AERIAL REMOTE SENSING

UNIT 1 to 3

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

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Aerial photography, photogrammetry and aerial photo interpretation are relatively recently developed techniques. Their development has closely been connected with the development of aeronautics, high precision aerial cameras and photogrammetry and photo-interpretation instruments.

Aerial Photography: Aerial photography has been defined as the science of taking a photograph from a point in the air for the purpose of making some type of study of the surface of the earth.

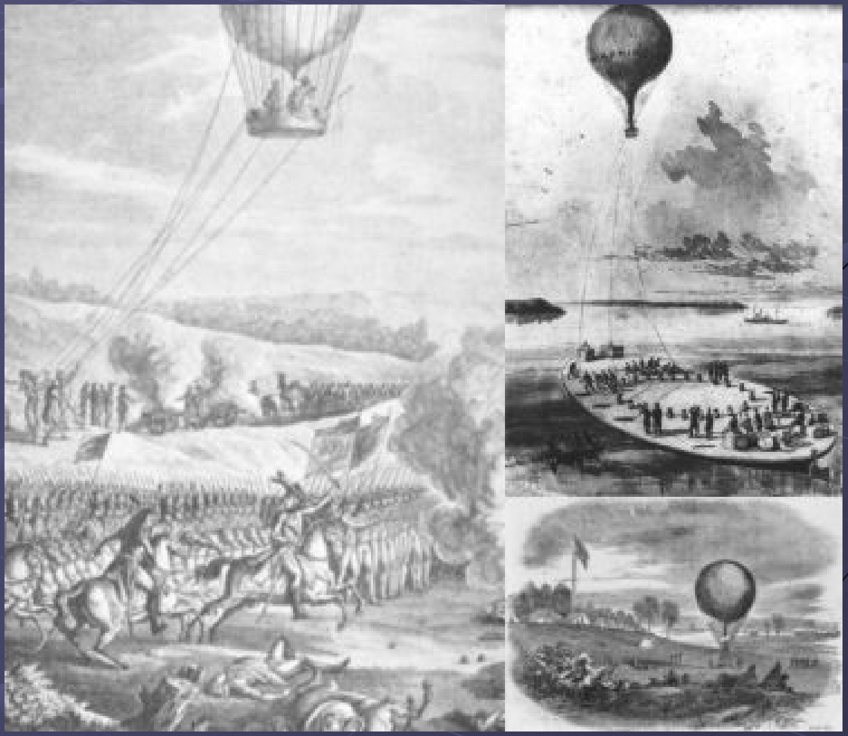
Photographic interpretation is an art of examining these photographic images for the purpose of identifying objects and judging their significance

Photogrammetry is the art of making reliable measurements from the air photographs

Unique perspective of aerial imagery – the aerial/regional perspective

- While human vision provides a unique perspective, it is a limited perspective
- Humans primarily observe the world from a limited, ground-level view – vertical perspective
- Aerial platforms allow the viewing of an area from a more synoptic, horizontal perspective

History of Remote Sensing



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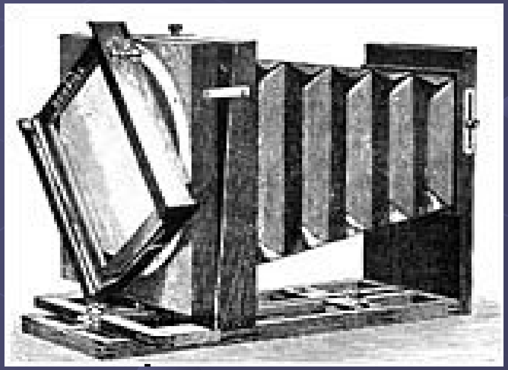
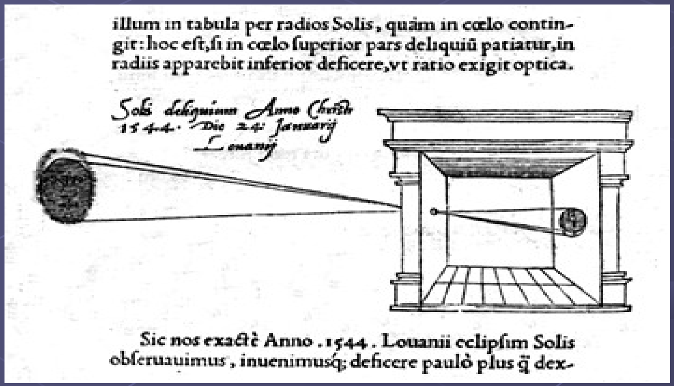
Some Important Dates in the Chronological History of Remote Sensing

The history of remote sensing began with the invention of photography. The term "photography" is derived from two Greek words meaning "light" (phos) and "writing" (graphien).



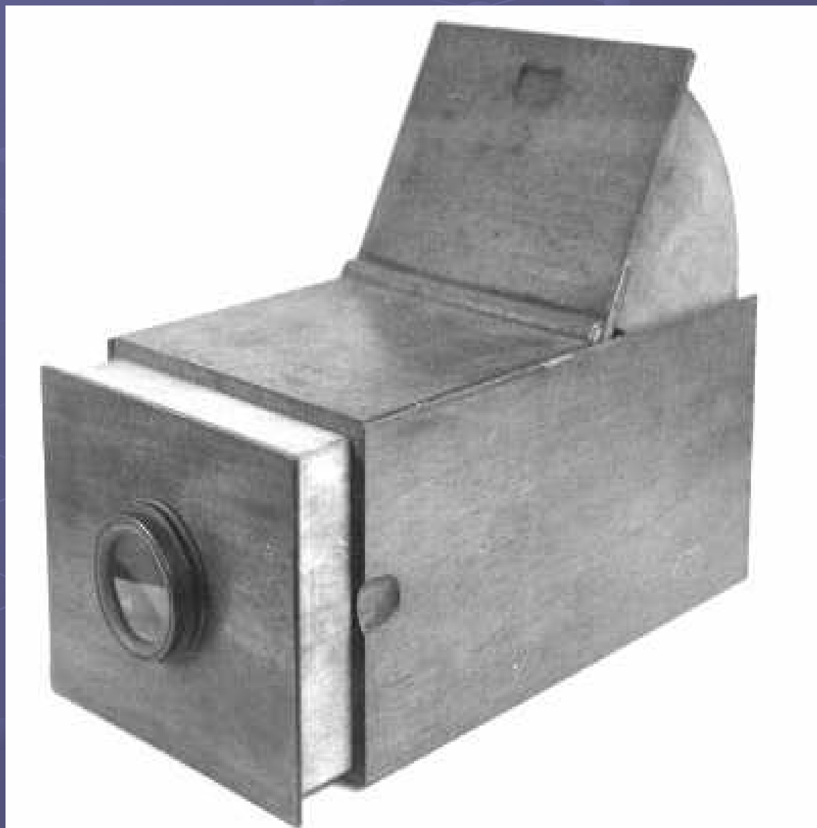
- 1038 AD - Al Hazen an Arabian mathematician explained the principle of the camera obscura to observe sun eclipse.

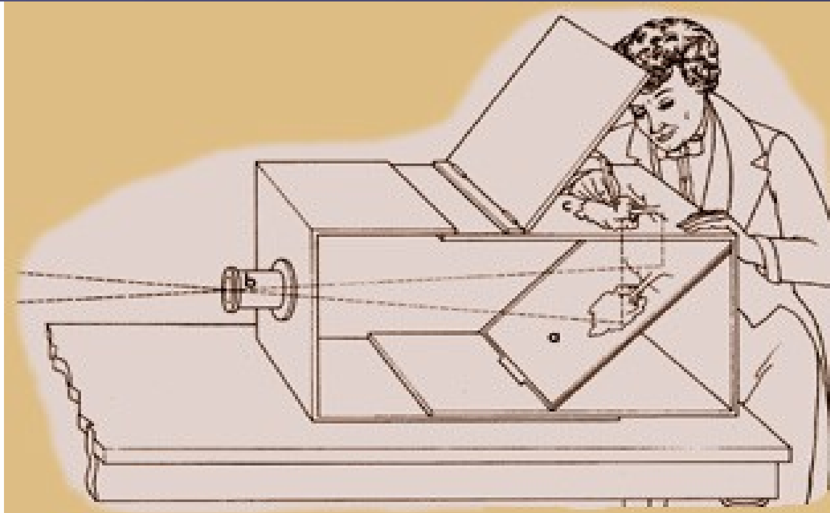

illum in tabula per radios Solis, quàm in cœlo contingit: hoc est, si in cœlo superior pars deliquiũ patiatur, in radiis apparebit inferior deficere, vt ratio exigit optica.

Solis deliquium Anno Christi 1544 Die 24 Januarij Louanij

Sic nos exactè Anno .1544. Louanii eclipsim Solis obseruauimus, inuenimusq; deficere paulò plus q̃ dex-

Camera Obscura



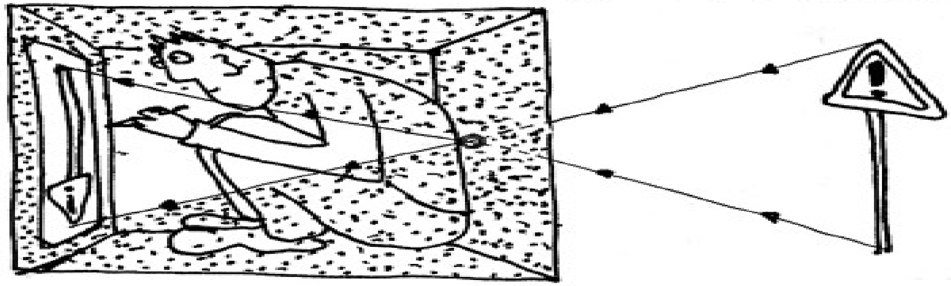


A typical camera obscura at the beginning of the 19th Century, somewhat larger than the replica shown above, incorporating a mirror (1), which directs the image from the lens onto translucent paper (c) supported on a glass plate. The double interlocking box enables focusing.

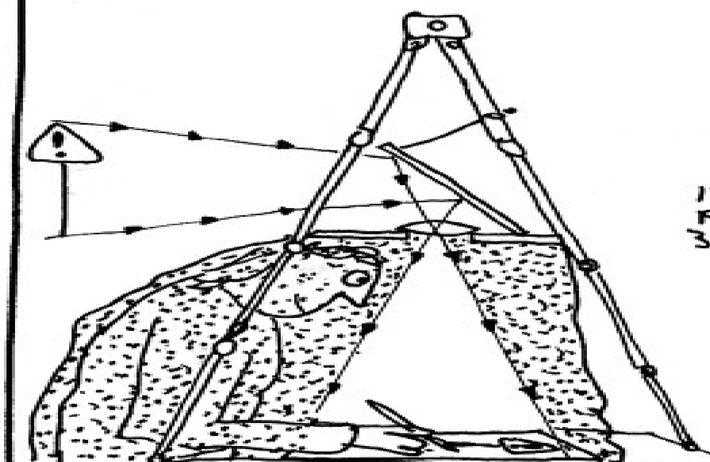
After Brian Coe, *Cameras: From Daguerrotypes to Instant Pictures* (Gothenberg, Sweden: Nordbok; New York: Crown Press, 1978), p. 2.

HOW TO MAKE A CAMERA OBSCURA

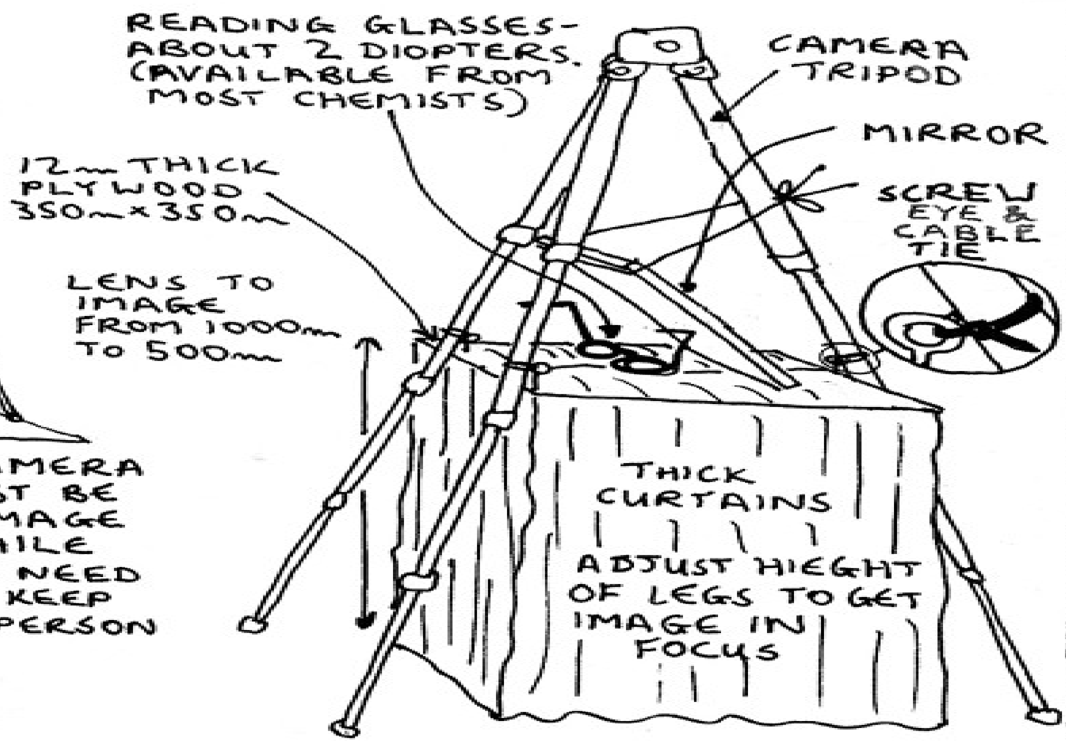
BY TIM HUNKIN



A CARDBOARD BOX WITH A HOLE IN THE SIDE MAKES A SIMPLE CAMERA OBSCURA. WITH A SMALL HOLE (3mm), THE IMAGE WILL BE VERY DIM. ENLARGING THE HOLE MAKES THE IMAGE BRIGHTER BUT NO LONGER IN FOCUS. TO CREATE A BRIGHT, SHARP IMAGE A LENS IS NEEDED INSTEAD OF A PINHOLE.



THIS OBSCURA USES A CAMERA TRIPOD. EVERYTHING MUST BE RIGIDLY FIXED OR THE IMAGE WILL WOBBLE ABOUT WHILE DRAWING. THE CURTAINS NEED TO BE LARGE ENOUGH TO KEEP OUT THE LIGHT WHEN A PERSON IS UNDERNEATH.



- 1490 - Leonardo da Vinci describes in detail the principles underlying the *CAMERA OBSCURA* (literally *DARK ROOM*).
- 1550- Cirolama Cardano first put optic on camera obscura for creating more quality image.
- 1614 - Angelo Sala discovers that silver salts darken when exposed to sunlight.

- 1666 - Sir Isaac Newton, while experimenting with a prism, found that he could disperse light into a spectrum of red, orange, yellow, green, blue, indigo, and violet. Utilizing a second prism, he found that he could re-combine the colors into white light.
- 1676 - Johann Christopher Sturm, introduces the relax lens principle where by a mirror is mounted at a 45 degree angle that projects an image, the essential development that led to the modern single lens reflex camera.

- 1777 - Carl Wilhelm Scheele, discovers that silver chromate darkened by exposure to sunlight could be rinsed off with ammonia leaving the dark unexposed silver chromate crystals to form a "fixed" image, a precursor to modern photographic film.
- 1800 - Sir William Herschel, measures the temperatures of light split with a prism into the spectrum of visible colors. He had discovered *thermal infrared electromagnetic radiation.*
- 1827 - Niepce takes *first picture* of nature from a window view of the French countryside using a camera obscura and an emulsion using bitumen of Judea, a resinous substance, and oil of lavender (it took 8 hours in bright sunlight to produce the image)

First photograph in the world by Niepce

- 1839 - Daguerre announces the invention of Daguerrotype which consisted of a polished silver plate, mercury vapors and sodium thiosulfate ("hypo") that was used to fix the image and make it permanent.
- 1839 - William Henry Fox Talbot invents a system of imaging on silver nitrate of silver chromate treated paper and using a fixative solution of sodium chloride.

1830's - The invention of stereoscopes

- The pictures used in the stereo views where in the form of "stereographs" which were two pictures of the same scene that were slightly offset and mounted side-by-side.

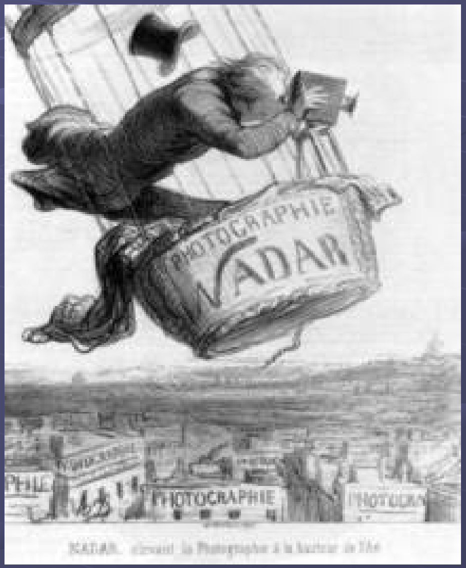
Old-fashioned parlor stereoscope (the stereopticon). Note paired photographs of the Sphinx. (Courtesy Keystone View Co.)

1855 – James Clerk Maxwell, describes

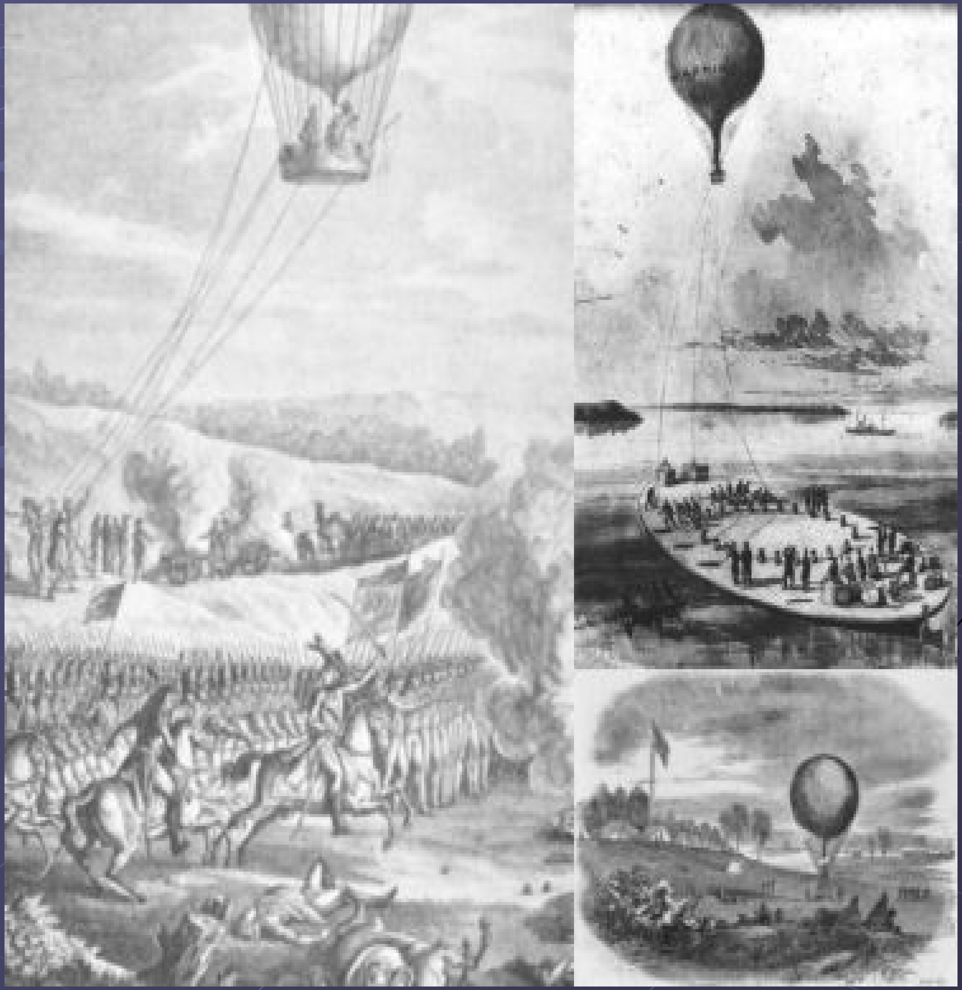
color additive theory.

The color additive theory describes how be perceive color and how they are created.

- 1858 - Gasper Felix Tournachon “Nadar" takes the first aerial photograph from a captive balloon from an altitude of 1,200 feet over Paris.



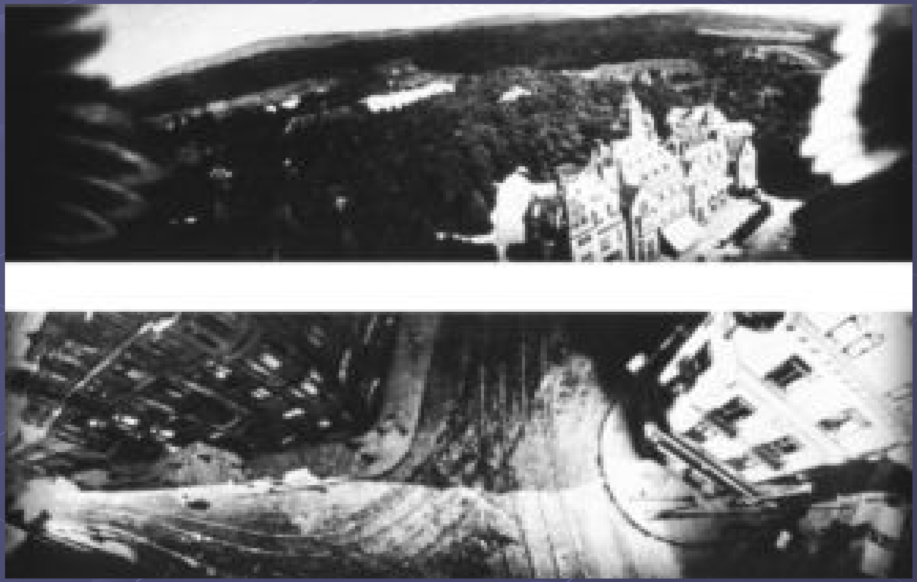
- 1860's - Aerial observations, and possible photography, for military purposes were acquired from balloons in the Civil War. Balloons were used to map forest in 1862, but not used to acquire aerial photographs as far as scholars can tell



- 1873 - Herman Vogel discovered that by soaking silver halide emulsions (sensitive to blue light) in various dyes, that he could extend their sensitivity to progressively longer wavelengths, this discover led to near infrared sensitive films.
- 1887 - Germans began experiments with aerial photographs and photogrammetric techniques for measuring features and areas in forests.
- 1889 - Arthur Batut take the first aerial photograph from using a kite of Labruguiere France.

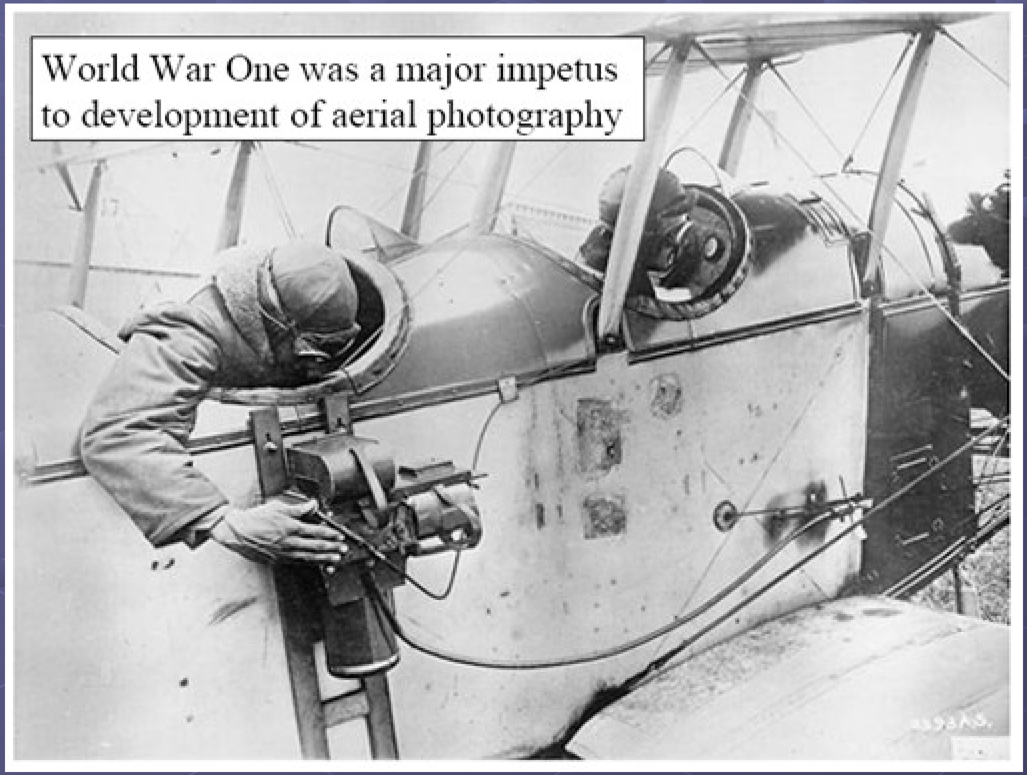
- 1899 - George Eastman produced a nitro-cellulose based film type that retained the clarity of the glass plates which were in use at the time and introduced the first Kodak camera.
- 1900 - Max Planck's revelation of 'quanta' and the mathematical description of the 'black body' lays the foundation for numerous developments in quantum mechanics.

- 1903 - The Bavarian Pigeon Corps uses pigeons to transmit messages and take aerial photos.



- 1906 - Albert Maul, using a rocket propelled by compressed air, took an aerial photograph from a height of 2,600 feet, the camera was ejected and parachuted back to earth.
- 1906 - G.R. Lawrence who had been experimenting with cameras which were hoisted into the air with the aid of balloon kites.
- 1907 - Auguste and Louis Lumiere, two French brothers develop a simple color photography system and establish the 35 mm standard.

1914 - WWI provided a boost in the use of aerial photography, but after the war, enthusiasm waned



1934 - Photogrammetric Engineering first published. American Society of Photogrammetry founded and renamed ***Photogrammetric Engineering and Remote Sensing***. The Society was again renamed, and is now ***The American Society of Photogrammetry and Remote Sensing.***

- 1936 - Albert W. Stevens takes the first photograph of the actual curvature of the earth - taken from a free balloon at an altitude of 72,000 feet.
- 1938 - A German General Werner von Fritsch, made a prophetic statement at this time said: "The nation with the best photo reconnaissance will win the next war!!"
- 1940 - World War II brought about more sophisticated techniques in air photo interpretation.

1946 - First space photographs from V-2 rockets.

1954 - U-2 takes first flight.

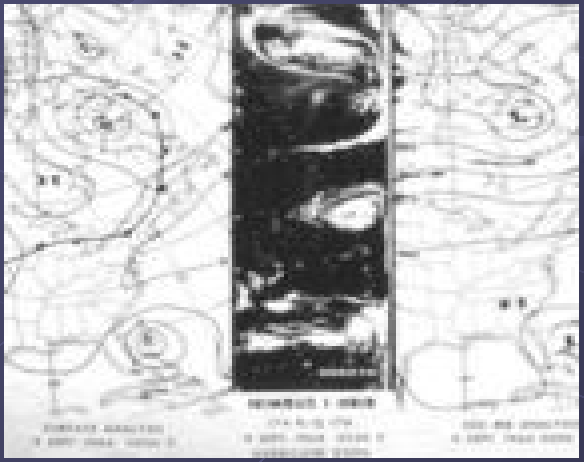
1957 - Russia launches Sputnik-1, this was unexpected and encouraged our government to make space exploration a priority.

- 1960 - TIROS-1 launched as first meteorological satellite.
- 1960 - U-2 is "shot down" over Sverdlovsk, USSR.
- 1960's - US begins collection of intelligence photography from Earth orbiting satellites, CORONA.

