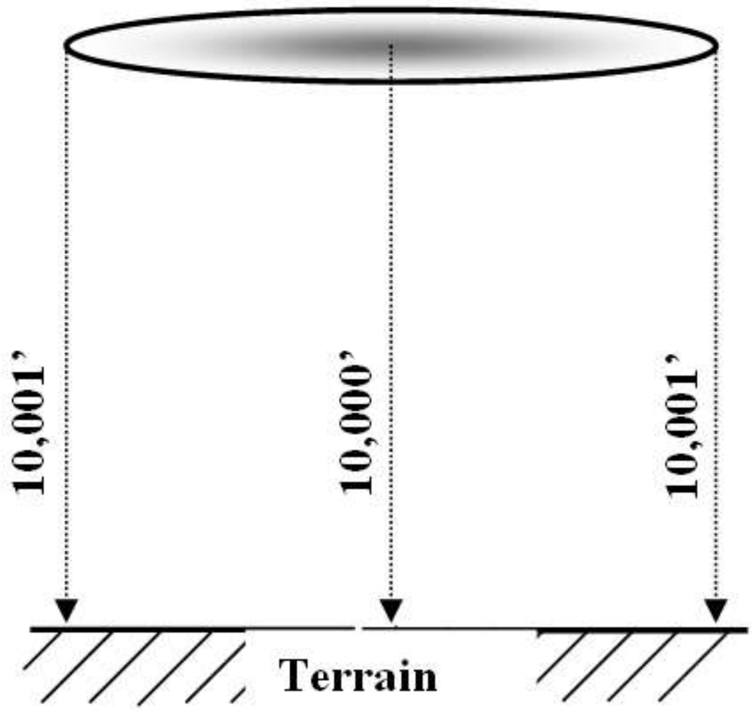


FIGURE 3-12
Lens distortion patterns: (a) symmetric radial, (b) decentering, and (c) combined symmetric radial and decentering.

Vertical Cross Section View of Biconvex Lens



Top view