- 1962 - Zaitor and Tsuprun construct prototype nine lens multispektral camera

- 1963 - D. Gregg, creates "videodisk"

- 1964- Nimbus Weather Satellite Program begins with the Launch of Nimbus1.



- Late 1960's - Gemini and Apollo Space photography.

- 1972 - Launch of ERTS-1 (the first Earth Resources Technology Satellite ,later renamed Landsat 1).
- 1972 - Photography from Skylab, America's first space station, was used to produce land use maps.
- 1975 - Landsat 2, GOES
- 1977 - Meteosat-1 the first in a long series of European weather satellites
- 1978 - Landsat 3
- 1978 - Seasat, the first civil Synthetic Aperture Radar (SAR) satellite.

- 1978 - Launch of Nimbus-7 with Total Ozone Mapping Sensor (TOMS) and the Coastal Zone Color Scanner (CZCS),GOES-3.
- 1981 - Space-Shuttle Imaging Radar (SIR-A), Meteosat-2
- 1982 - Landsat-4
- 1984 - SIR-B
- 1984 - Landsat-5
- 1986 - SPOT-1

- 1986 - Launch of SPOT-1
- 1988 - IRS-1A, Meteosat 3, Ofeq-1
- 1989 - Meteosat-4, Ofeq-2
- 1990 - SPOT-2
- 1991 - ERS (European Radar Satellite), IRS-1B, Meteosat-5.
- 1992 - JERS-1,Topex/Poseidon.
- 1993 - SPOT-3, Landsat-6 fails to achieve orbit, Meteosat-6
- 1994 - SIR-C/X-SAR flys on the space shuttle.

- 1995 - Launch of OrbView-1, ERS-2, Radarsat-1, IRS-1C, Ofeq-3 fails.
- 1995 - KH-12 spy satellite
- 1996 - Launch of IRS-P3, SPOT-3 fails
- 1997 - Orbview-2 with SeaWiFS, GOES-10, DMSP-5D, Adeos-1 satellite fails after 8 months of operation, IRS-1D, Meteorsat-7, Lewis fails 3 days after launch, Earlybird fails 4 days after launch.
- 1998 - Launch of SPOT-4, SPIN-2, JERS-1

- 1999 - Launch of Landsat 7,IKONOS ,IRS-P4, QuickSCAT, CBERS-1,Terra, MODIS, ASTER, CERES, MISR,MOPITT, Kompsat 1.
- 2000 - SRTM (China), Tsinghau-1 , EROS A1 (Israel) , Jason-1
- 2001- Quickbird
- 2002 - Aqua, SPOT-5, ENVISAT, METSAT, Alsat-1, Meteosat Second Generation, ADEOS-II, Ofeq-5

- 2003 - Launch of ICESat, Orbview-3
- 2003 – Launch of ALOS (Advanced Land Observation Satellite) Japan
- 2003 – Launch Radarsat-2 (CANADA),

  CBERS-2 (China).

  DMC BilSat (TURKEY)

  DMC NigeriaSat-1 (Nigeria)

  DMC UK (UK)

- 2004 - China Satellite RocSat2 launched.
- 2005 - Launch of TopSat, a micro-satellite, with 2.5 m resolution and the ability to relay imagery to receiving stations within the safe image footprint.
- 2005 - Google Inc. releases Keyhole, http://earth.google.com, greatly increasing public awareness of the uses of satellite imagery and other geospatial information.

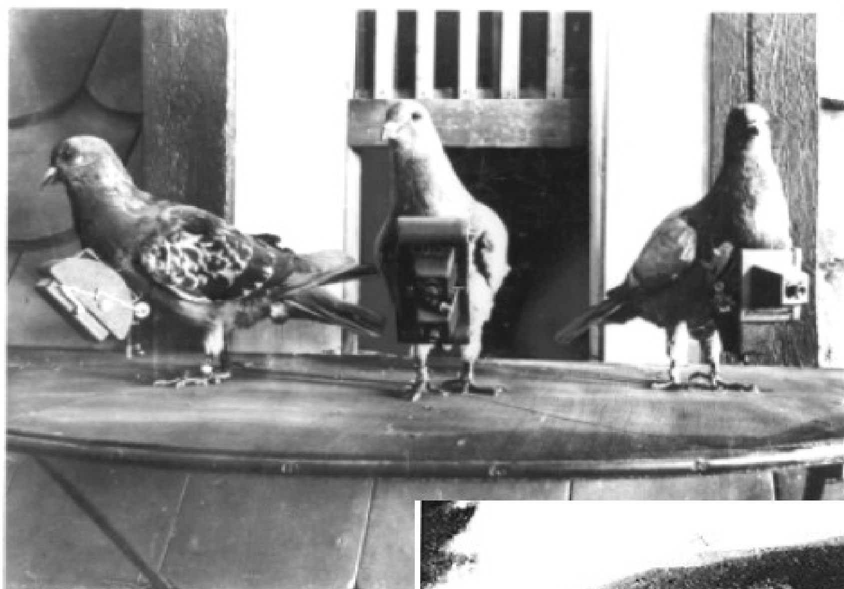
Google earth

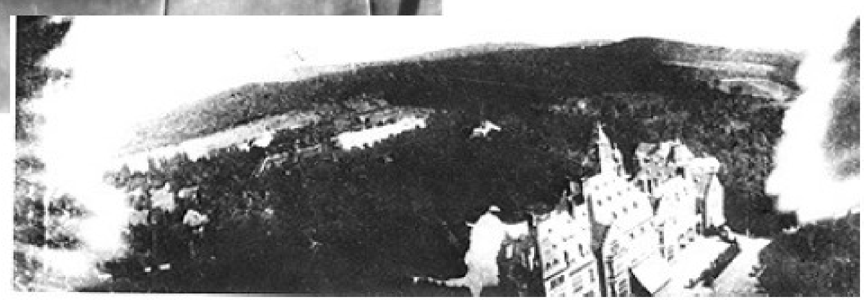
2007 – Expected launch of RapidEye...

Aerial Platforms for Cameras

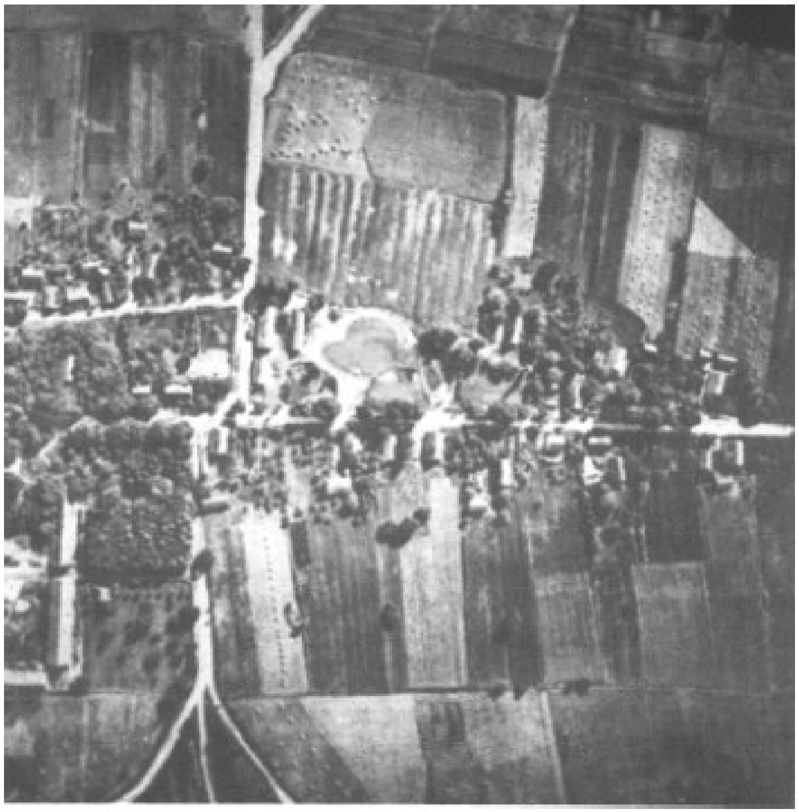
- ➔Balloons/Blimps
- ➔Pigeons
- ➔Kites
- ➔Airplanes

Remote sensing from above ground began in the 1840s as balloonists took pictures of the Earth's surface using the newly invented photo-camera.



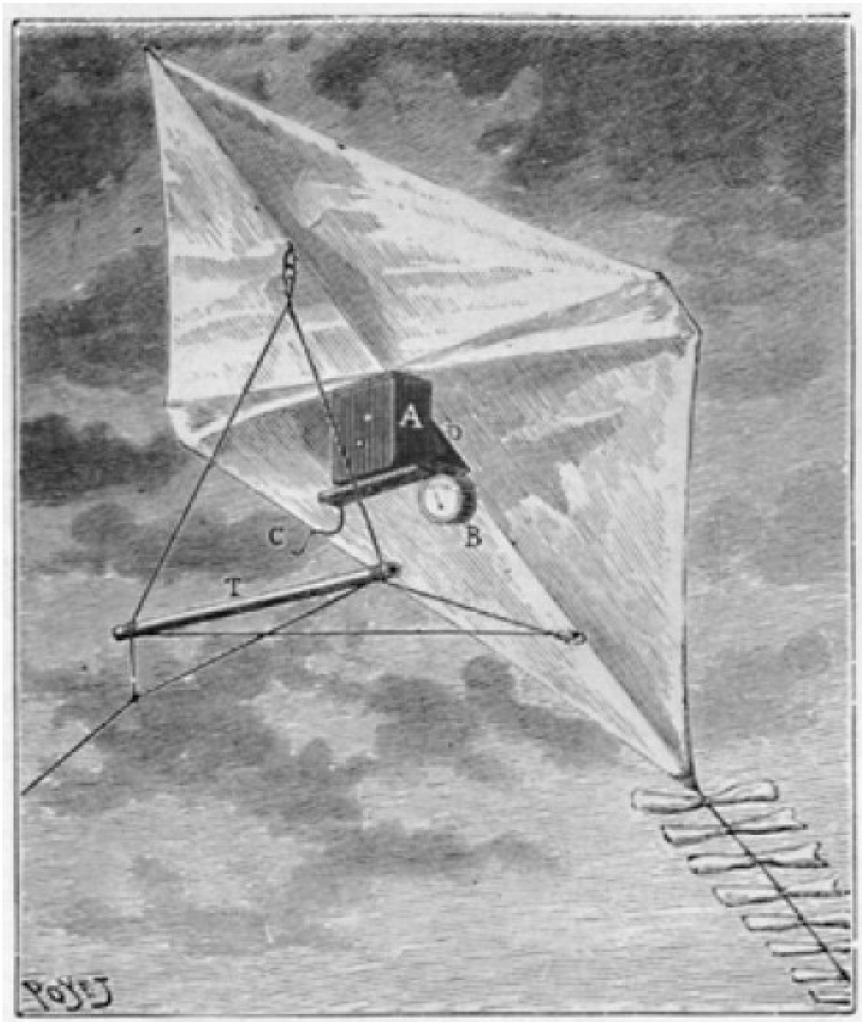


Balloons used to map forest in 1860th not aerial photo though. Pictures taken from greater heights, 33,000-34,000 feet, from free balloons.



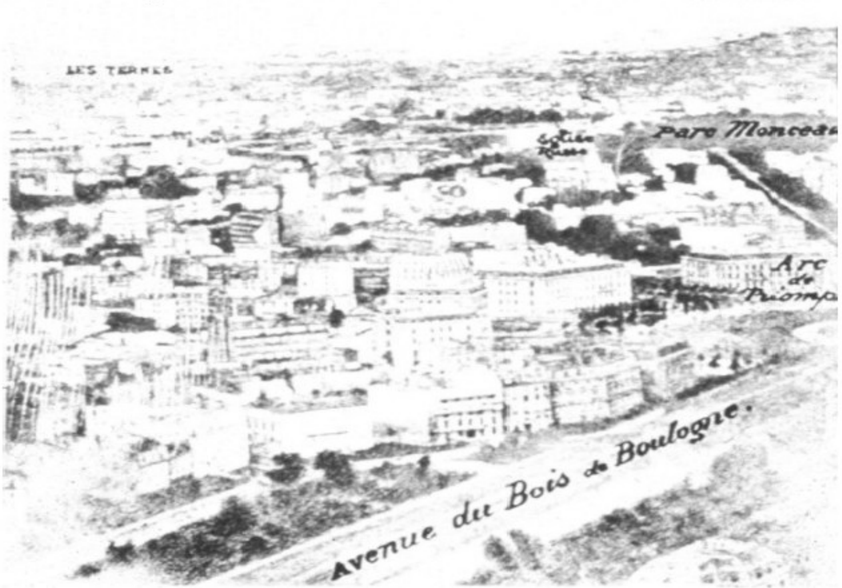
Kites

1850-1900: Kite cameras *Still in use!!! http://aircatcher.com/*



http://latteier.com/pigeoncam/

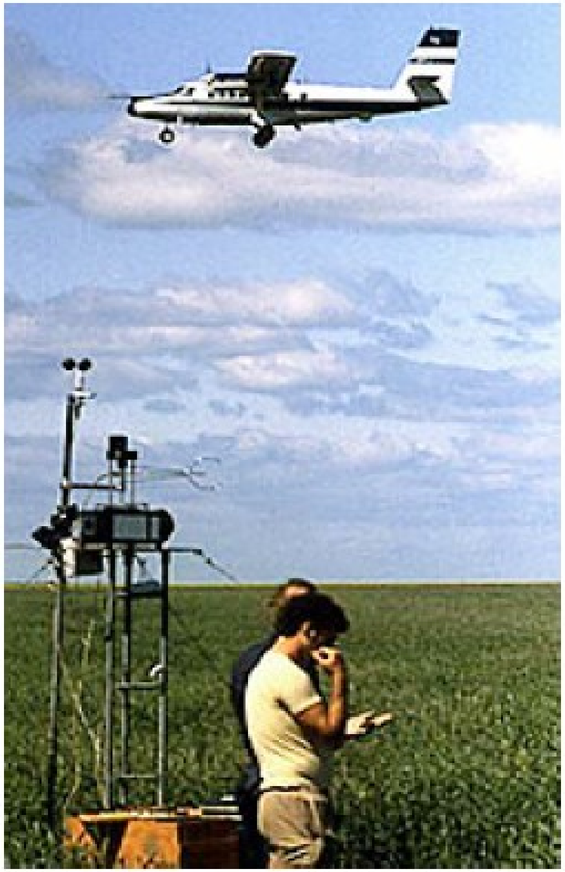
Paris by Nadar, circa 1859



Aerial photograph of San Francisco earthquake damage –5 May 1906 - collected from a kite

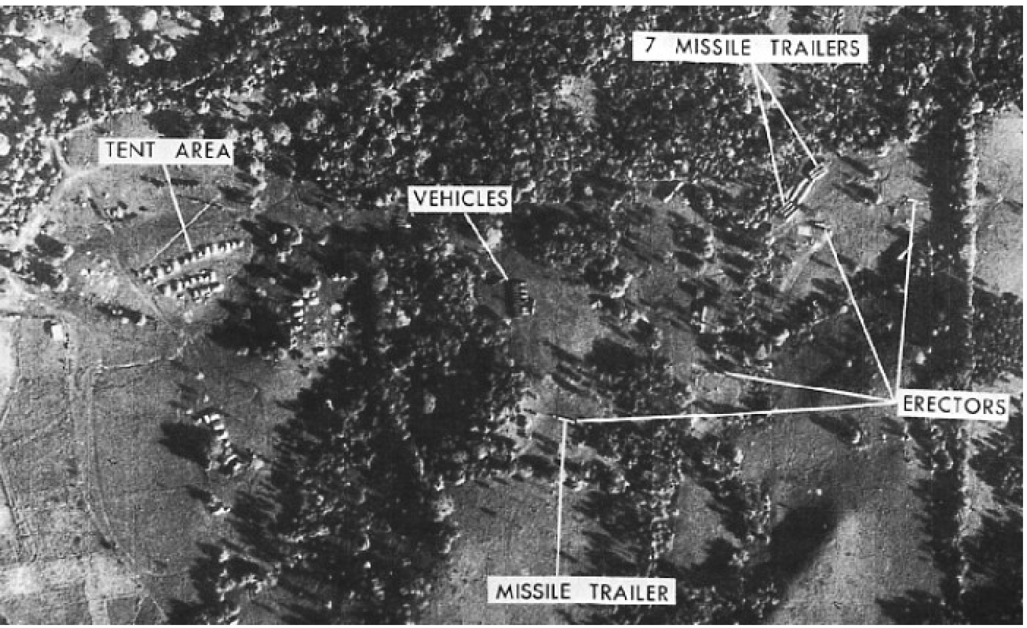
A 1926 photo of Dr.Goddard with one of his first liquid fuel rockets

Modern remote sensing platforms - aircrafts



Aerial Platforms - U-2 and SR-71

Developed for the military to carry high resolution aerial camera systems for intelligence gathering have been in continuous operation since the 1950s



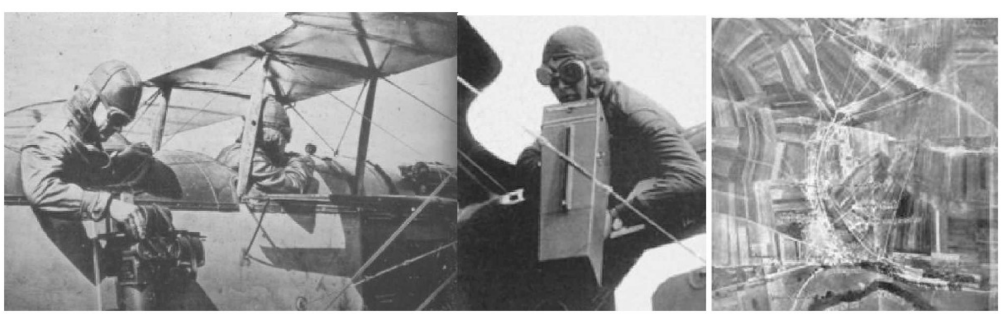
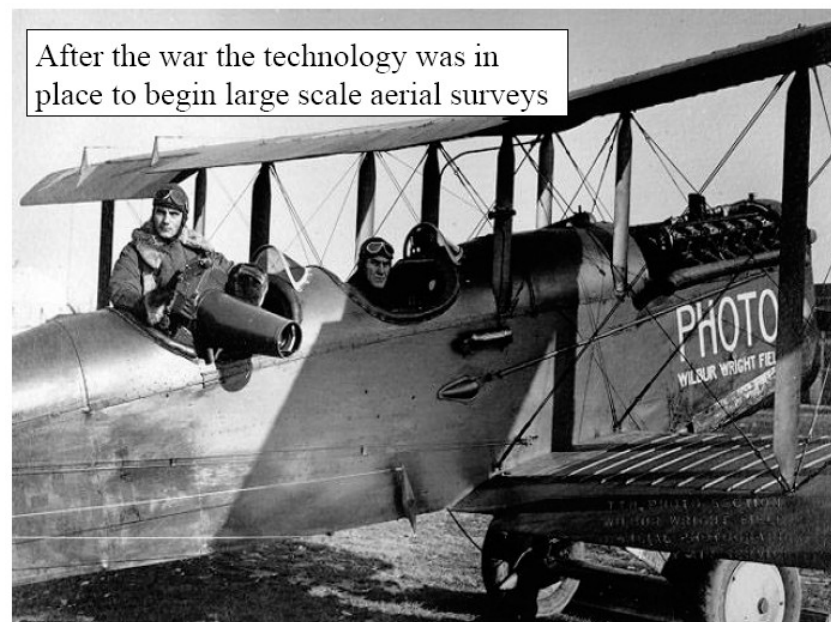


Figure 3-5: Reconnaissance during the World War-I (left), Graflex camera (middle) and an annotated photo of military locations in France during the World War-I, 1918 (right).



Generally photographs can be classified into two such as Terrestrial and Aerial photographs

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

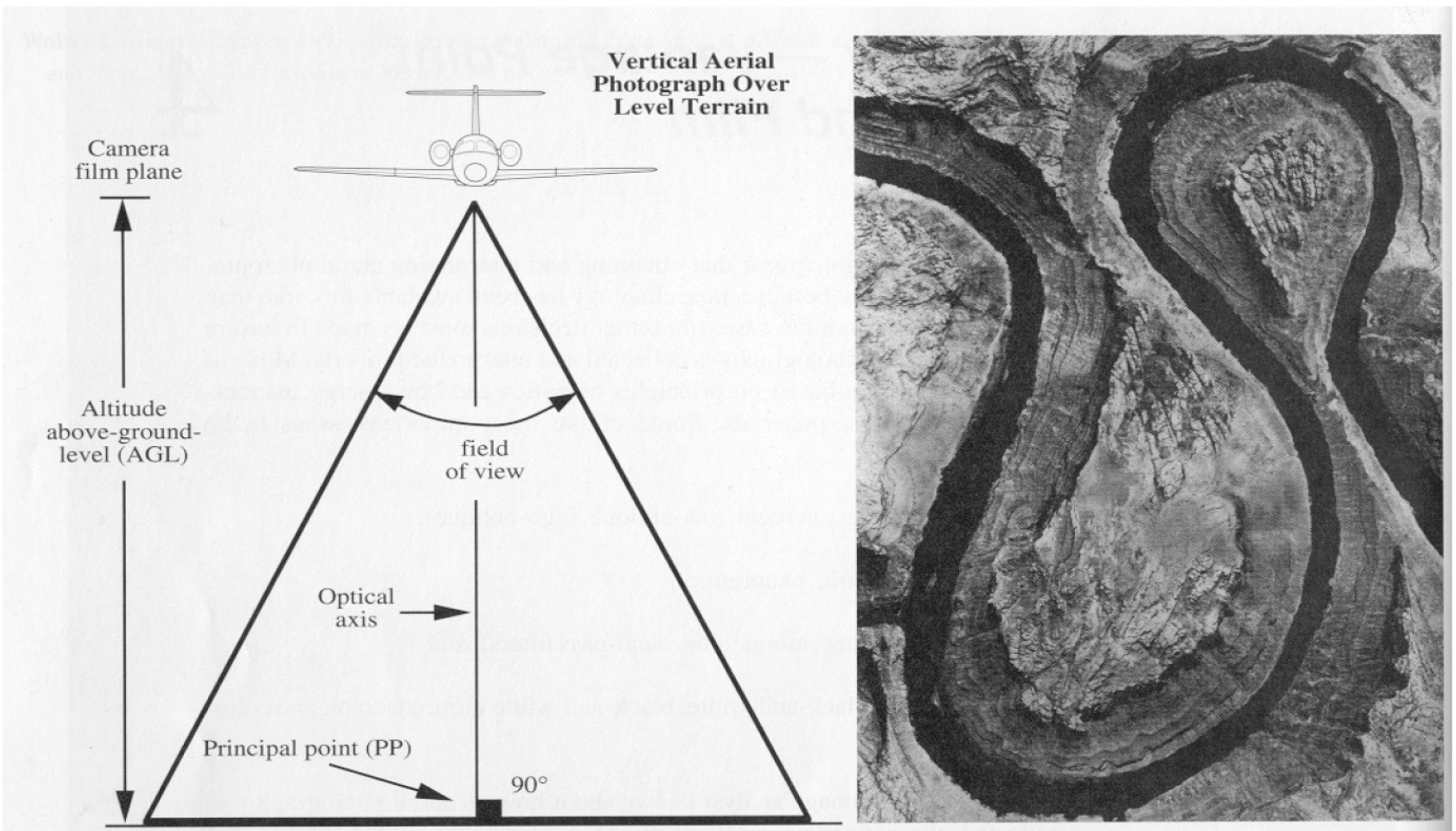
Terrestrial photographs

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

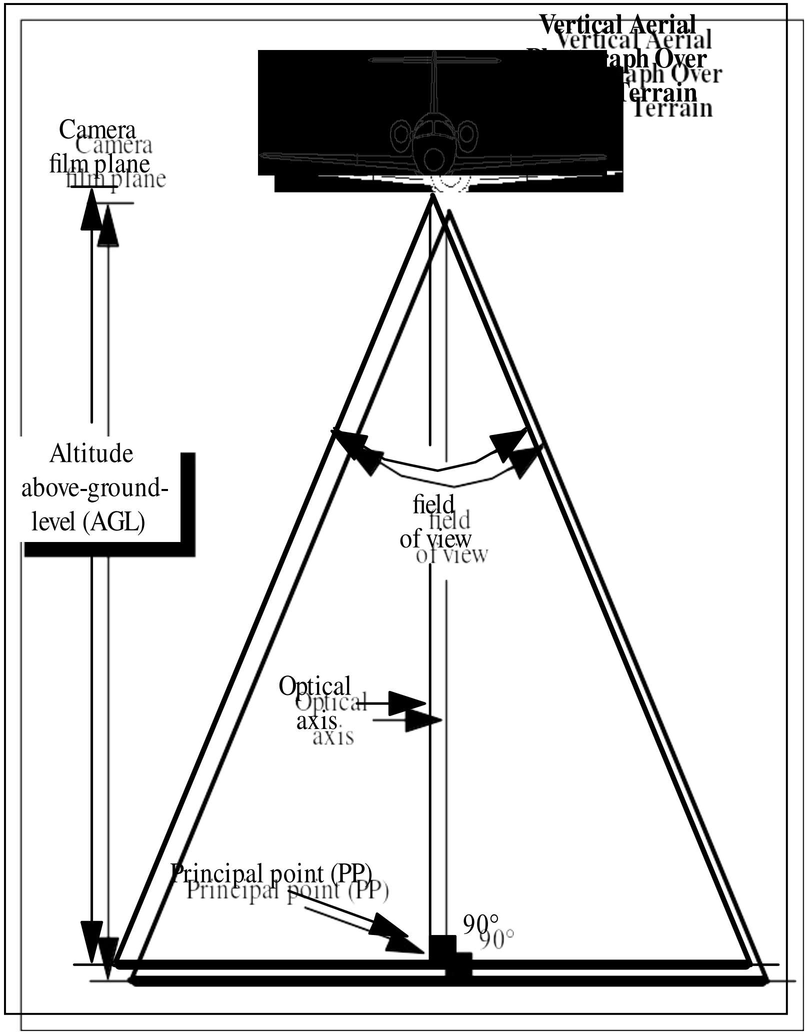
1	According to orientation of camera axis	A) Vertical photography B) Low oblique Photography C) High oblique Photography
2	According to lens system	A) Single lens photography B) Three lens photography (Trimetrogon photography) C) Four lens photography D) Nine lens photography E) Continuous strip photography
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**.



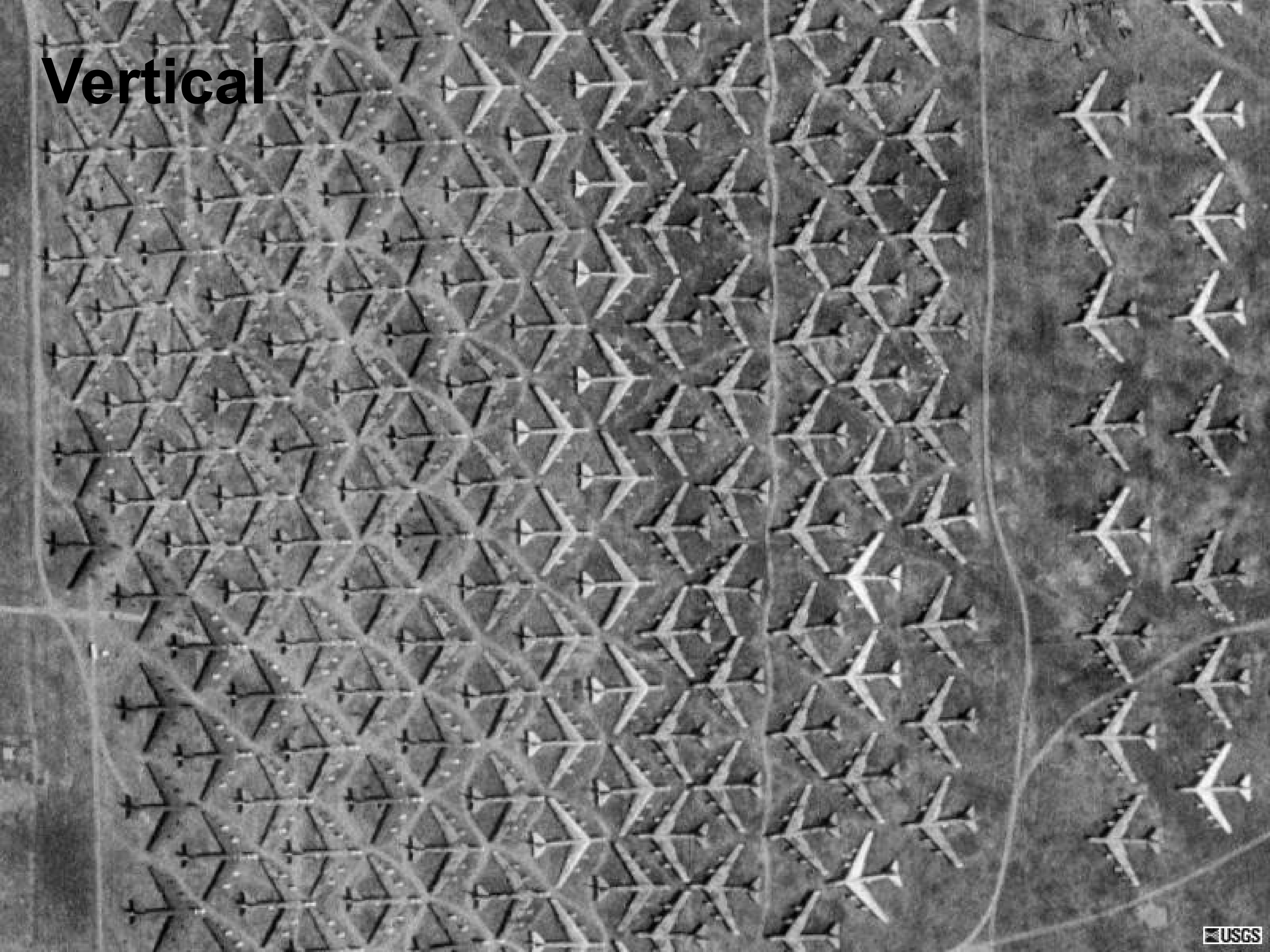
Vertical Aerial Photography



Goosenecks of the San Juan River in Utah

Jensen, 2000

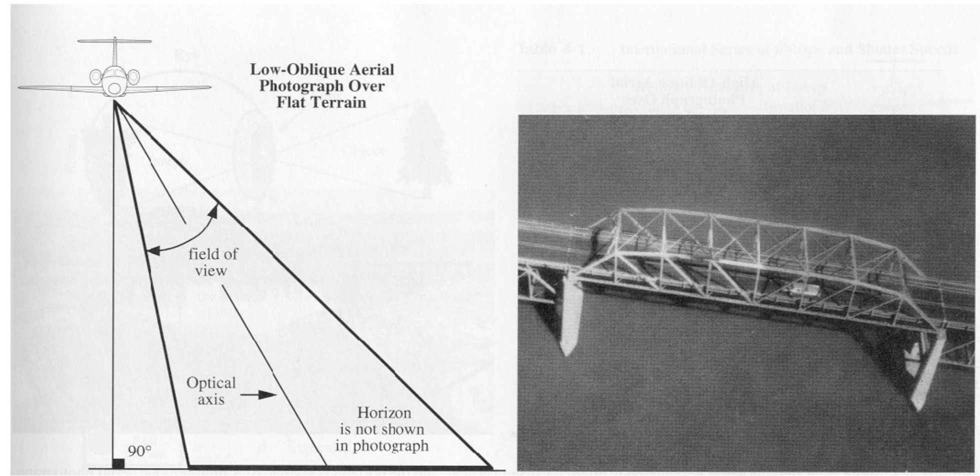
Most are vertical aerial photography


Vertical

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

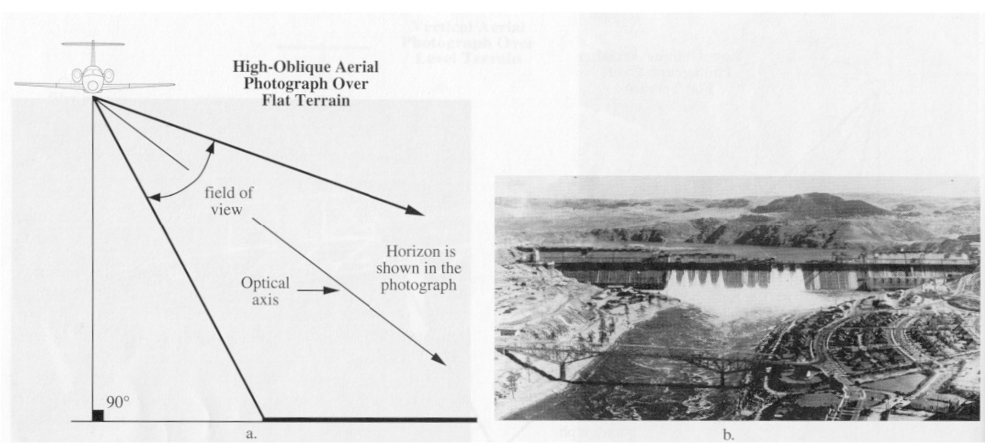
i) Low oblique photography:

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°)

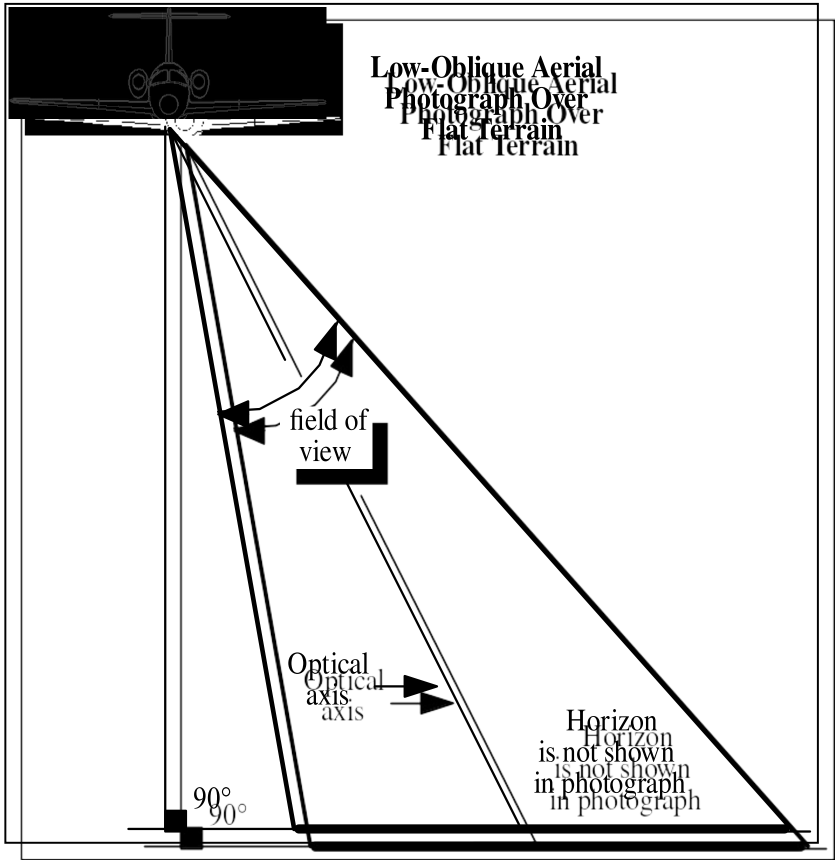


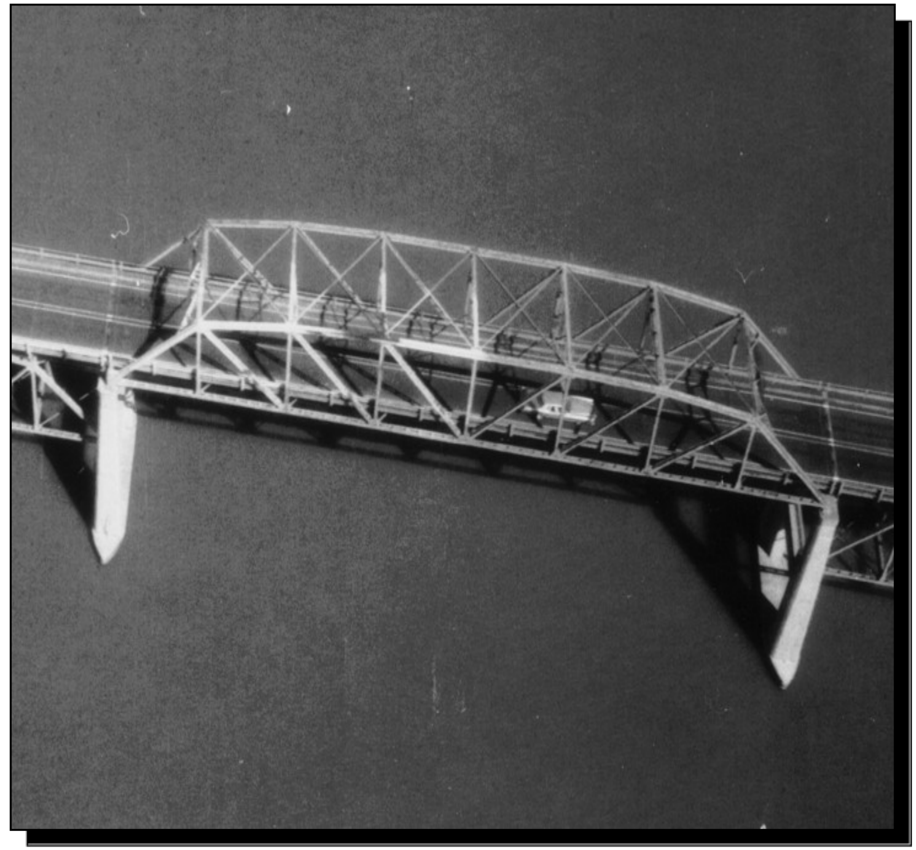
ii) High oblique photography:

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°). Such photographs are of importance in military purposes where scenery has to be appreciated with out stereo vision



Low-oblique Aerial Photography

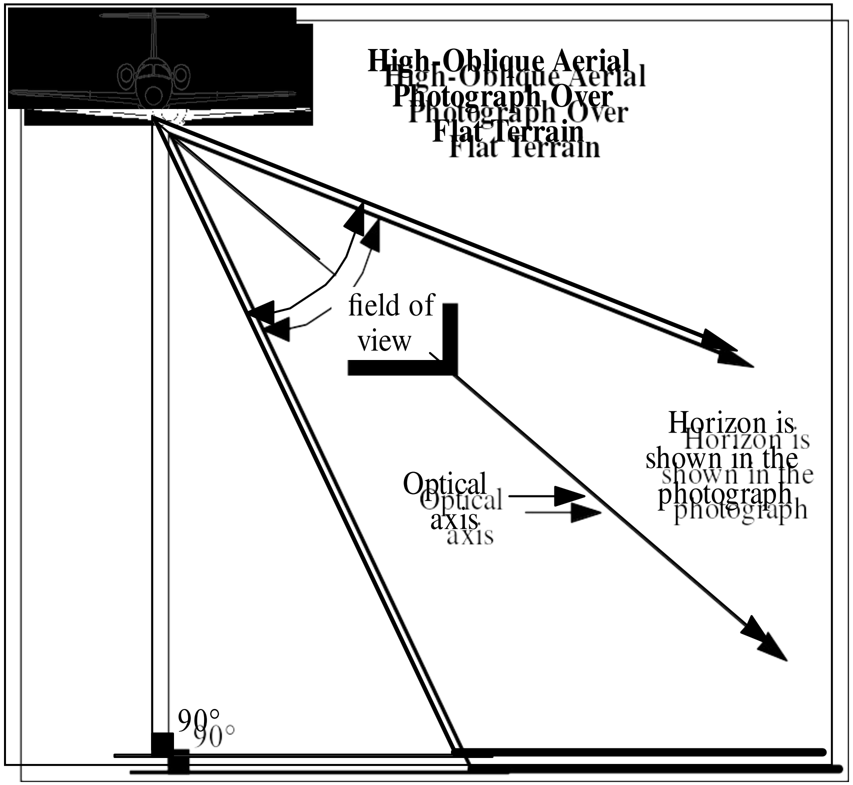




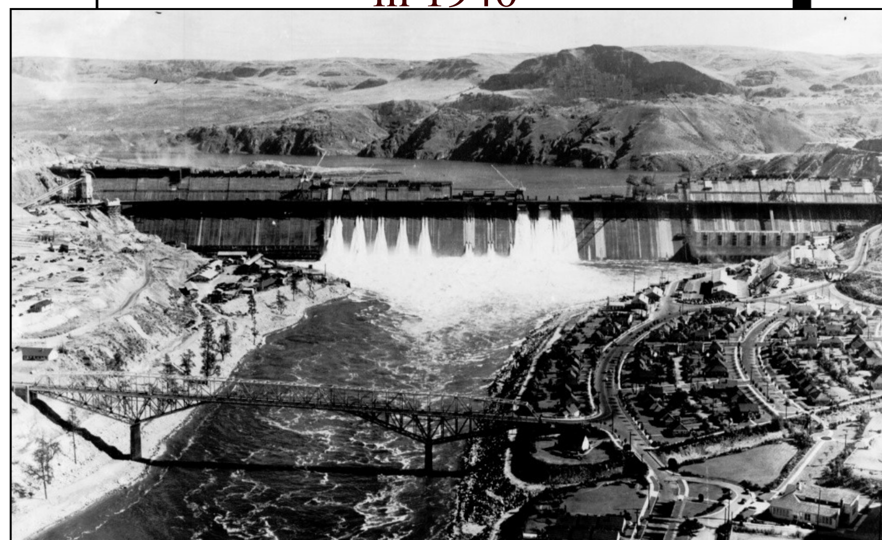
Low-oblique photograph of a bridge on the Congaree River near Columbia, SC.

Jensen, 2000

High-oblique Aerial Photography



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

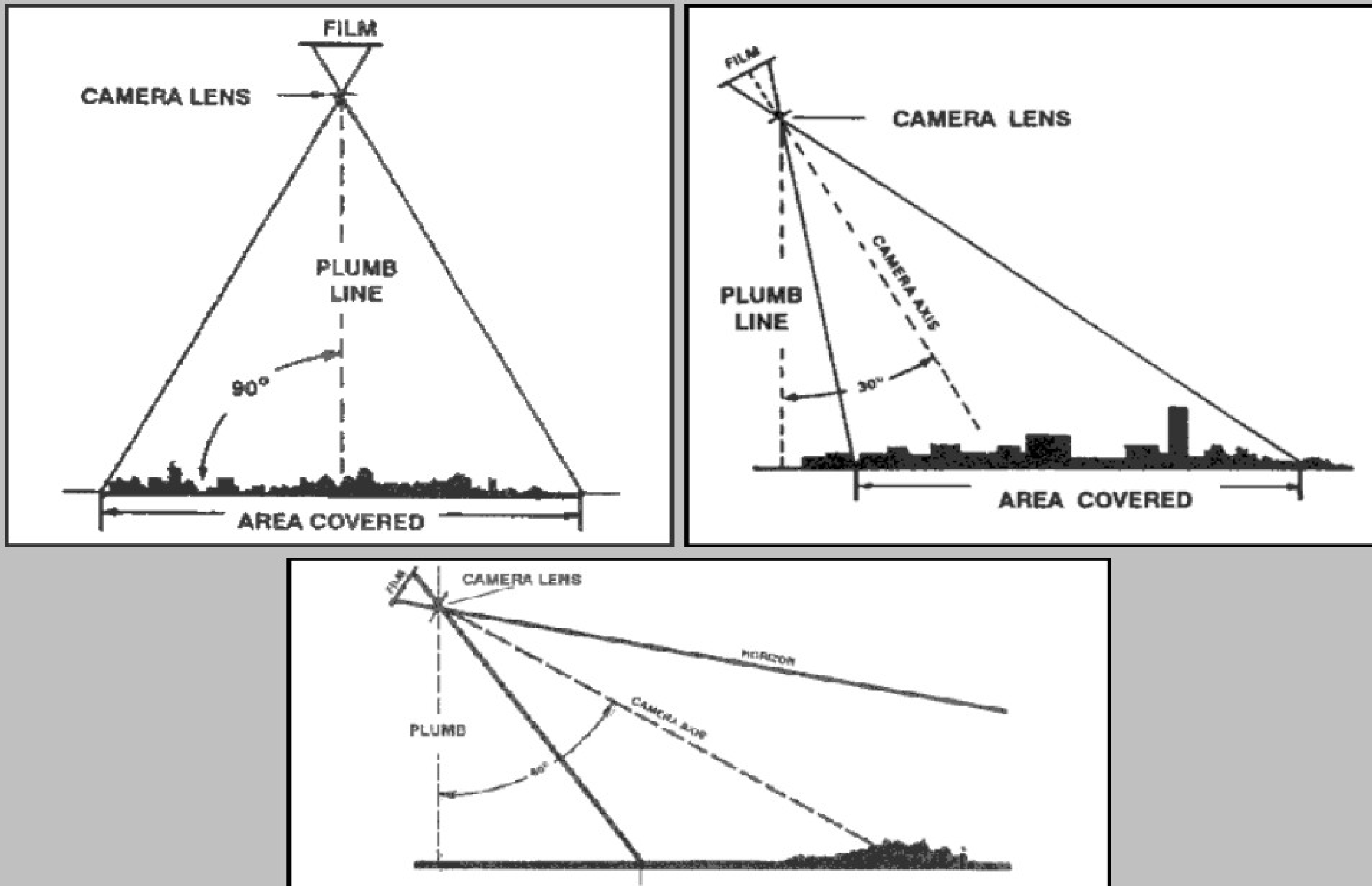


Jensen, 2000

High oblique

Small scale


Large scale
USGS



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

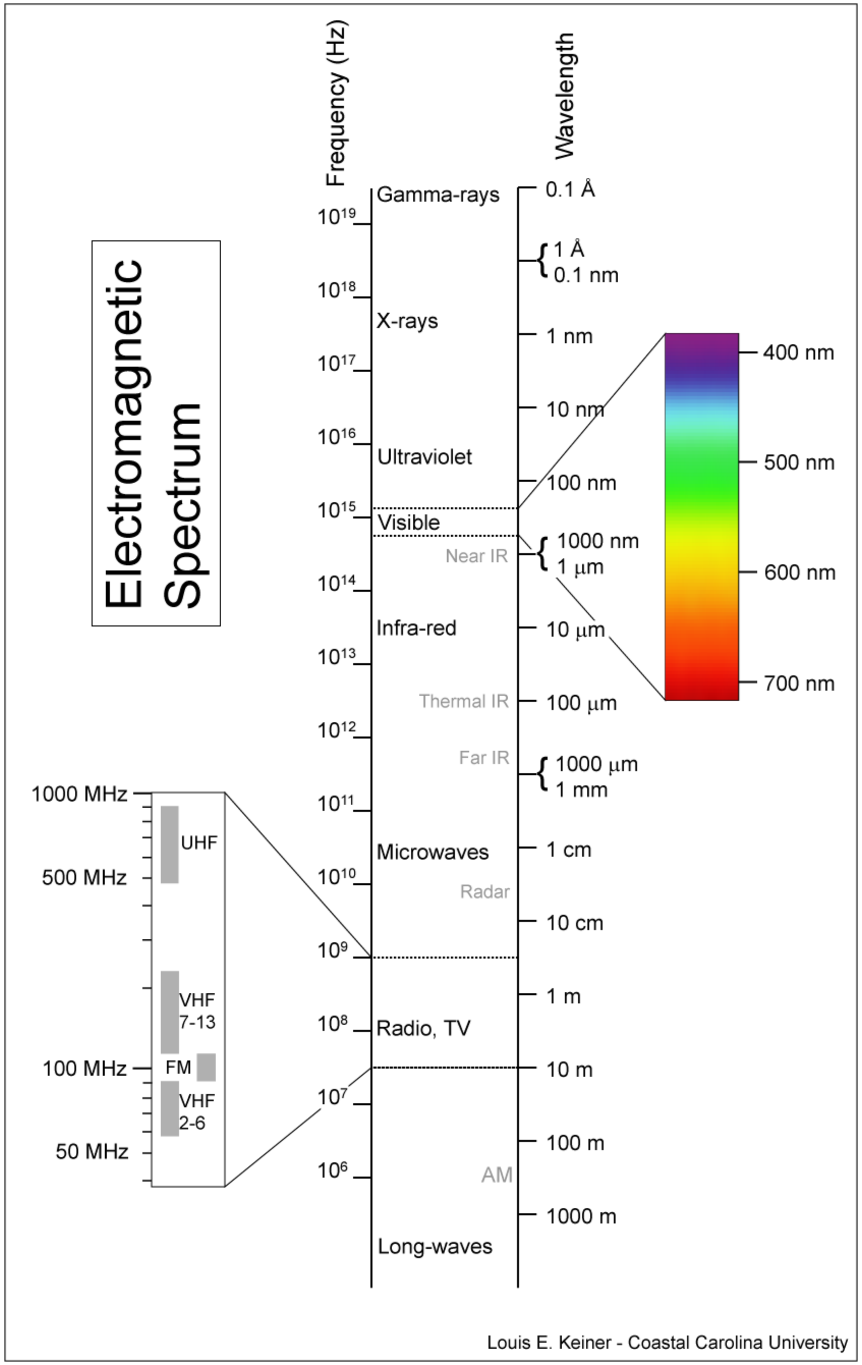
Photography according to Lens System

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

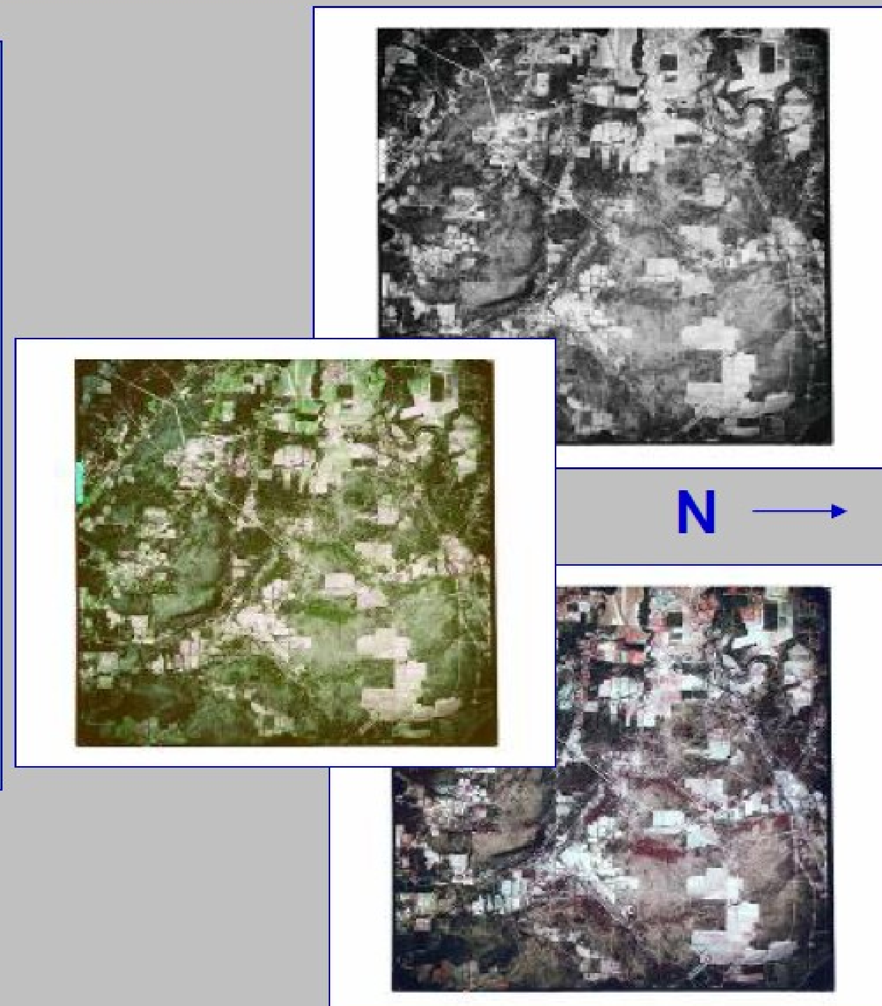


EM Spectrum Regions Used in Remote Sensing

- 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

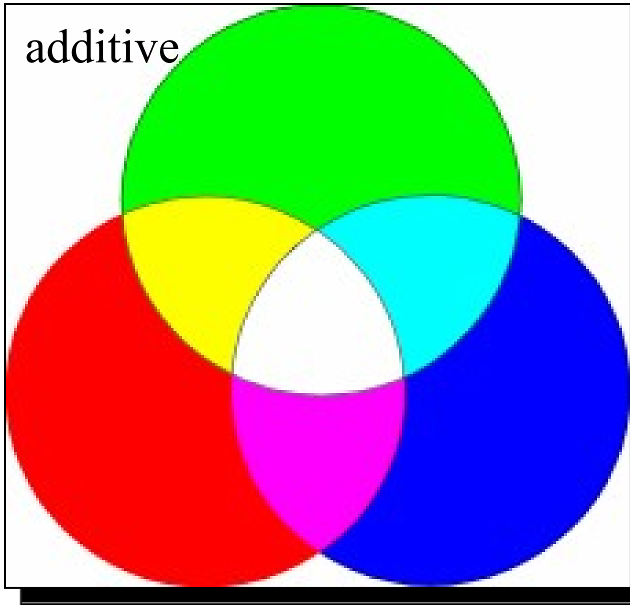
Common Types of Aerial Film

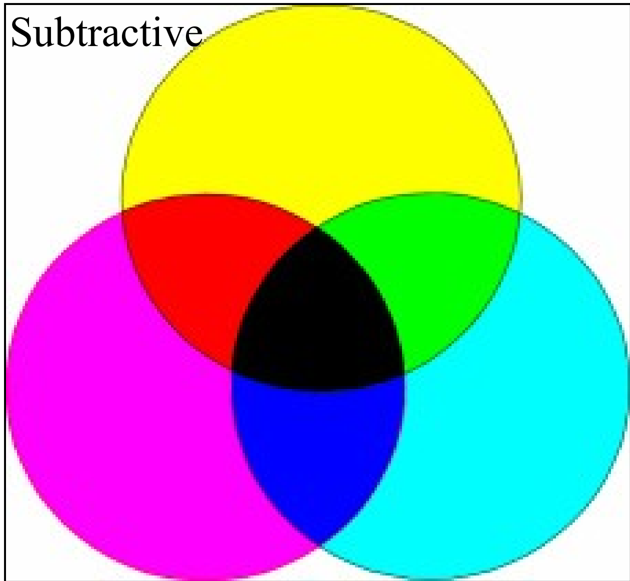
- Panchromatic
  - Sensitive to blue through red wavelengths
- Color
  - Three emulsion layers
- Color Infrared
  - Generally three layers sensitive in green, red, and IR



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

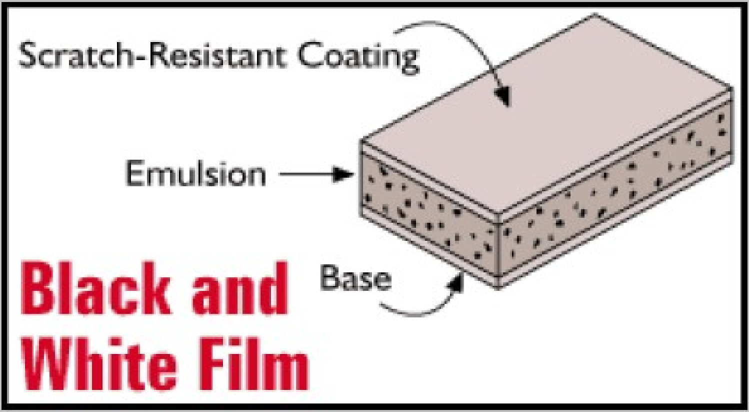
False-color infrared

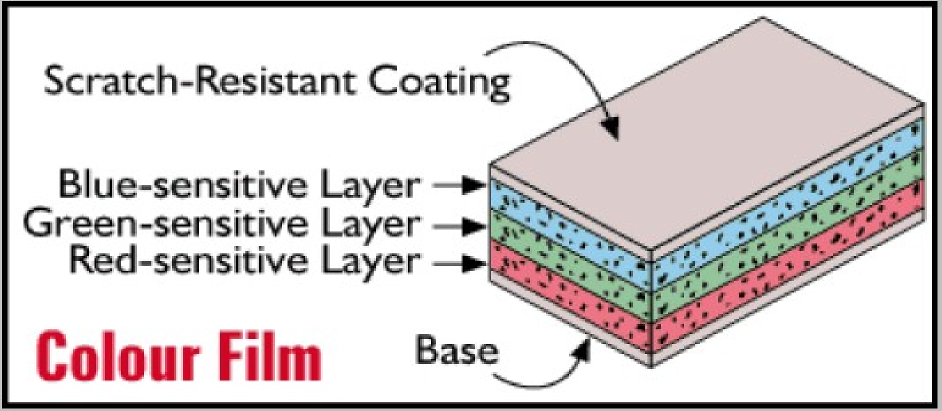
Normal color

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

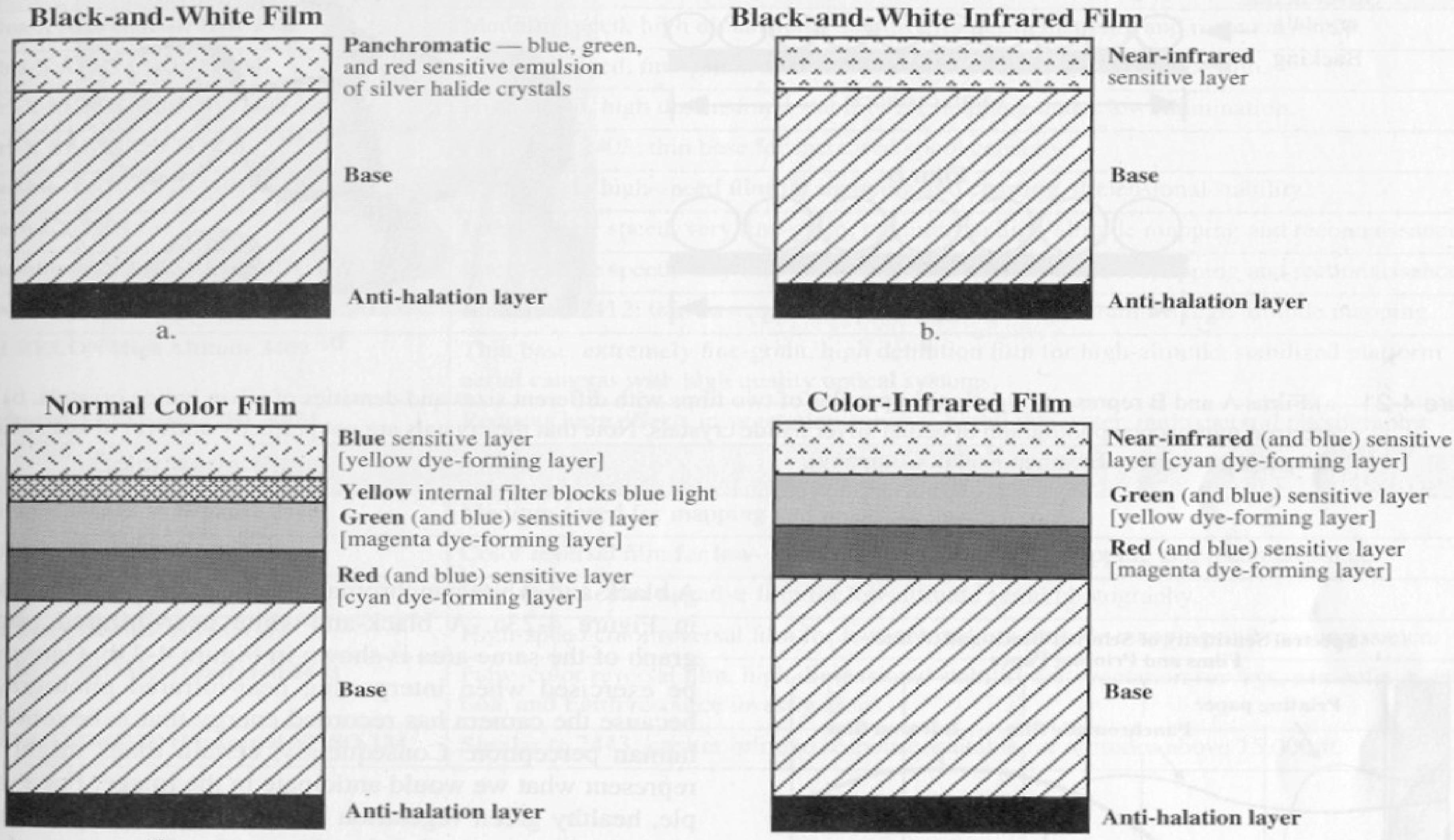
0.4 to 0.5 μm: blue region of the EM spectrum

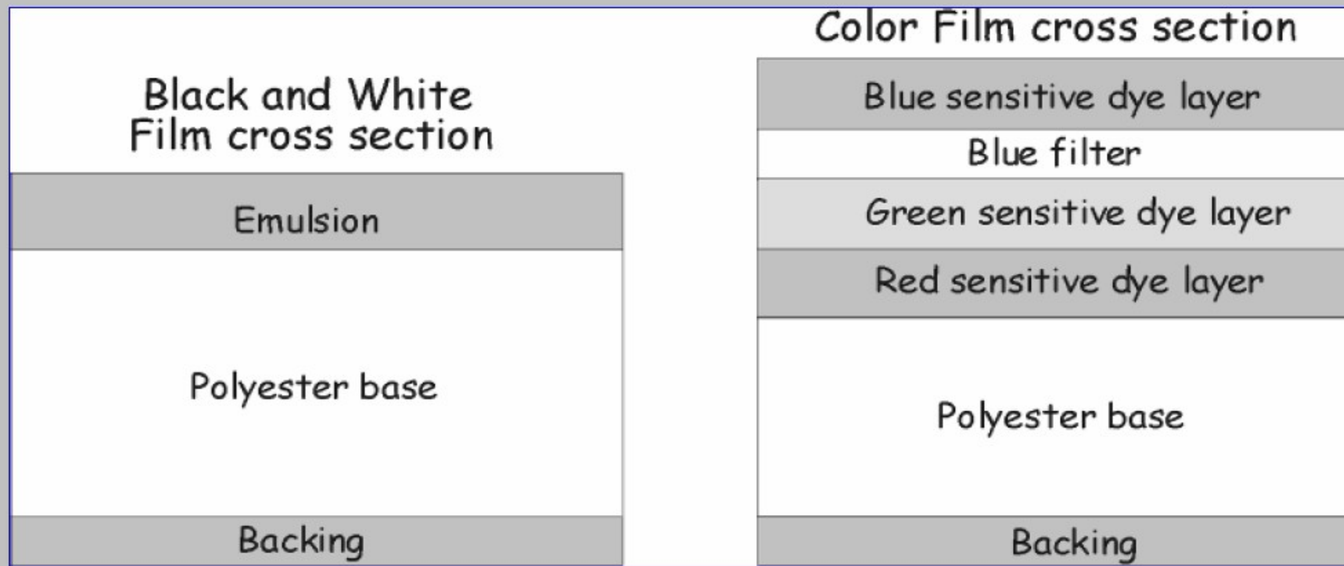
0.5 to 0.6 μm: green region of the EM spectrum

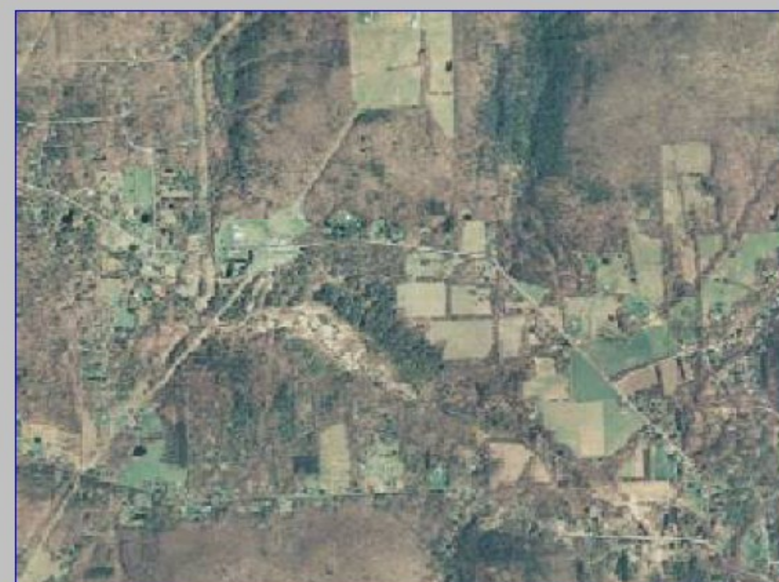
0.6 to 0.7 μm: red region of the EM spectrum

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

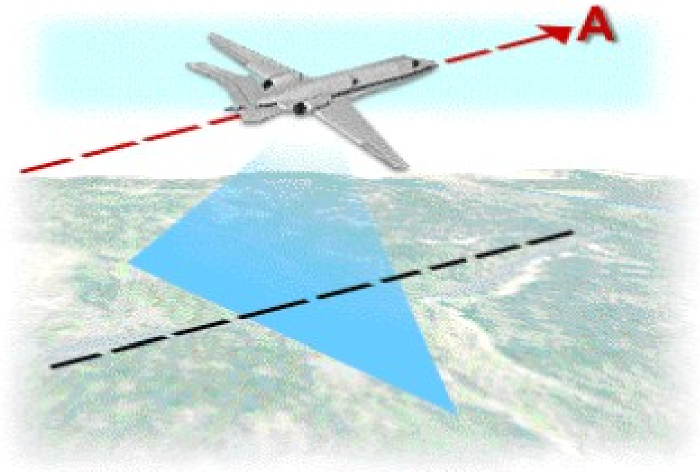


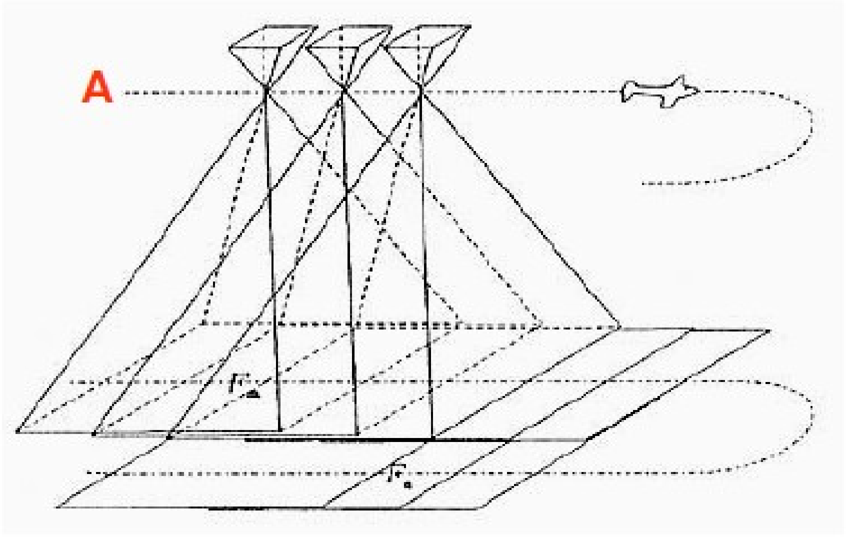

September 18, 2004


January 4, 2004

Flight runs

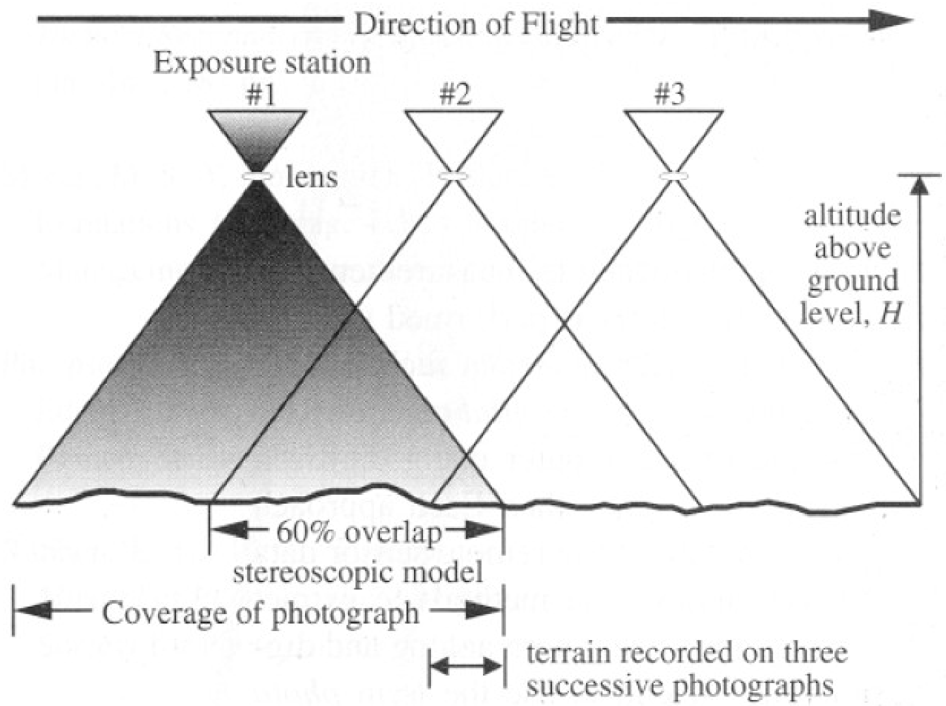
When obtaining vertical aerial photographs, the aircraft normally flies in a series of lines, each called a flight run (A).

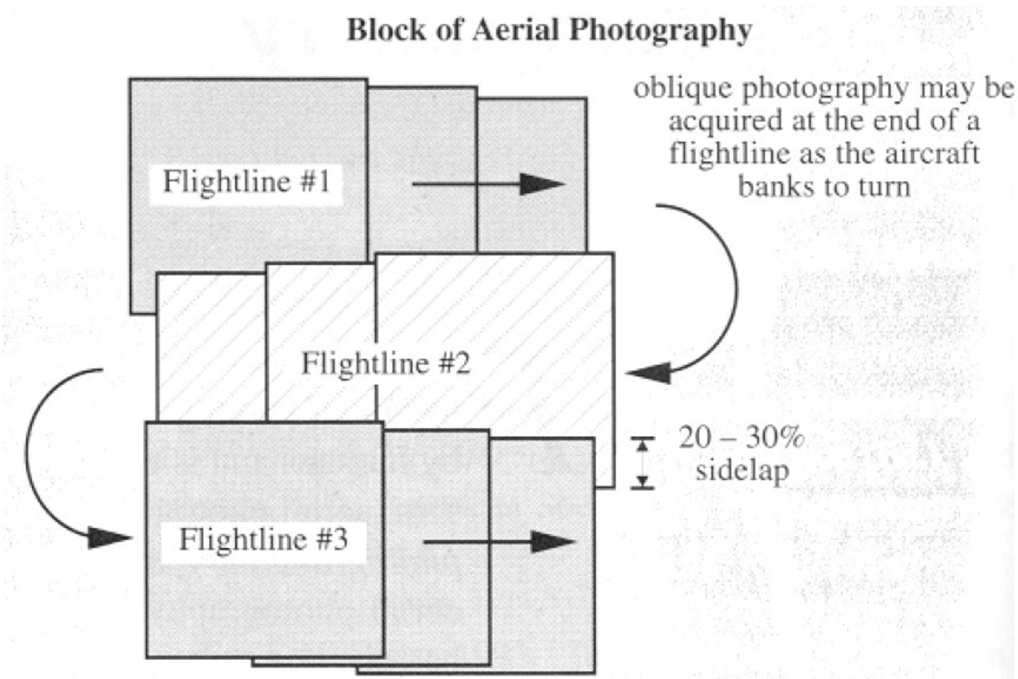


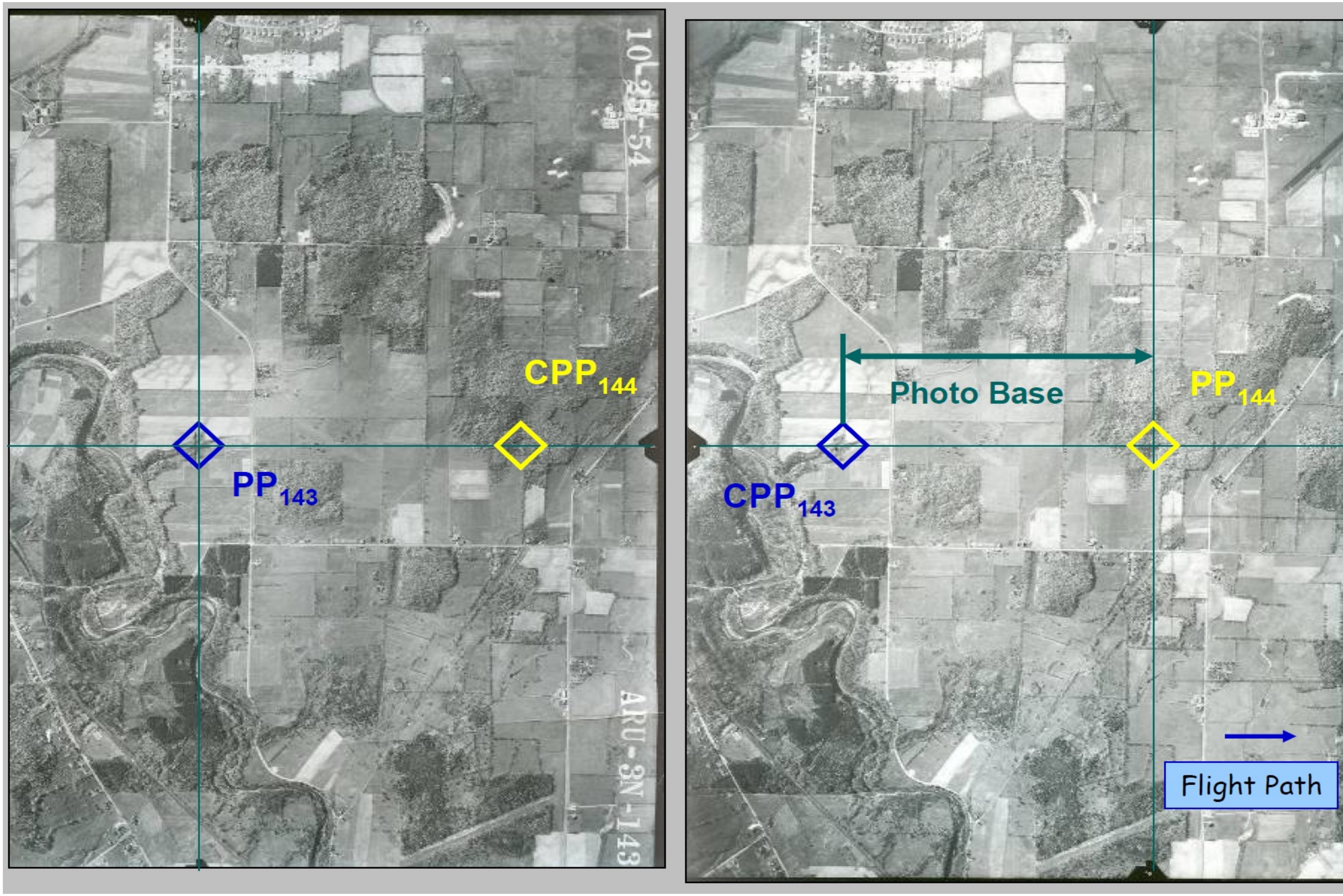


Acquisition of aerial photograph

Flightline of Aerial Photography



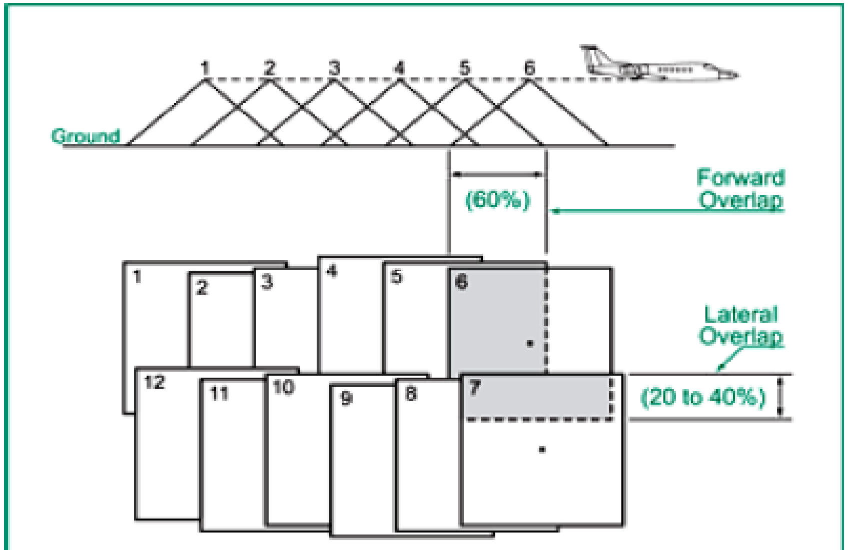




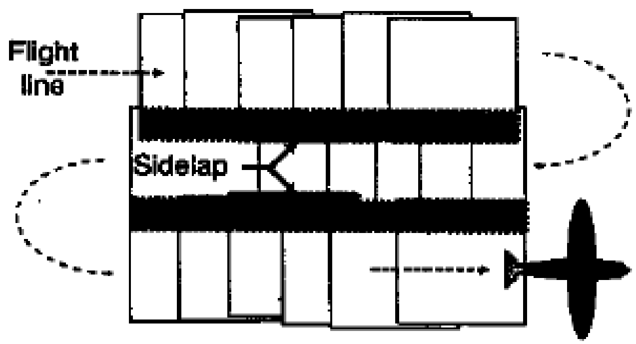
CPP144
PP143
ARU-3N-143
Photo Base
PP144
CPP143
Flight Path

60 % overlap

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

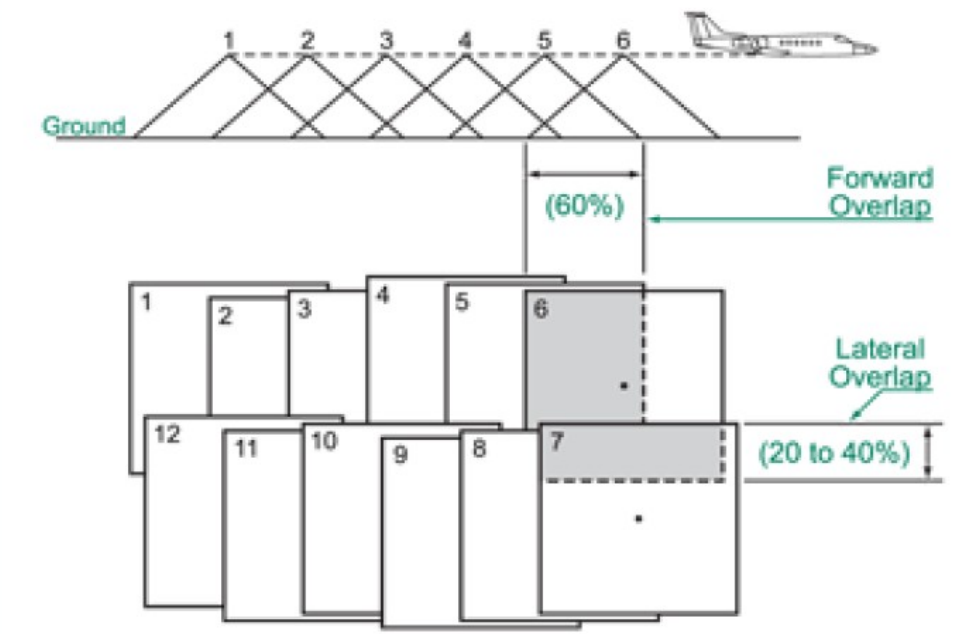


Photographic Overlap

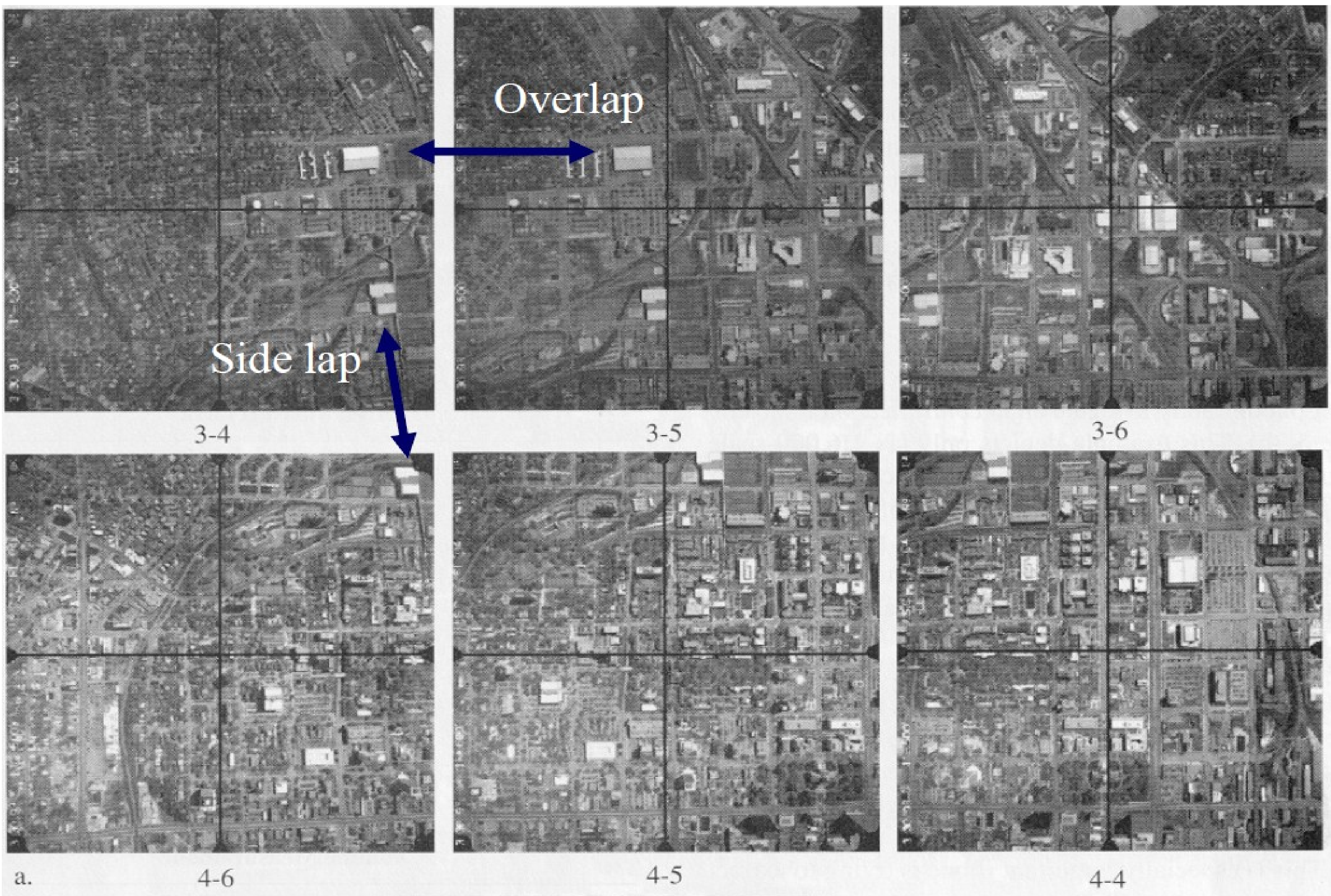


Vertical Photography

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



Photographic Overlap


Overlap
Side lap
3-4
3-5
3-6
a.
4-6
4-5
4-4

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*

Vertical Aerial Photographs

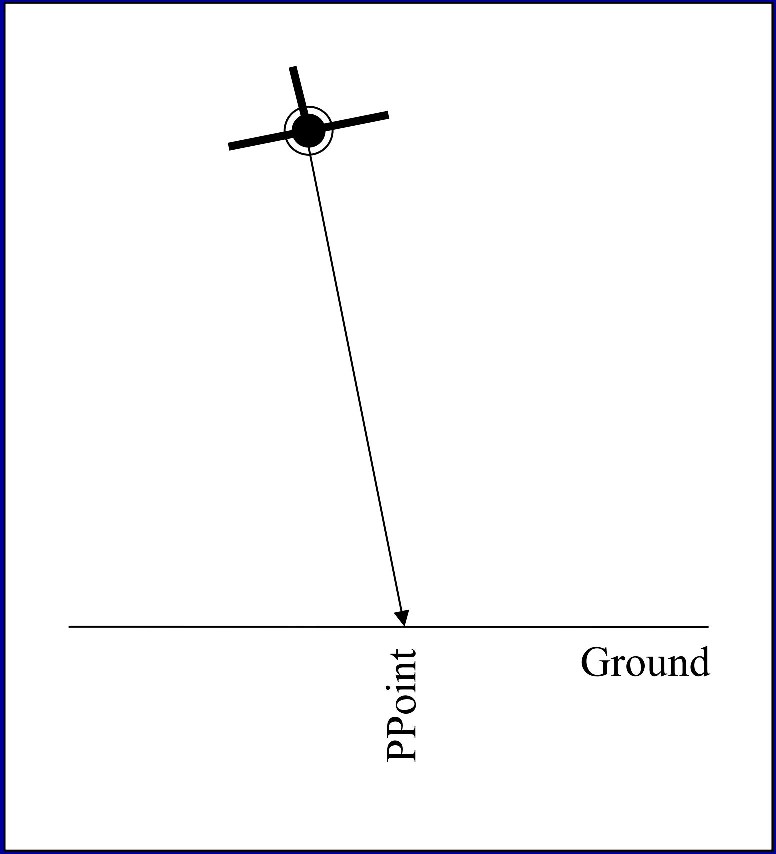
The three photo centers

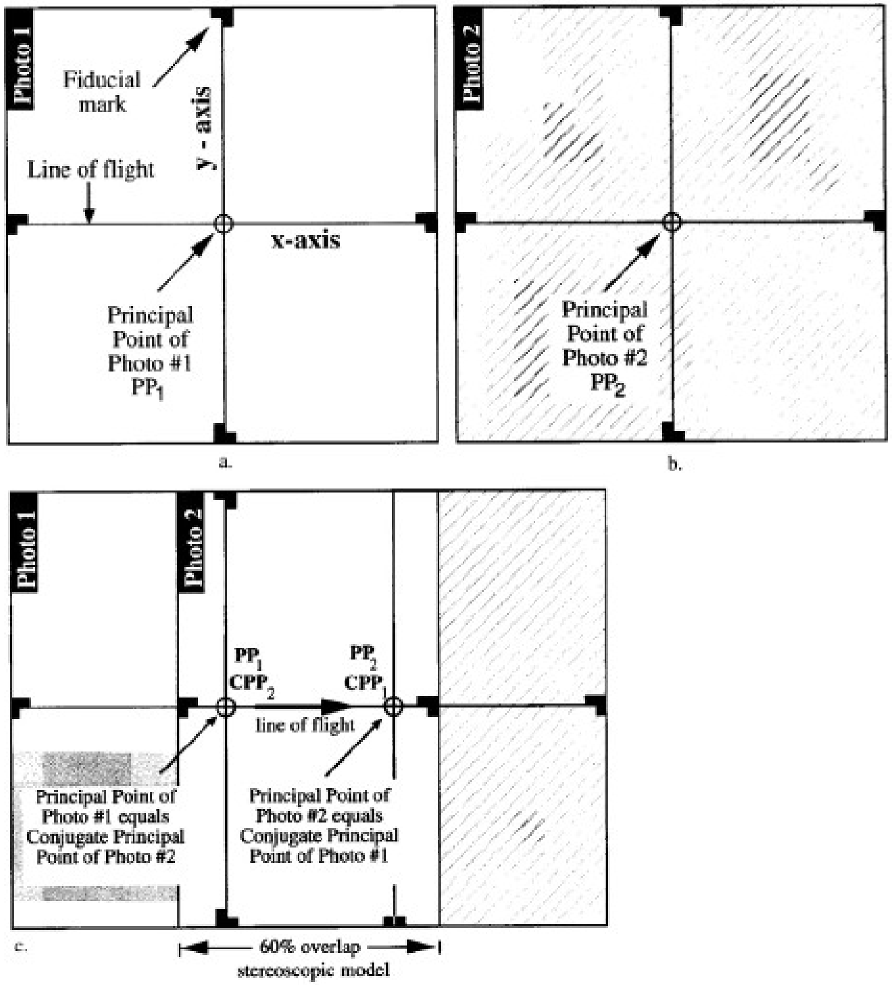
Different types of distortion and displacement radiate from each.

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.

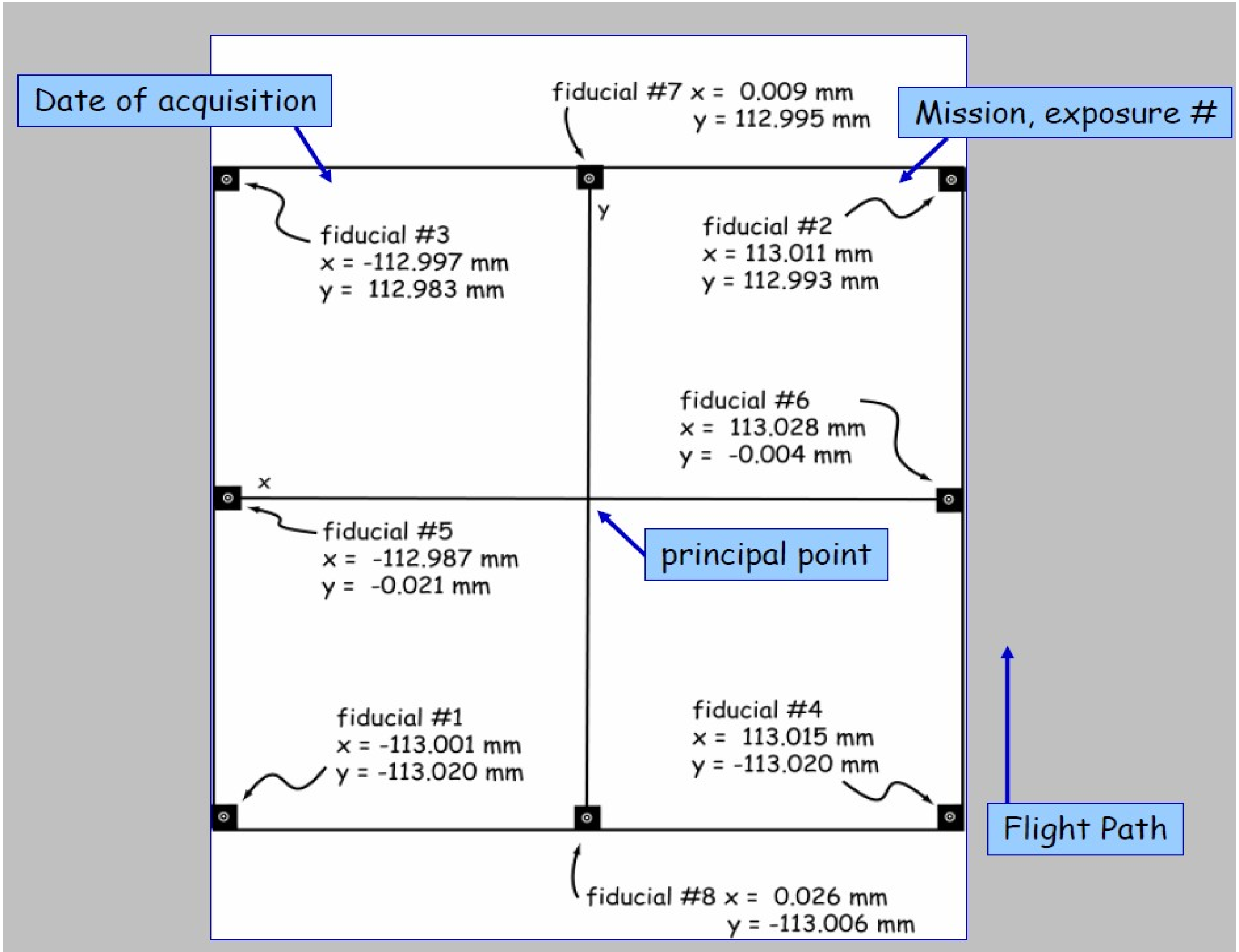
It is the intersection point between the projection of the optical axis (i.e., the perpendicular to the center of the lens) and the ground.

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*.

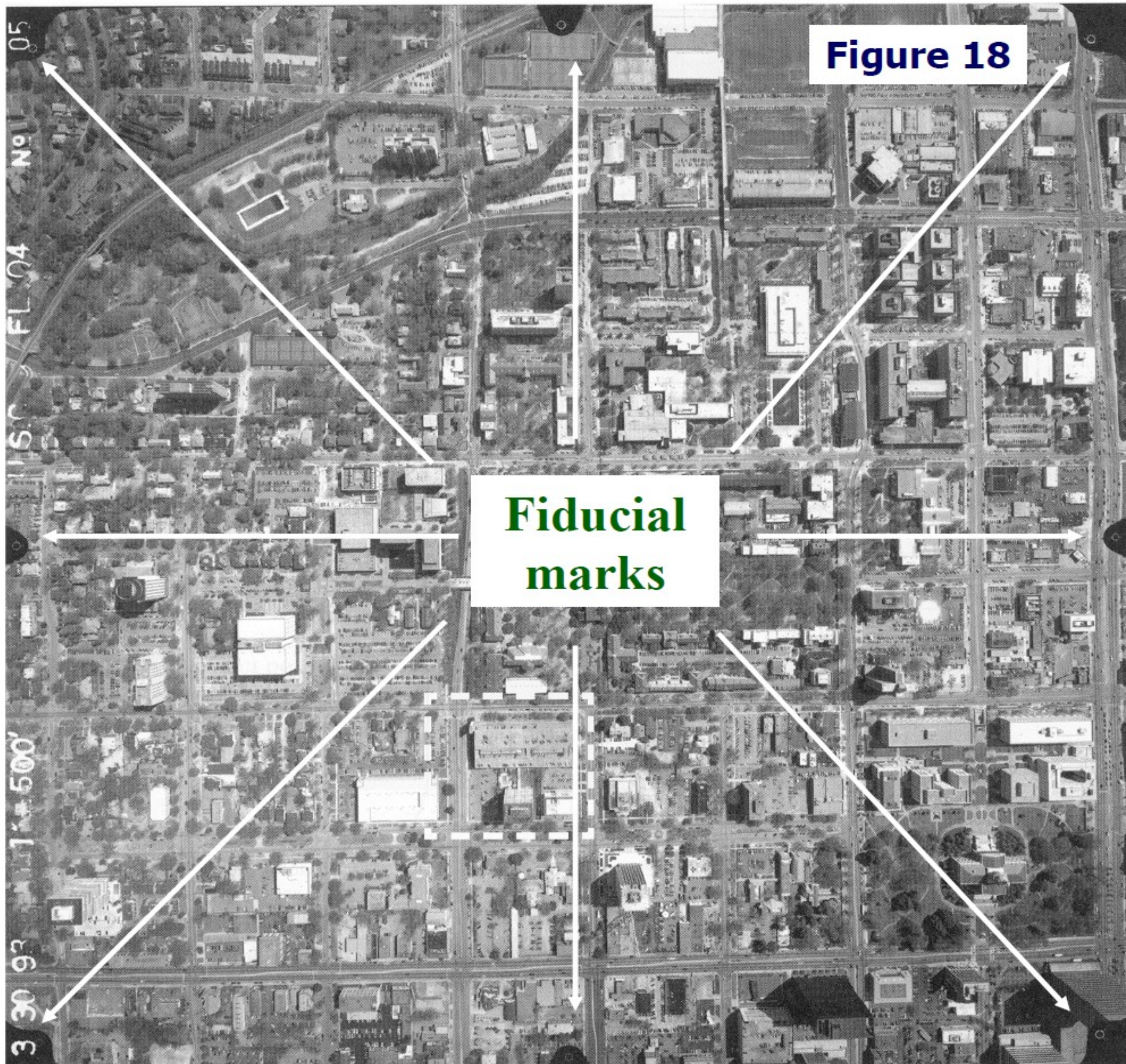
This PP is then transferred stereoscopically onto the adjacent (left and right) photographs of the same flight line

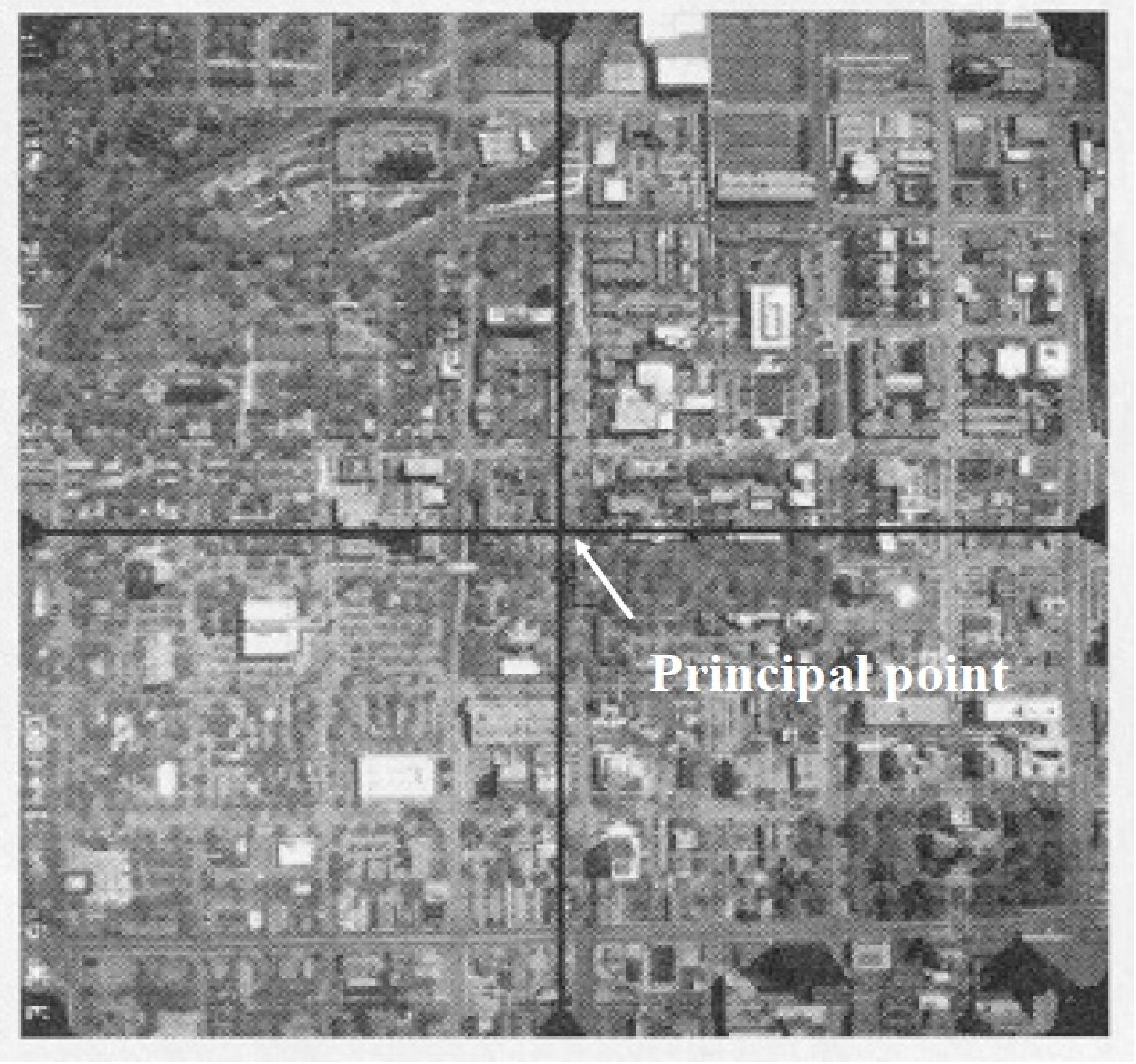
These transferred points are called transferred principal points or **conjugate principal points (CPP).** The line segment joining the principal points and the conjugate principal points constitute the flight line of the aircraft, also called base line or air base


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

$f = 6''$

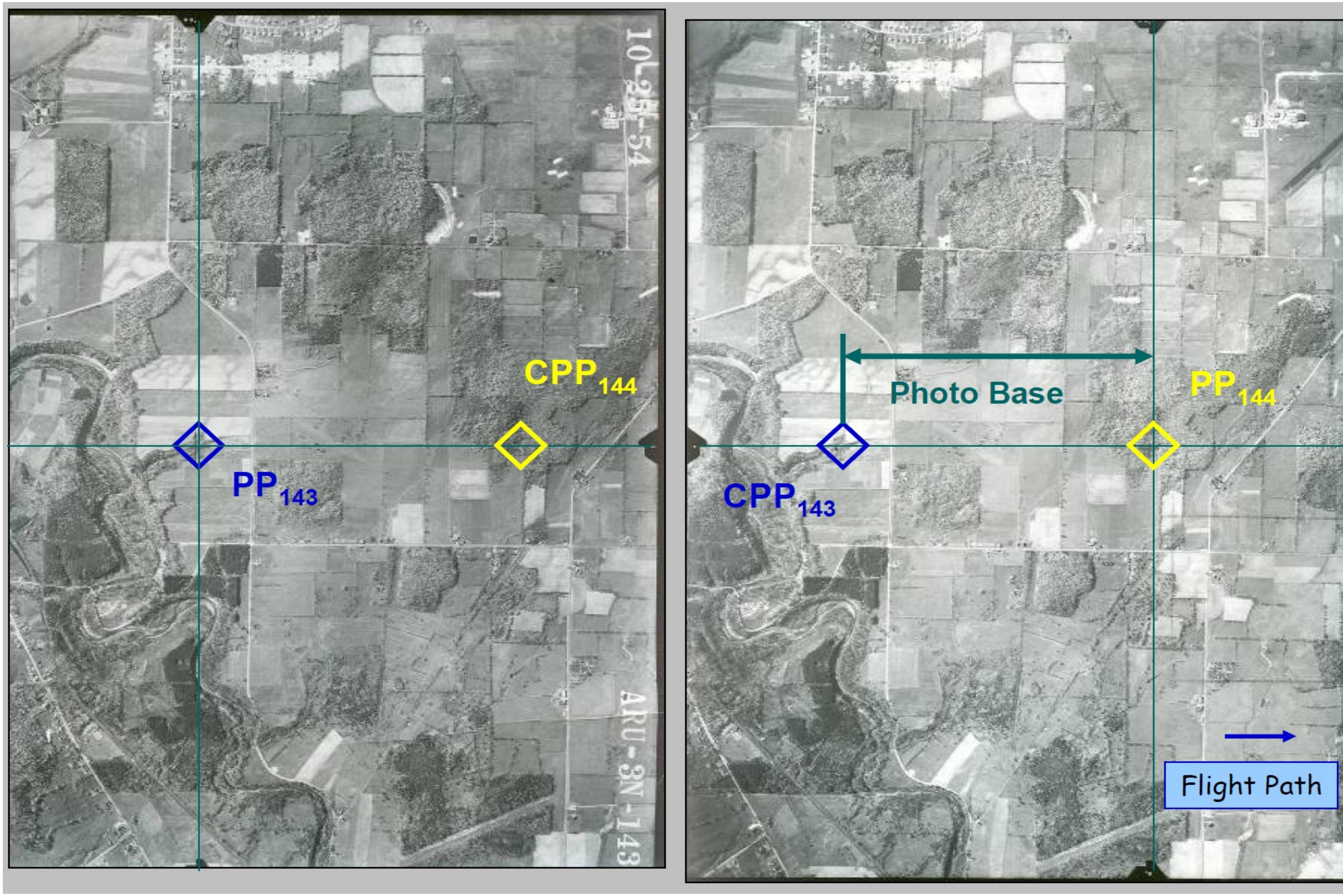
Ancillary data





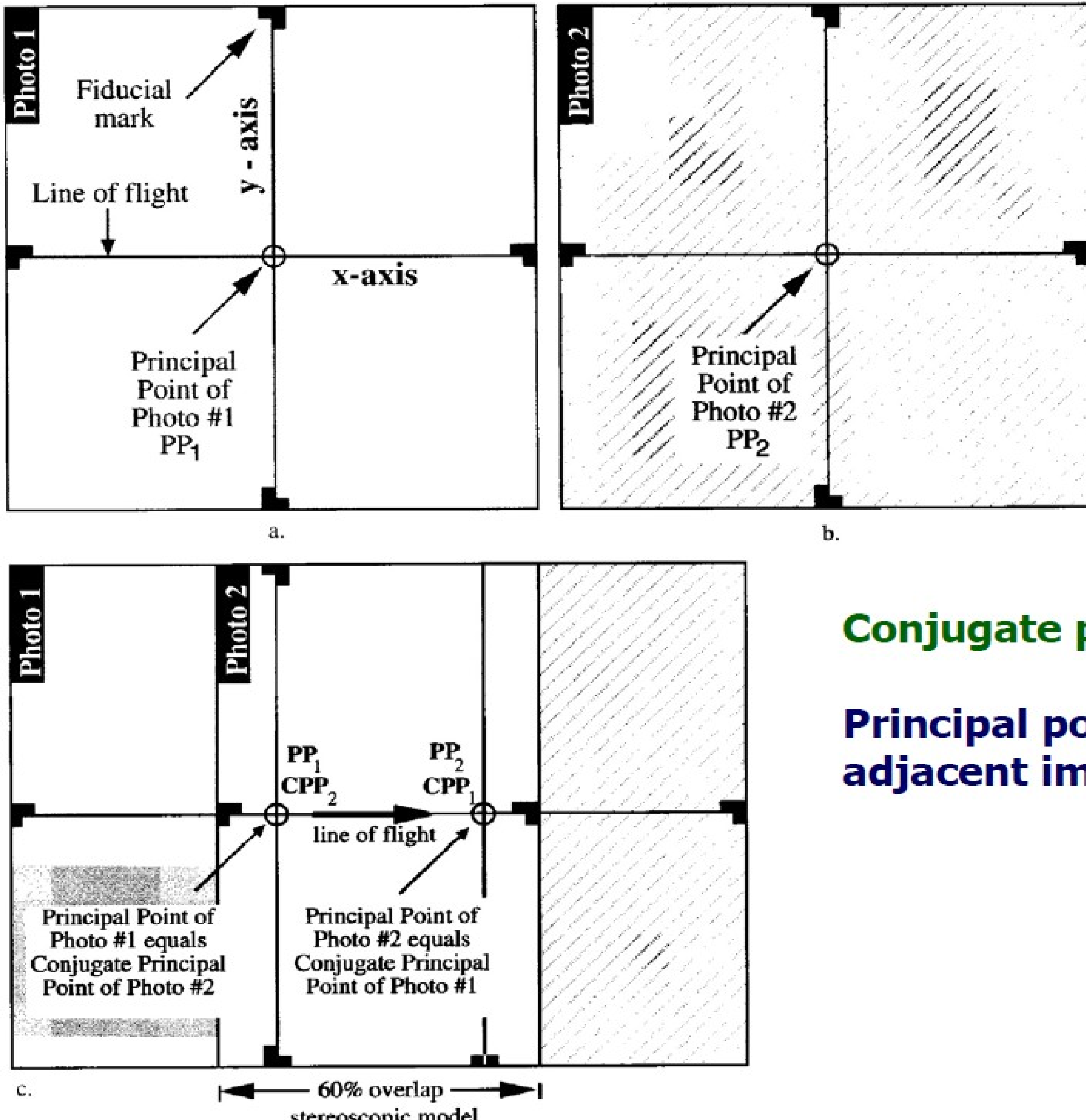
Principal point
- the intersection of the lines connecting two sets of fiducial marks
- represents the point on the ground where the camera was pointing when the photograph was taken

Figure 19



CPP_{144}
PP_{143}
ARU-3N-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*

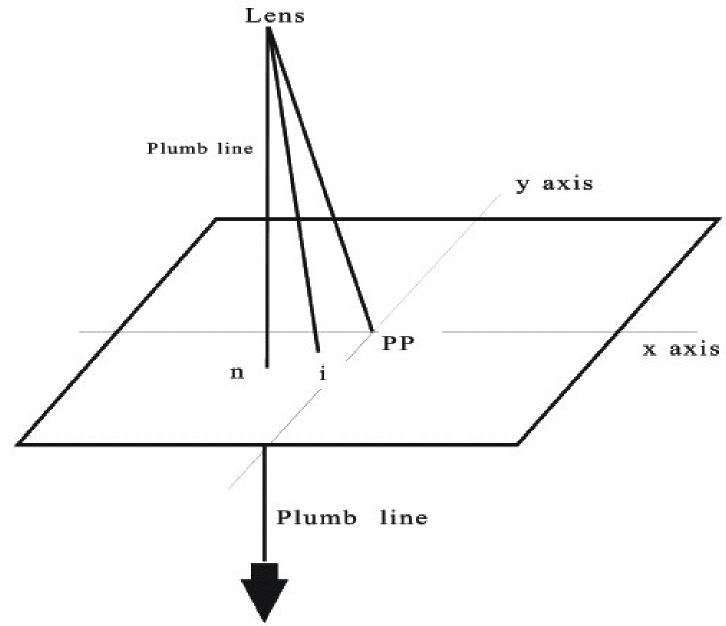
It is the intersection point between the plumb line directly beneath the camera center at the time of exposure and the ground.

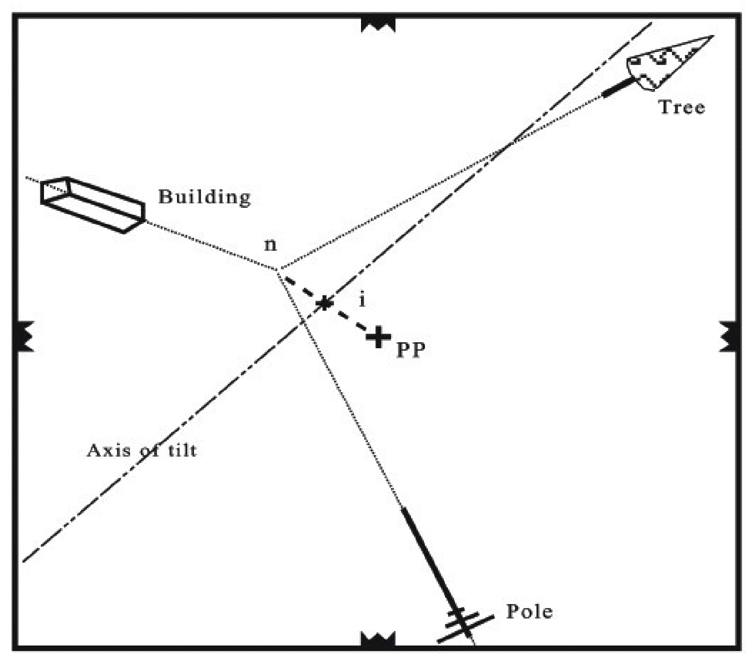
The nadir is important because relief displacement is radial from this point

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.





Vertical Aerial Photographs

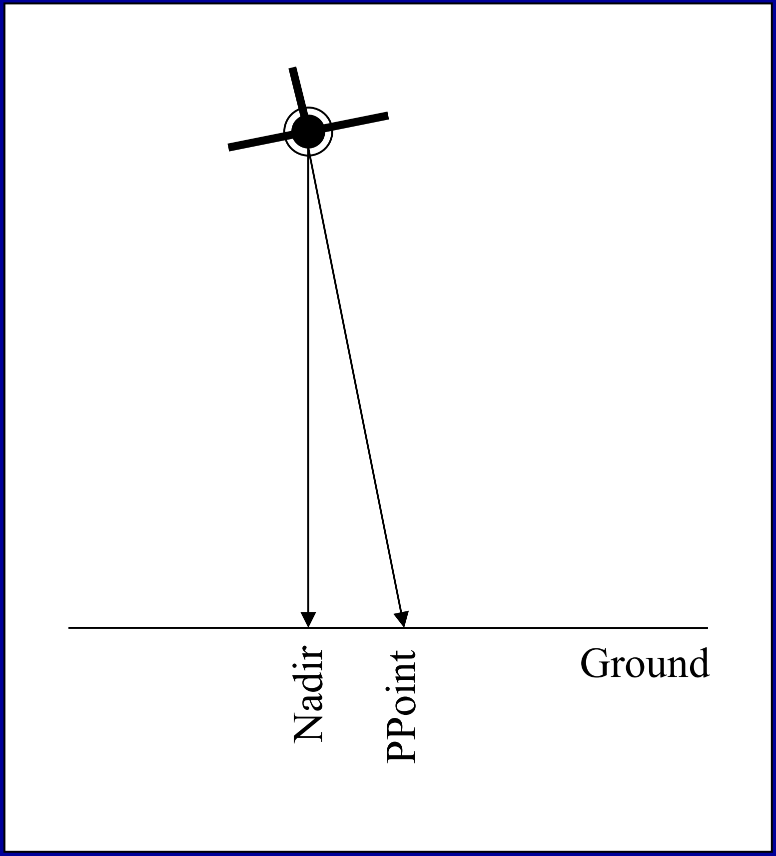
The three photo centers

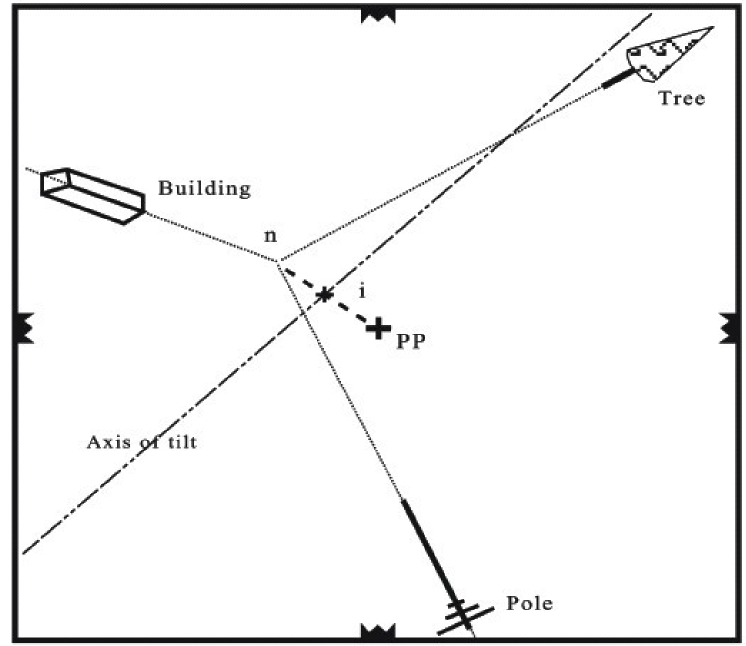
2

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.

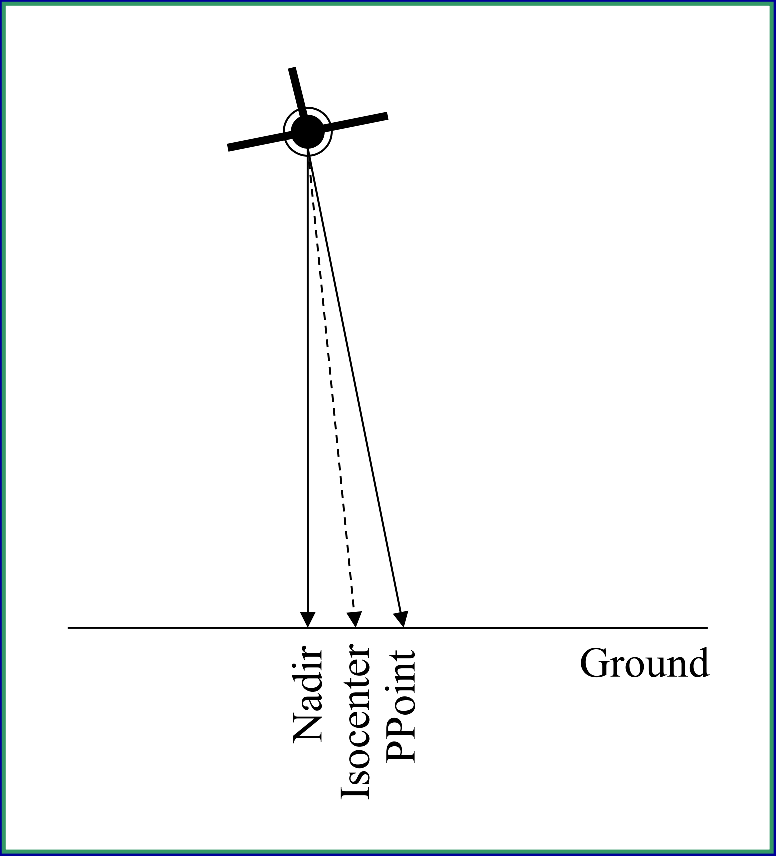
The isocentre is the point from which tilt displacement radiates.

The three photo centers

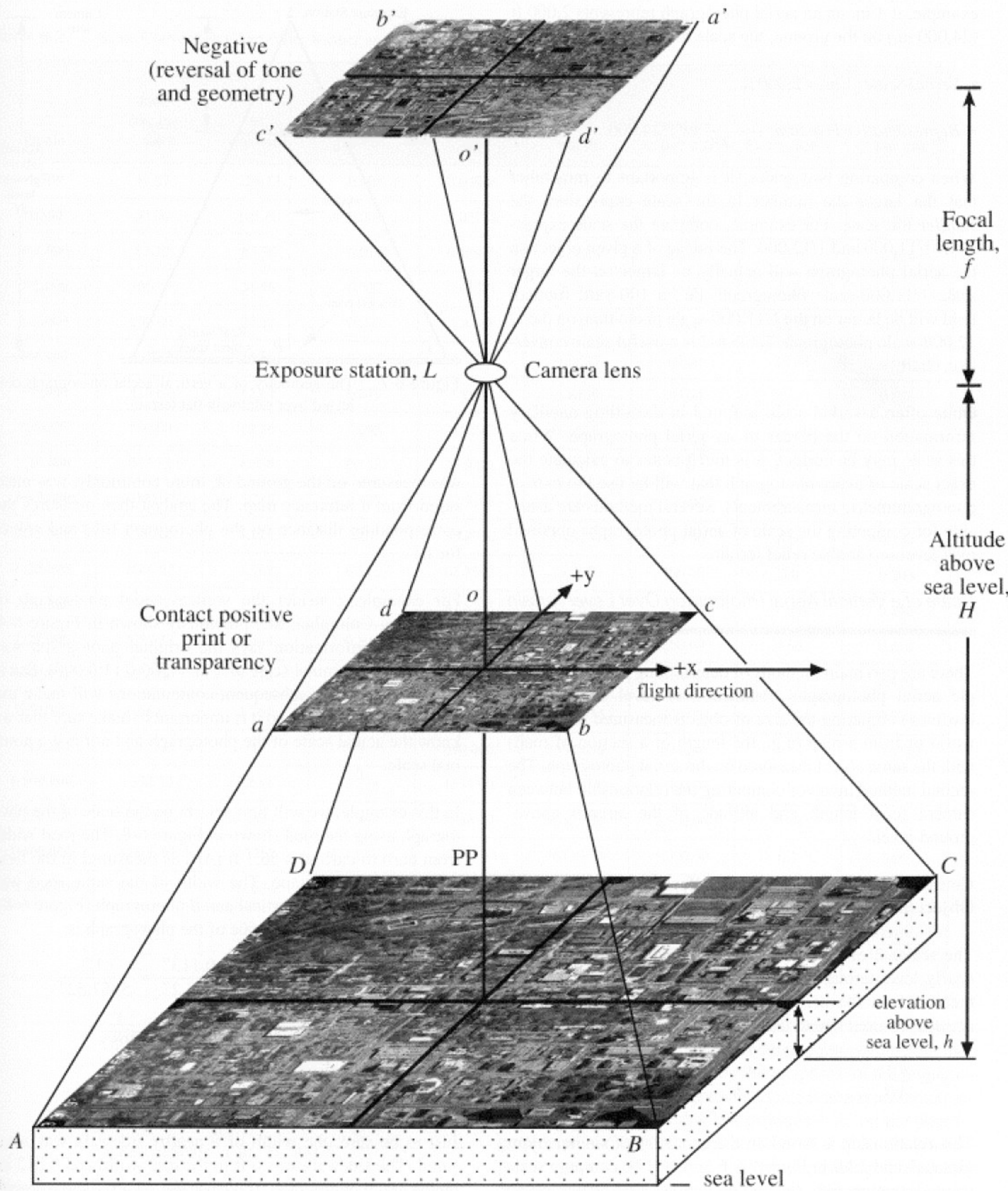
3

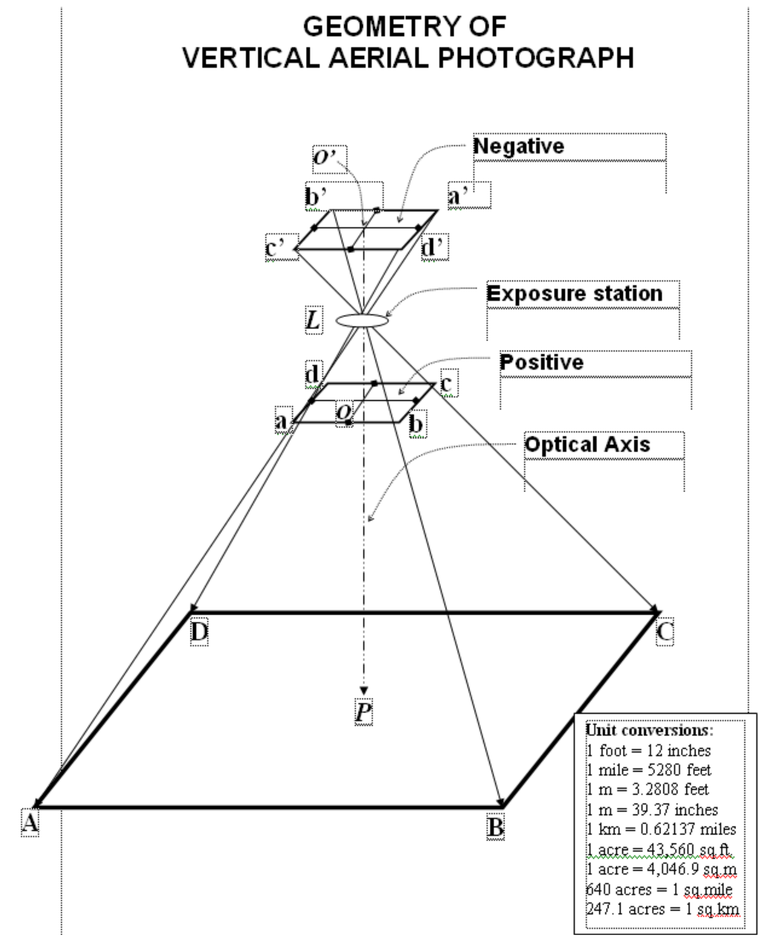
Isocenter: The point that falls on a line halfway between the Principal Point and the Nadir.

Tilt displacement radiates from the isocenter

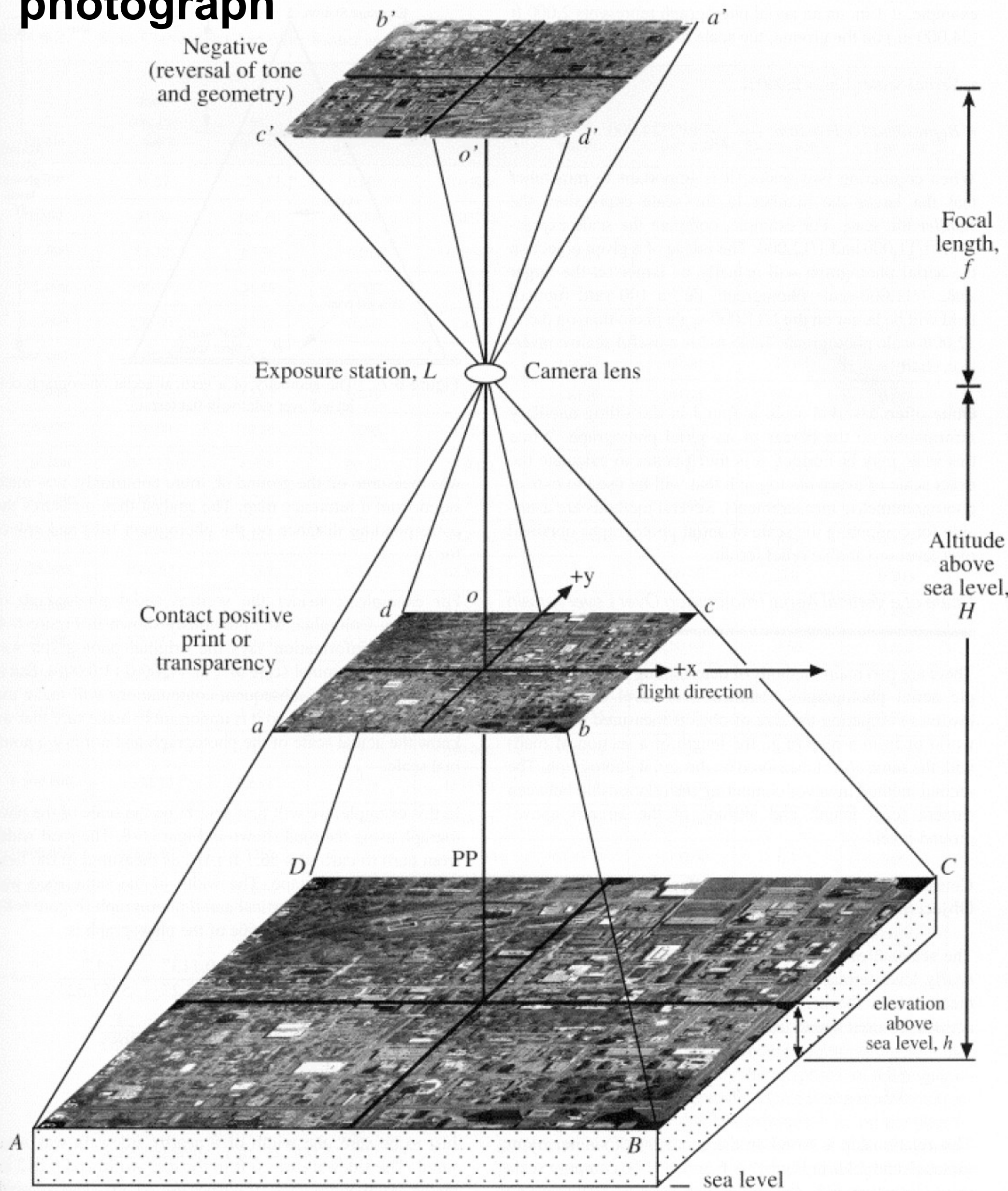


Geometry of a vertical aerial photograph





Geometry of a vertical aerial photograph

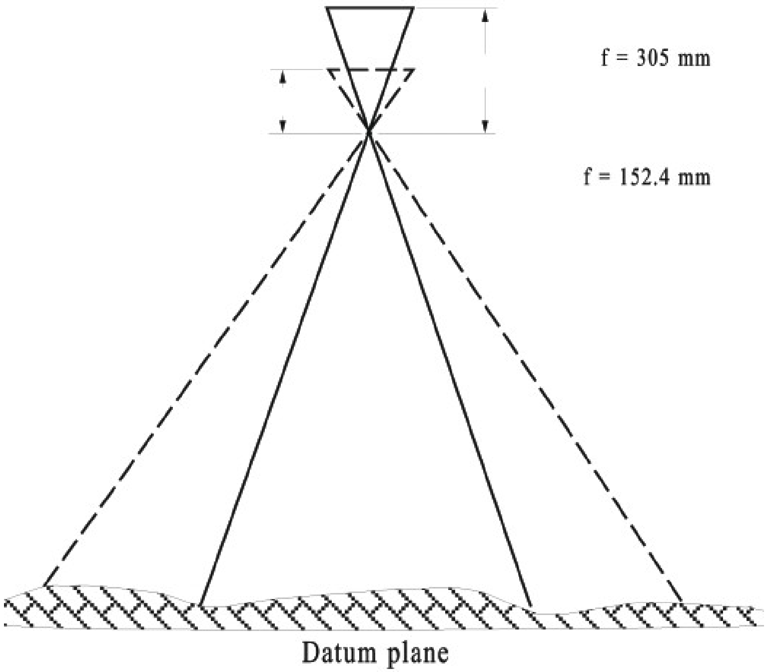


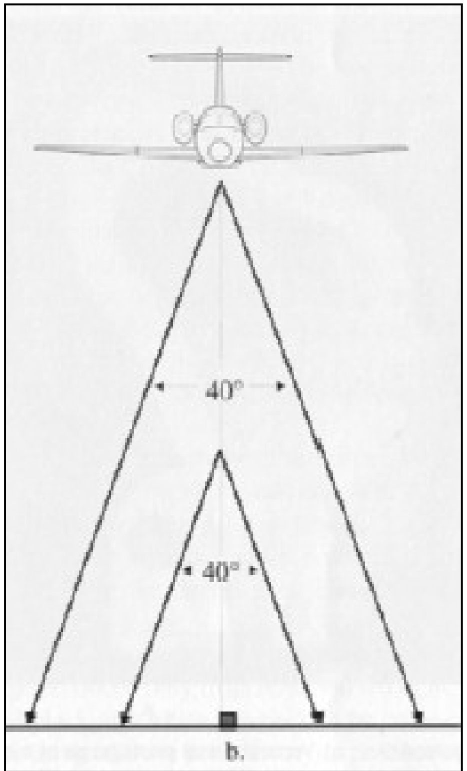
- ➔Incoming light rays from objects on the ground pass through the camera lens before they are imaged on the film in the focal plane.
- ➔The distance between the lens and the focal plane is termed ***focal length***
- ➔The *x* coordinate axis is arbitrarily assigned to the imaginary flight line direction 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

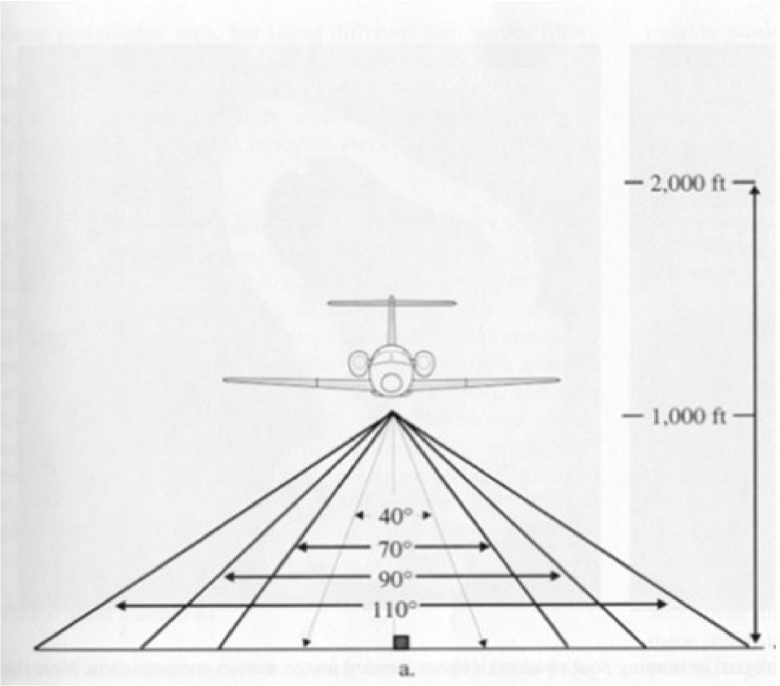
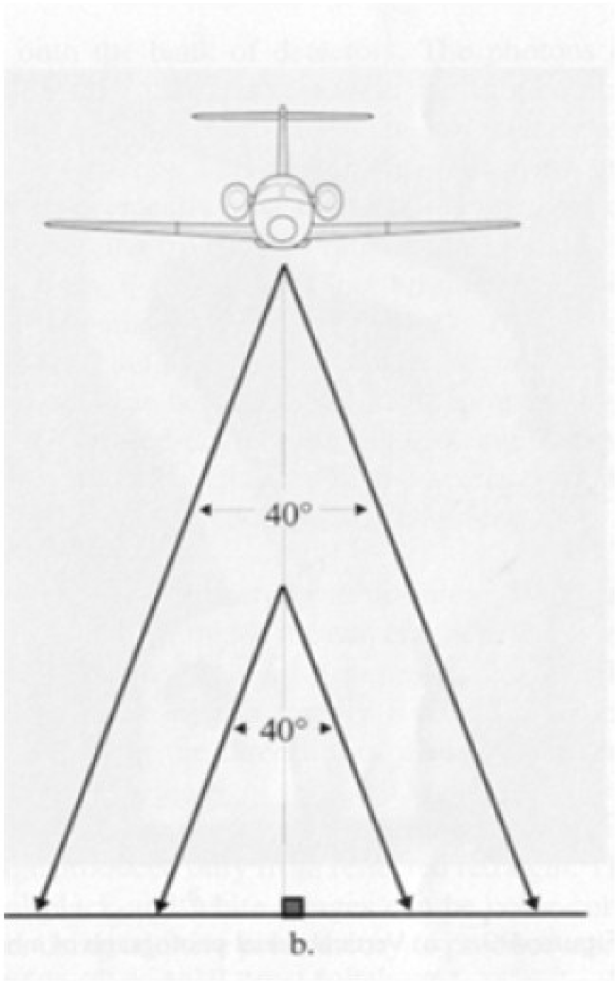


Figure 23

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.

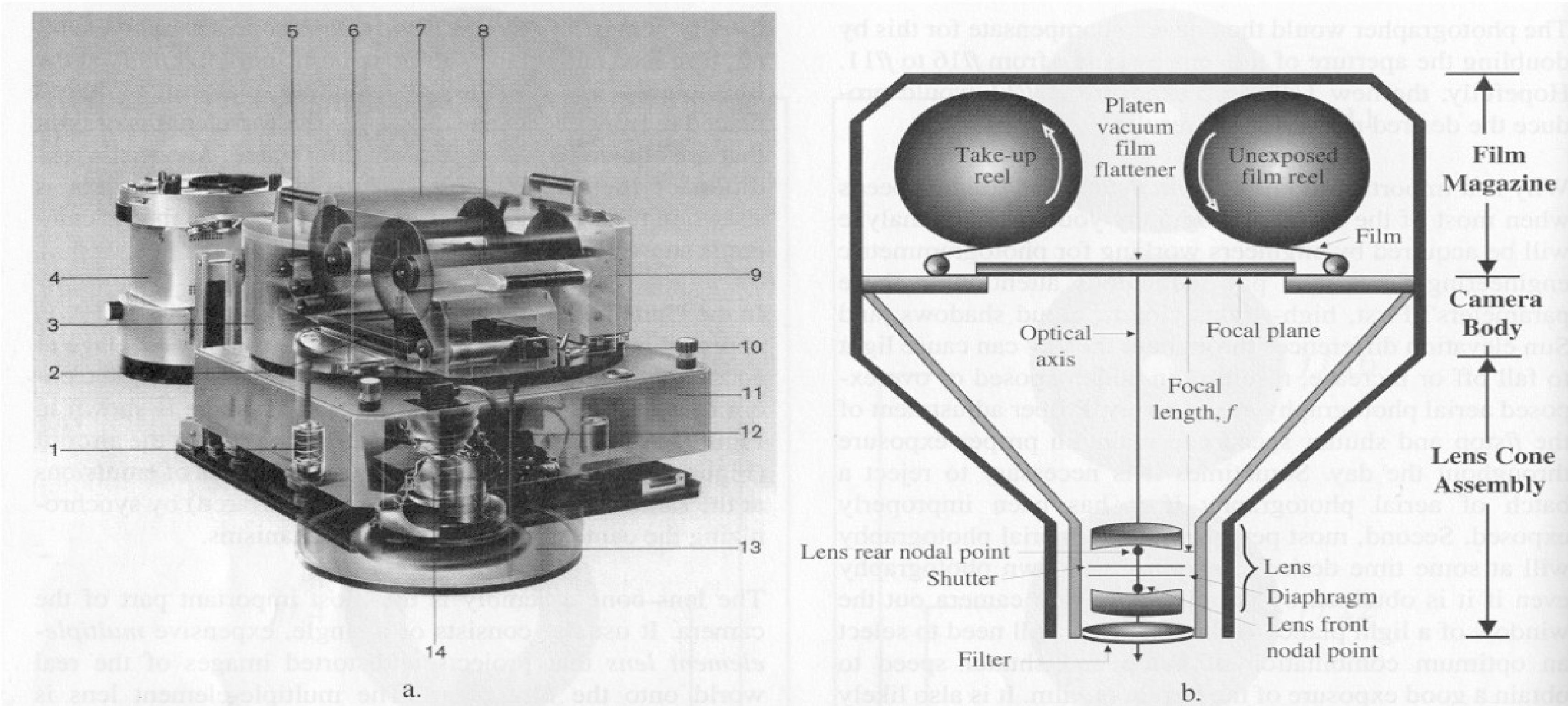
The camera magazine houses the reels which hold exposed and unexposed film and it also contains the film-advancing and film flattening mechanisms.

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.

Figure 6

Aerial metric camera



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.

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.

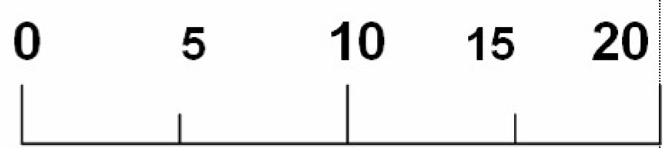
Expressed in 3 ways,

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.



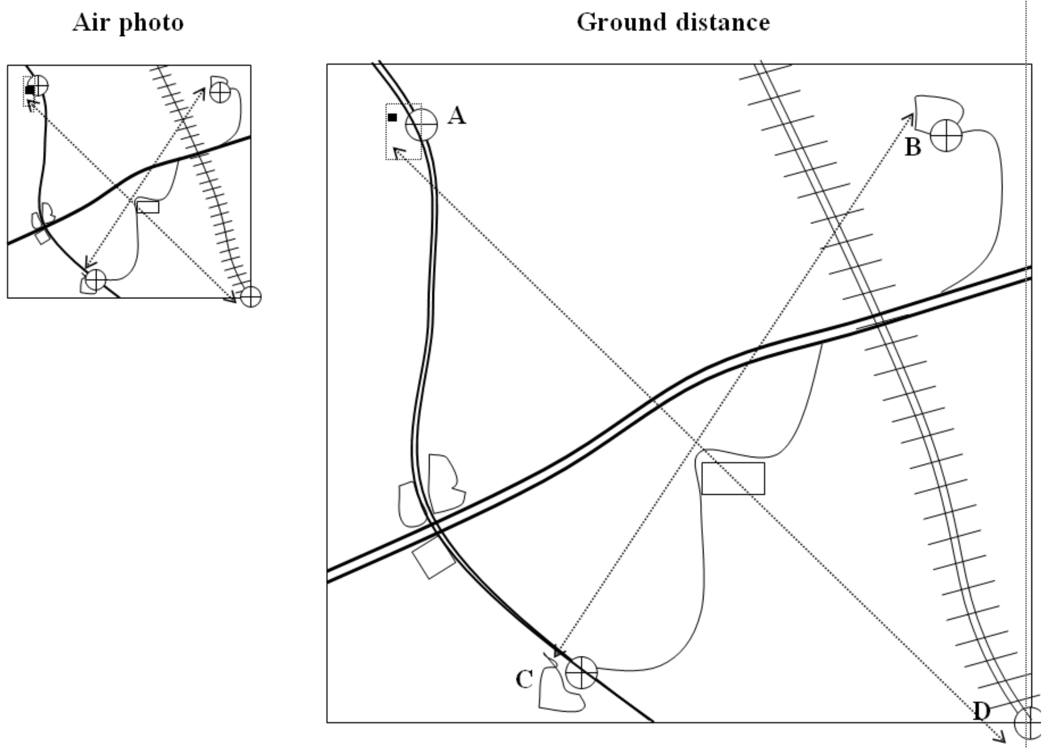
The photo scale can be determined in 3 ways

- 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

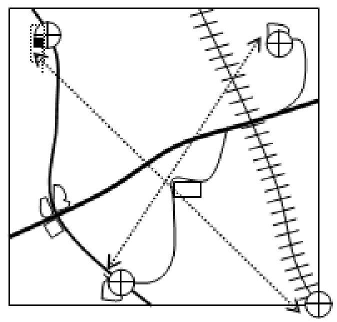
10/6,00,000 = 1/60,000

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

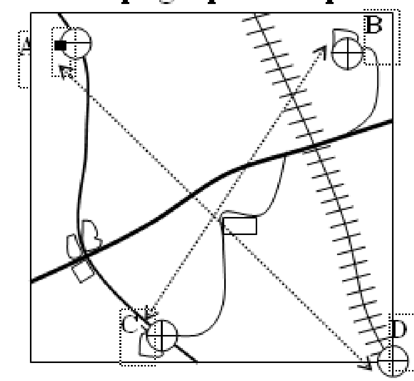
➔ **By establishing the relation between photo distance and Map distance** <u>**Using Topographic map sheet**</u>

- ❖ **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

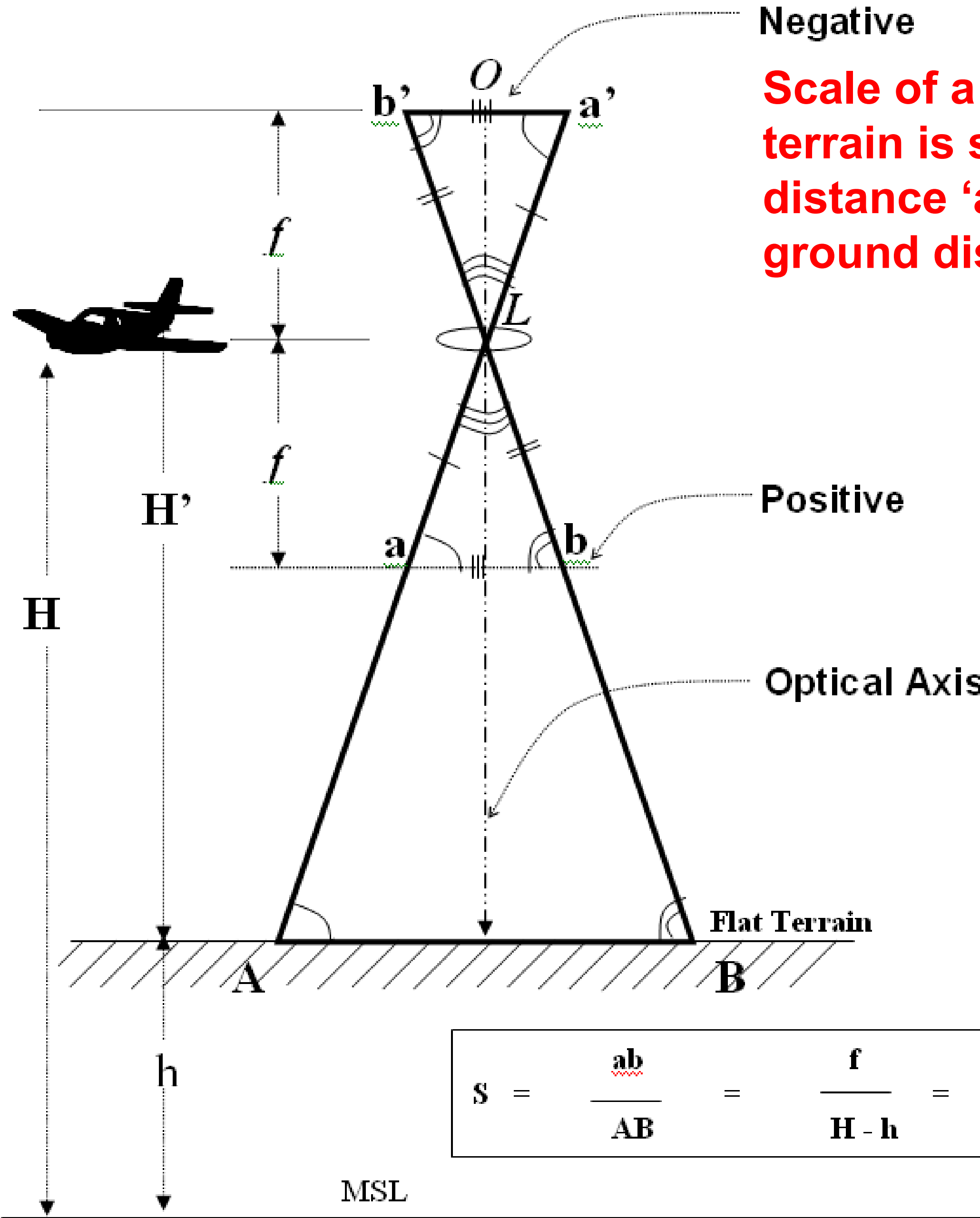
(i) The distance between points A and D in toposheet = 12 cm and in air photo = 10 cm

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



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).

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

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

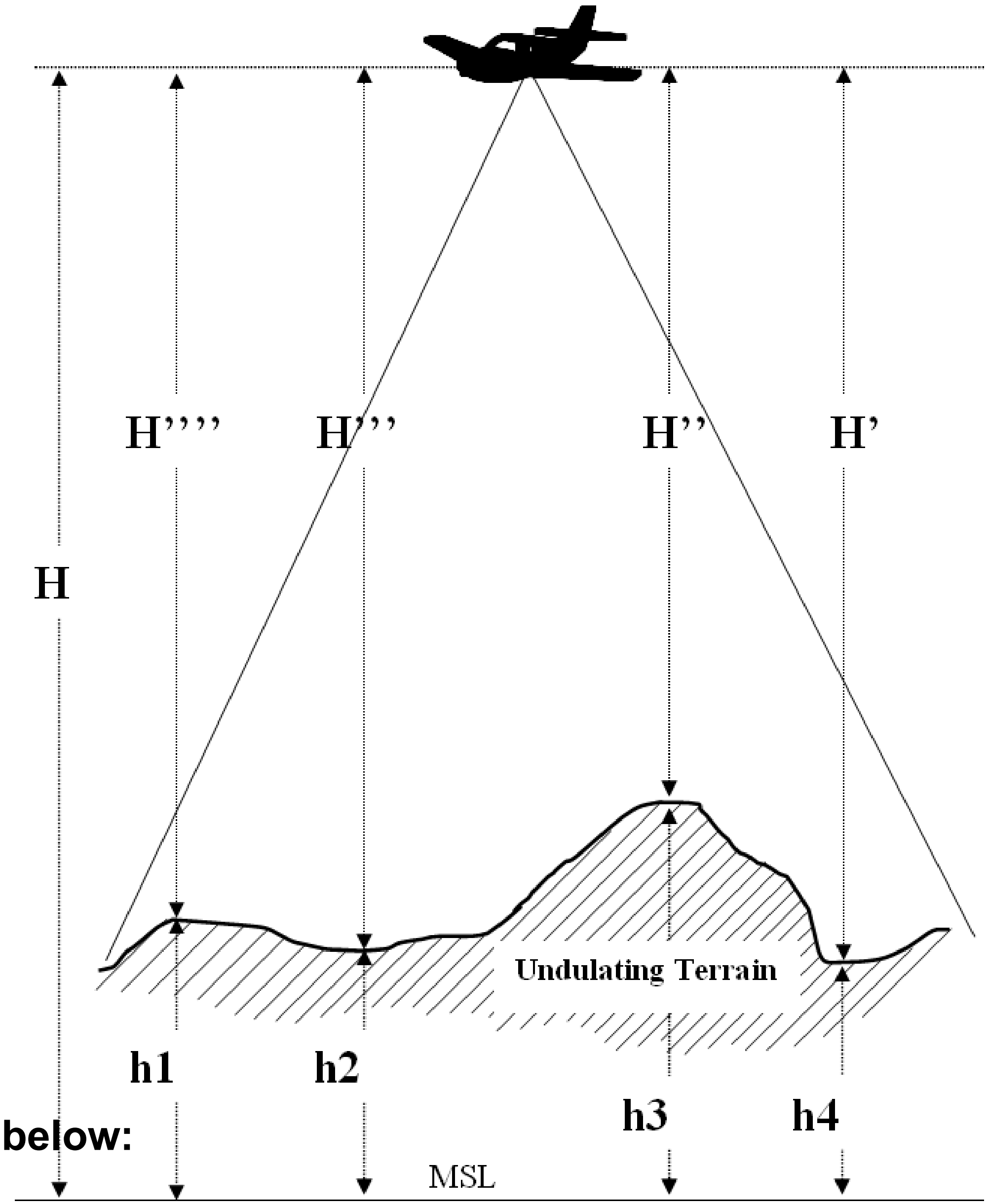
Scale = 8 inches / 50640 inches = 1 / 6330 = 1 : 6330

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.

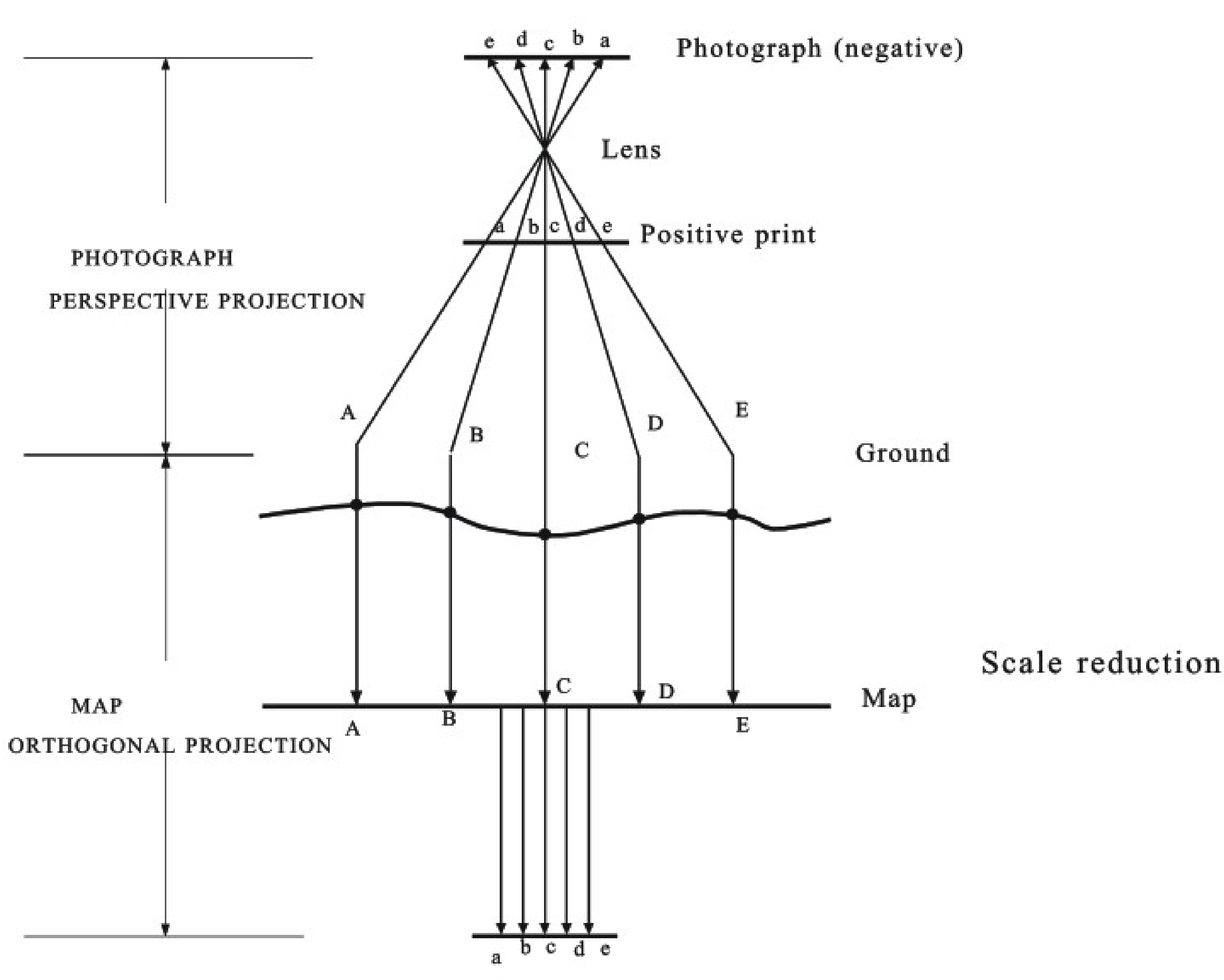
DISTORTION AND DISPLACEMENT

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.

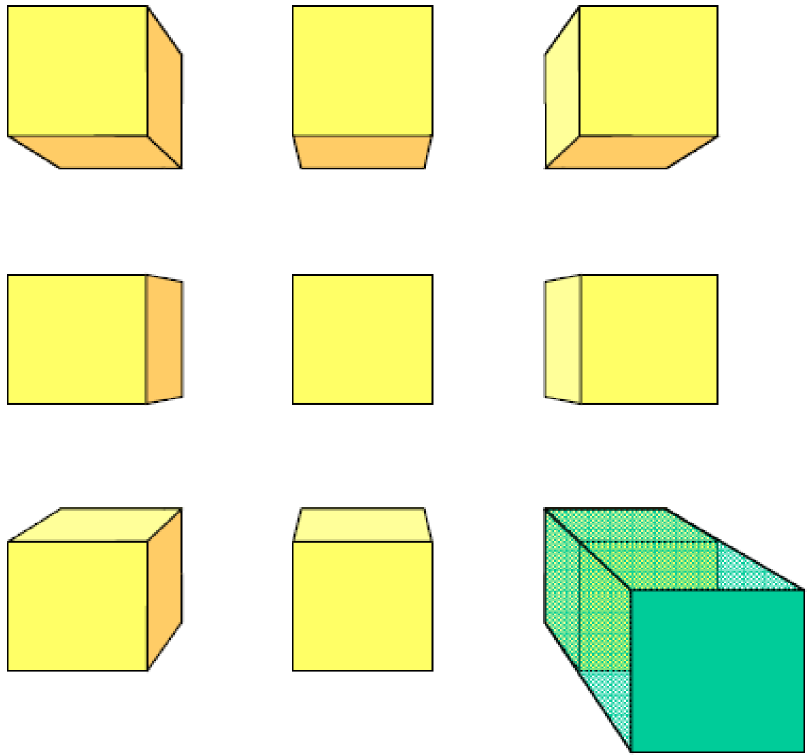


e d c b a
Photograph (negative)
Lens
a b c d e
Positive print
PHOTOGRAPH
PERSPECTIVE PROJECTION
A
B
C
D
E
Ground
Scale reduction
C
D
Map
MAP
A
B
E
ORTHOGONAL PROJECTION
a b c d e

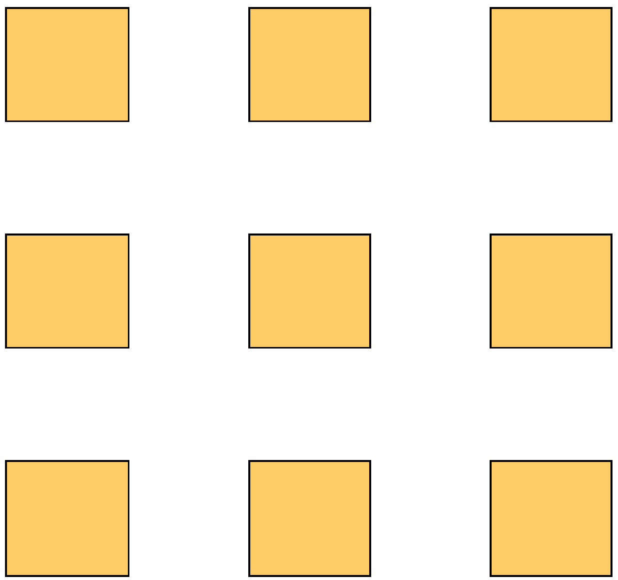
Central Perspective

Imagine nine high-rise buildings wiewed from above

Central Projection (photo):



Orthogonal Projection (map):



- Radial displacement
- Scale differences

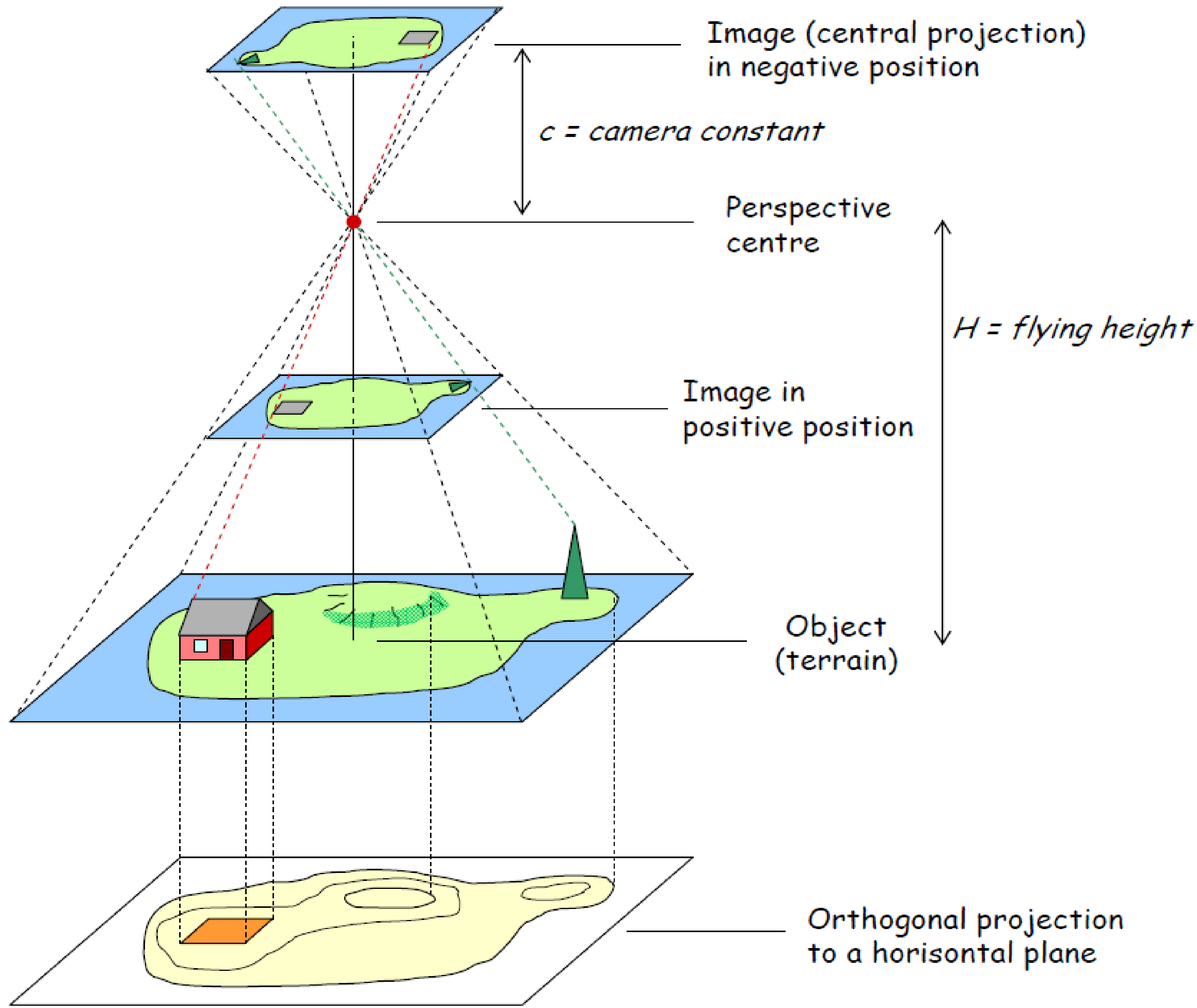
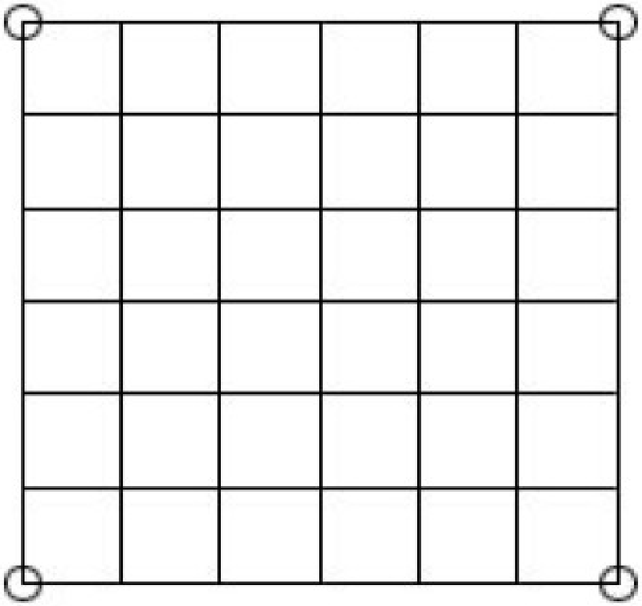
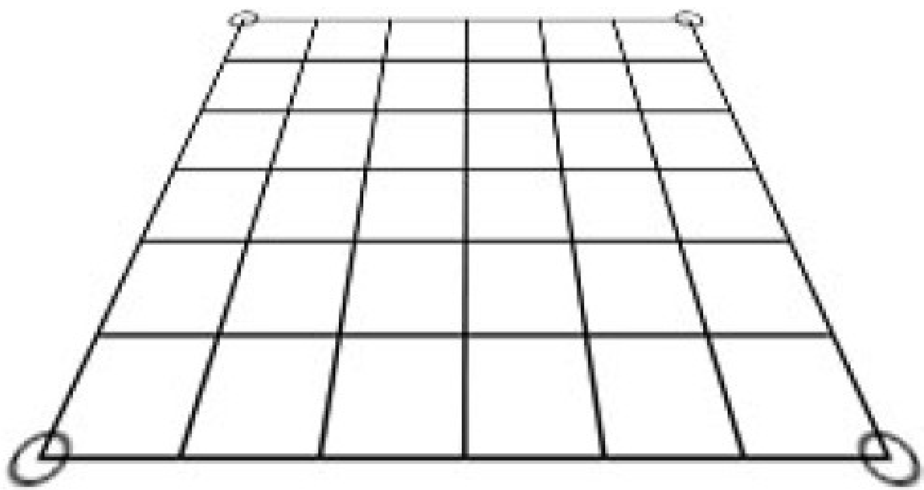


Image (central projection)
in negative position
c = camera constant
Perspective
centre
H = flying height
Image in
positive position
Object
(terrain)
Orthogonal projection
to a horisontal plane

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.

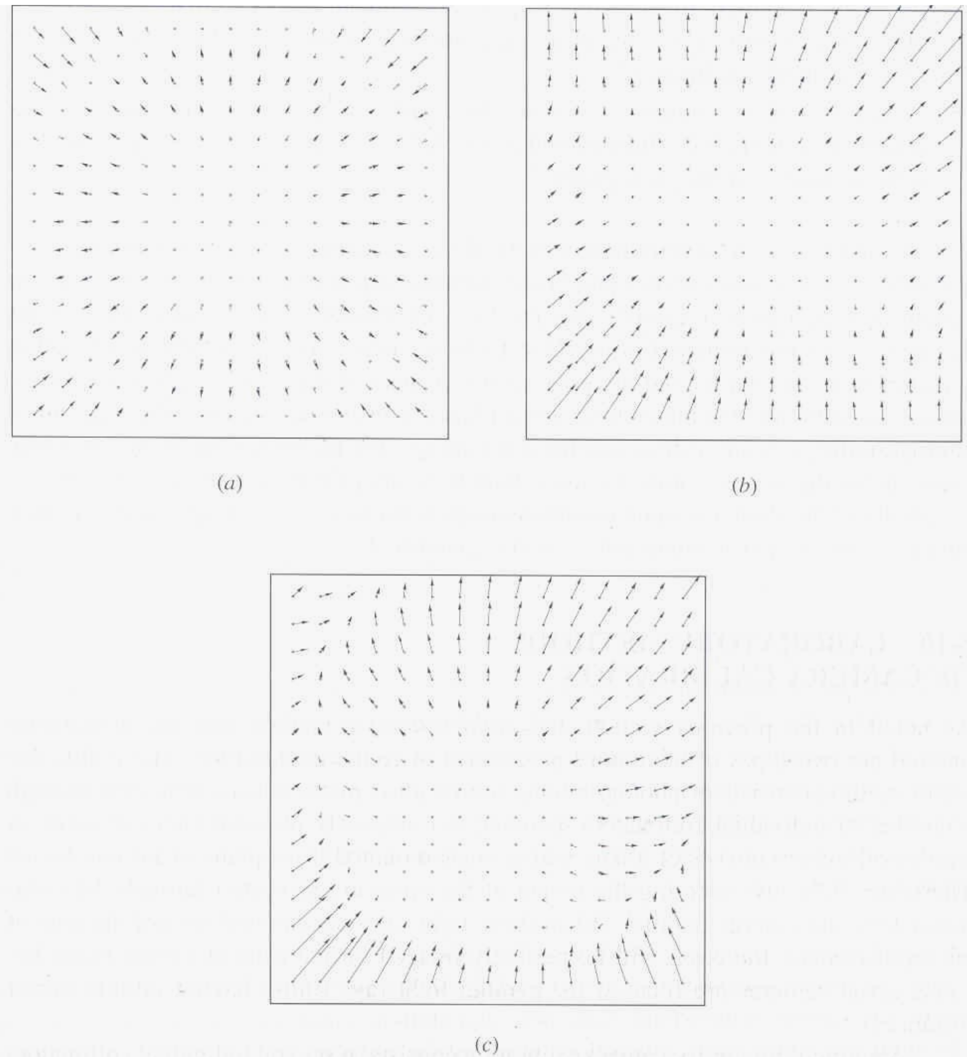
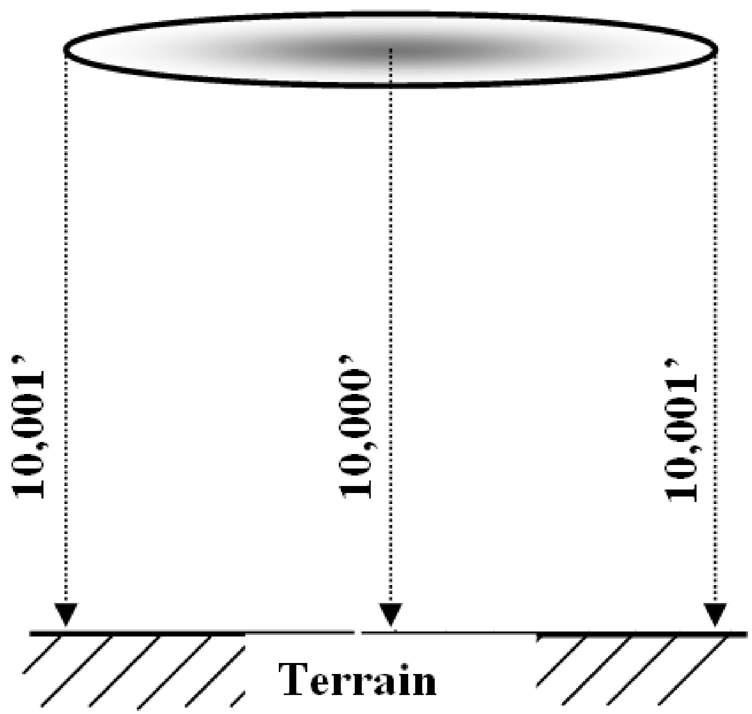
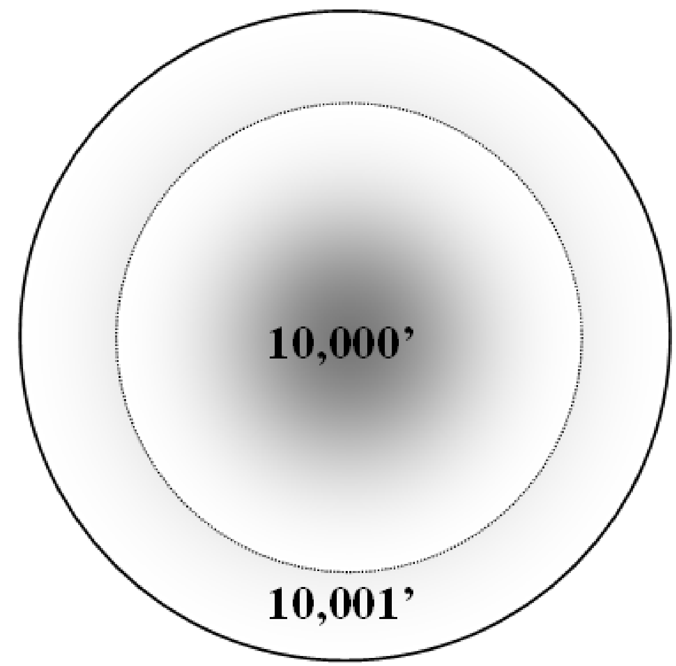


FIGURE 3-12
Lens distortion patterns: (*a*) symmetric radial, (*b*) decentering, and (*c*) combined symmetric radial and decentering.

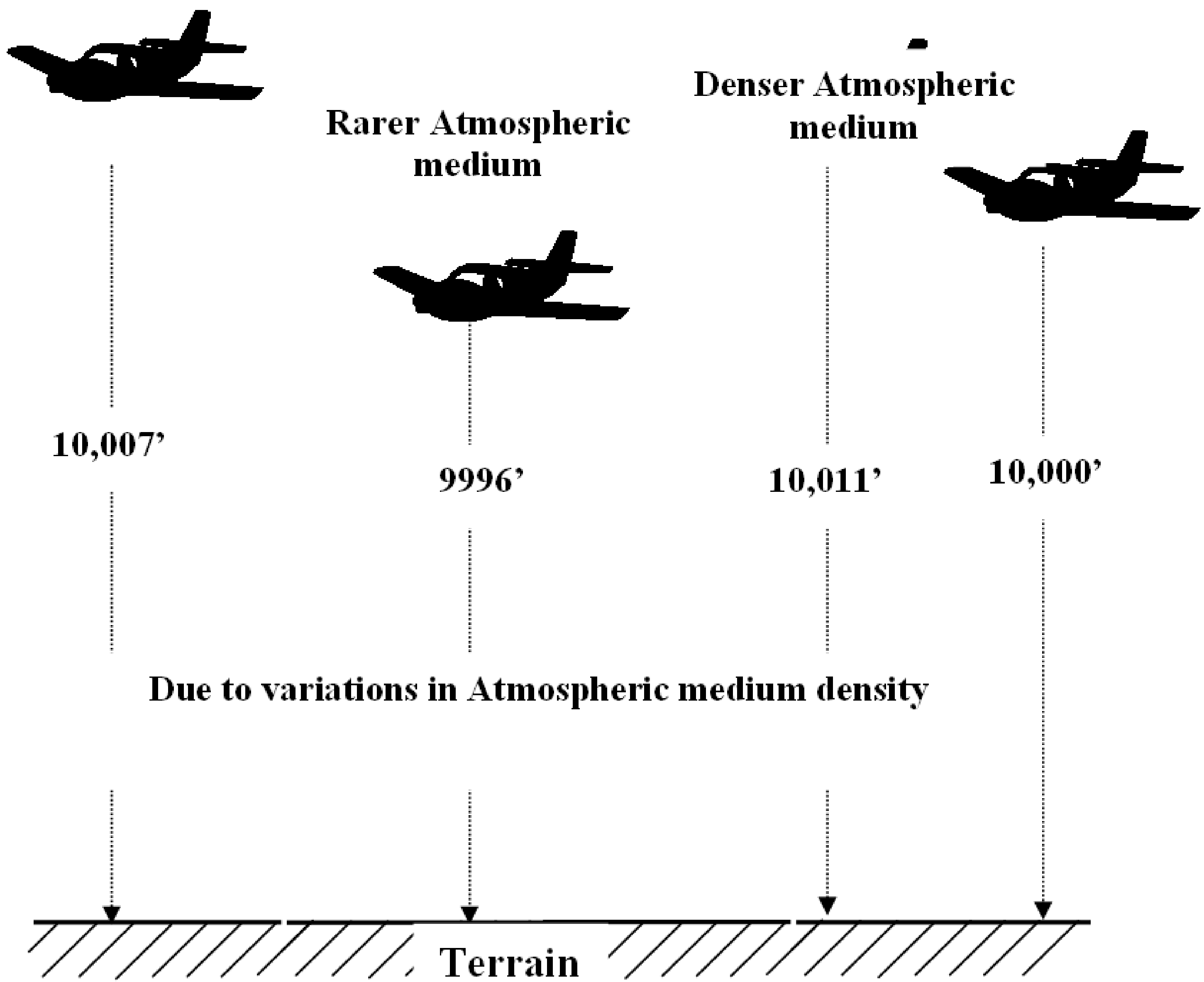
Vertical Cross Section View of Biconvex Lens



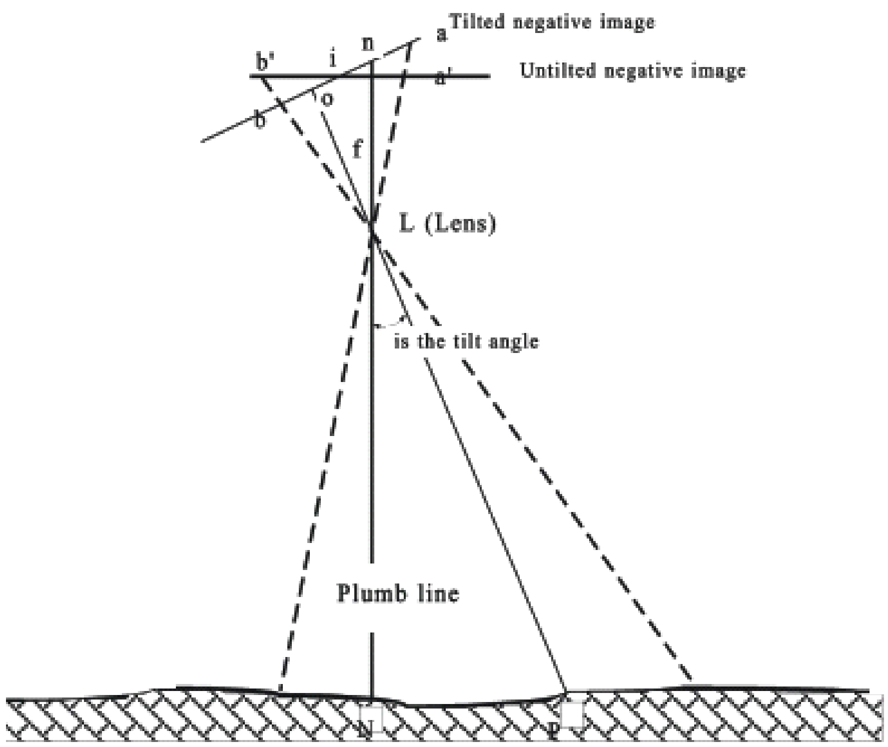
Top view



distortions due to sudden change in Flying height



Scale displacement due to Tilt in the Aircraft



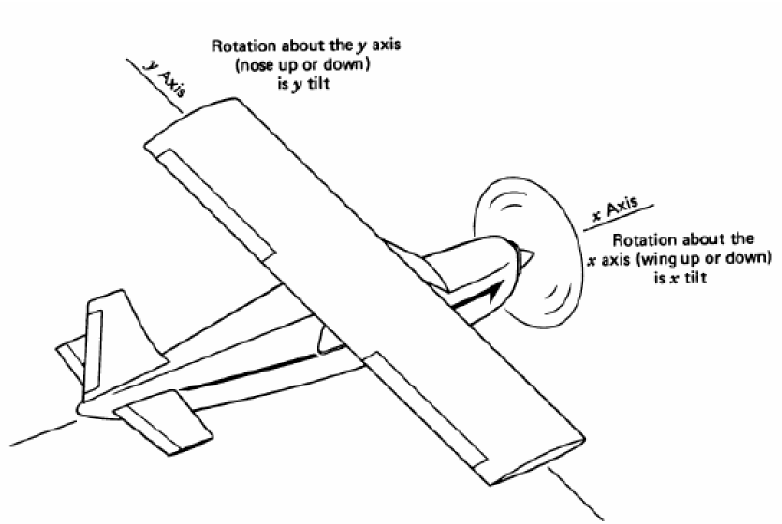
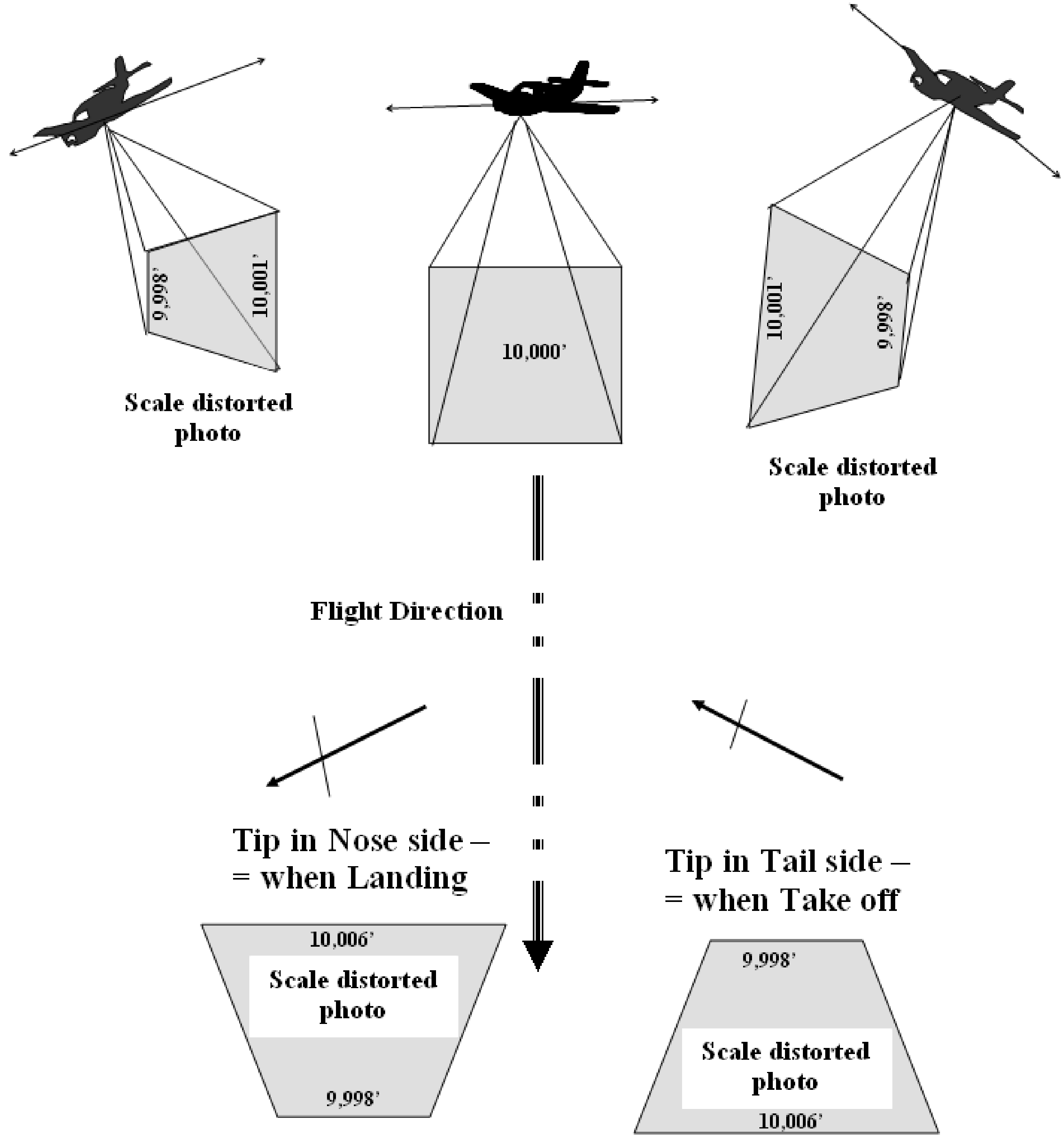


Figure 2.9. x and y tilt caused by the attitude of the aircraft (actually the camera) at the instant of exposure.

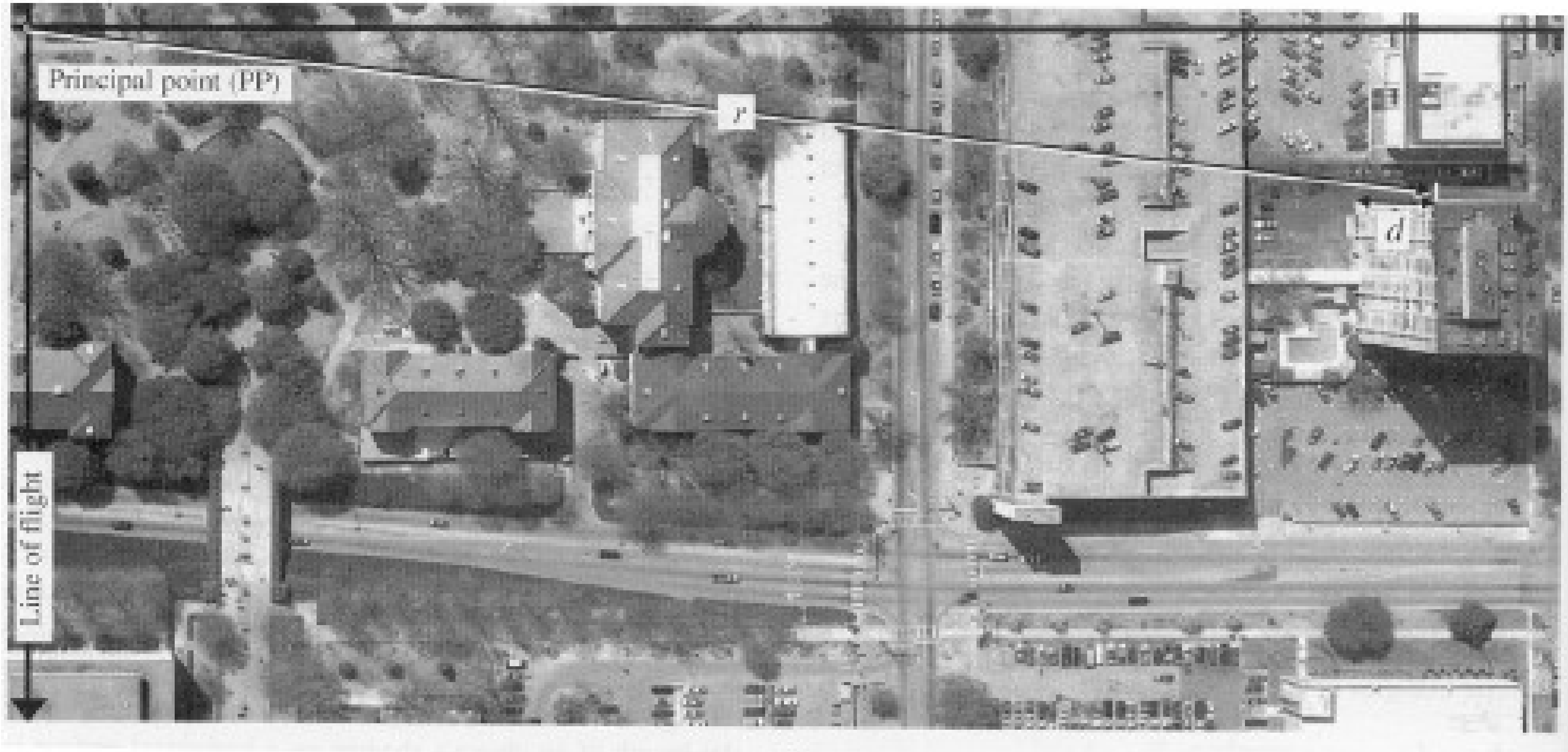
Displacement due to tilt is caused by the aircraft or other airborne platform not being perfectly horizontal at the moment of exposure. Rotation of the camera about the y axis (nose up or down) is y tilt and rotation about the x axis (wing up or down) is x tilt

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
Tip in Tail side – = when Take off
10,006'
Scale distorted photo
9,998'
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.

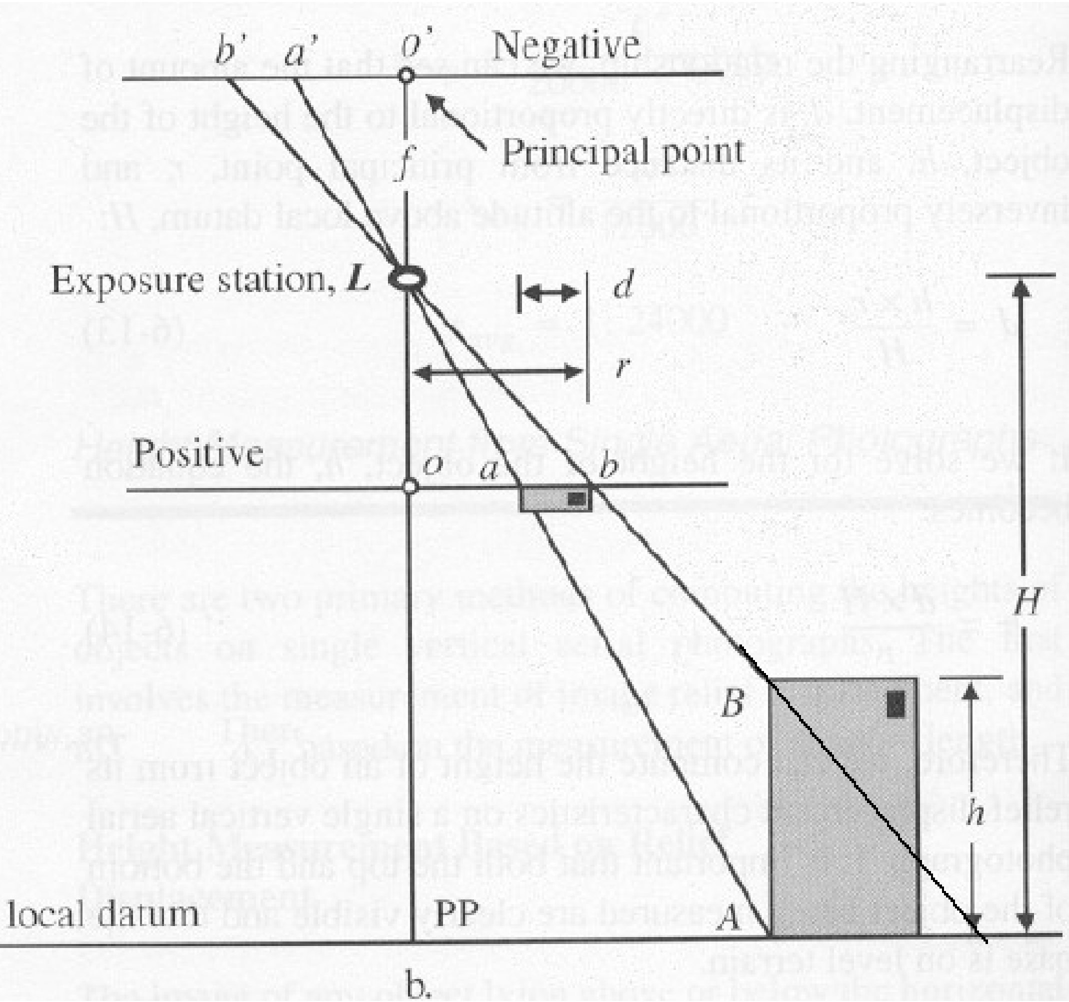
Relief Displacement

- 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

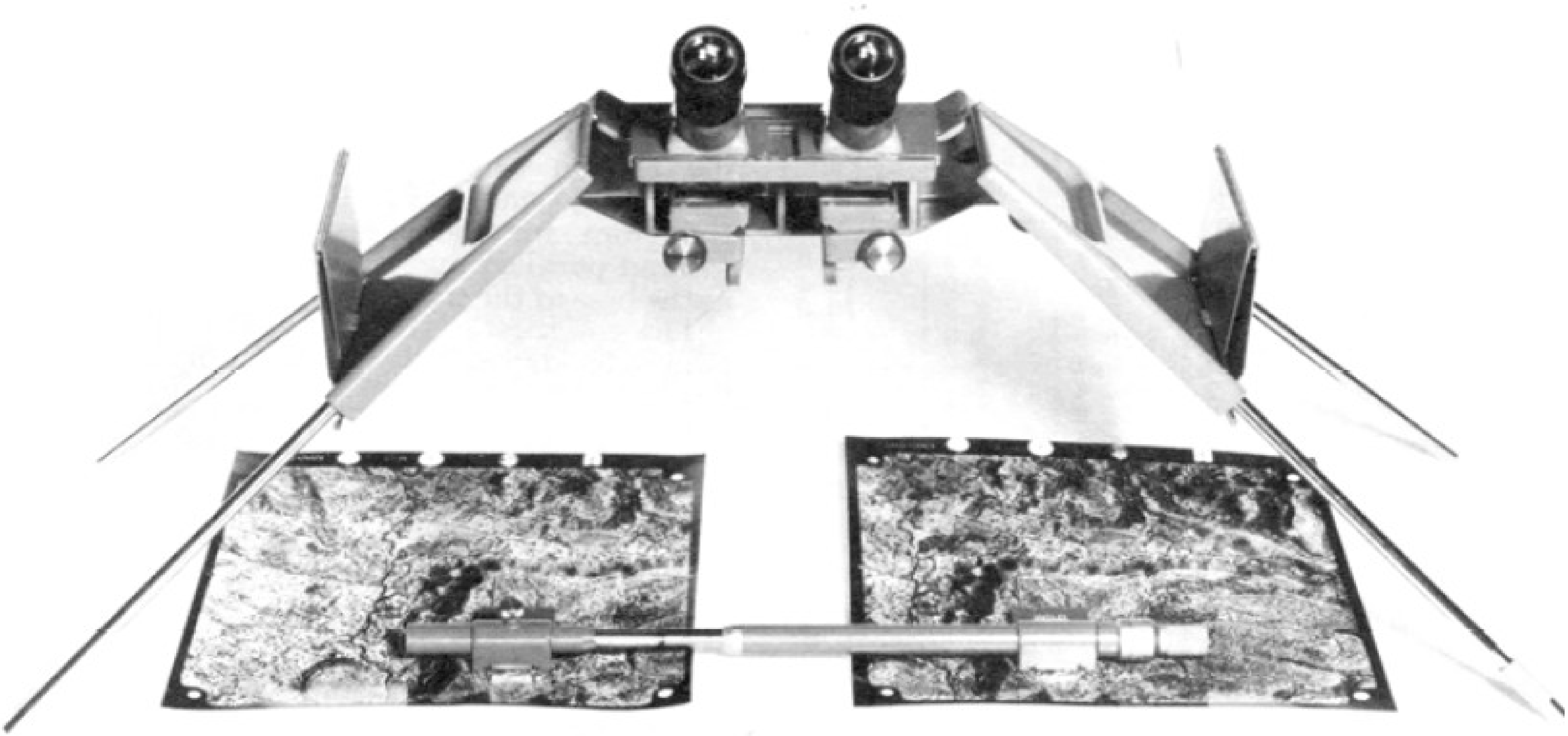
$H = 535 - 259$

d = 54.1mm, 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

Principles of Stereoscopy



STEREO MODELS

In our daily activities, we unconsciously measure depth or judge distances to vast number of objects about us through our normal process of vision

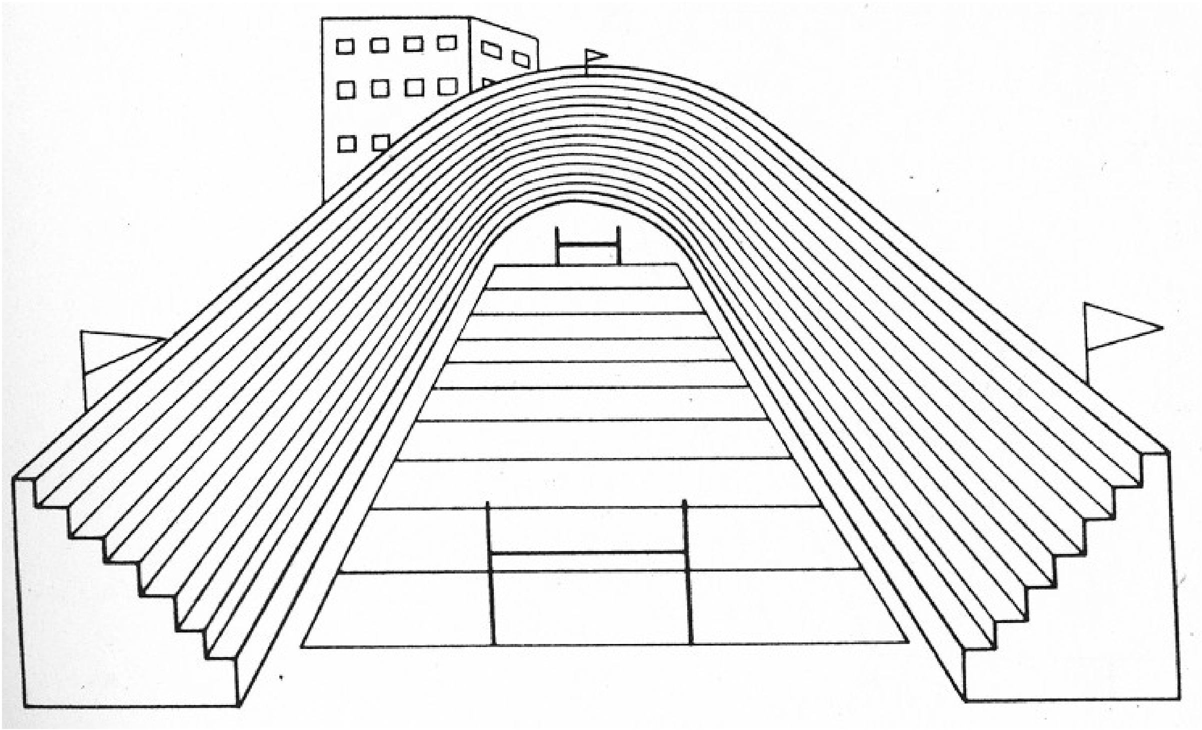
Methods of judging depth may be classified as either **stereoscopic or monoscopic**.

Persons with normal vision (those capable of viewing with both eyes simultaneously) are said to have binocular vision and perception of depth through binocular vision is called **stereoscopic viewing**. Studying the aerial photographs with aid of stereoscope

Monocular vision is the term applied to viewing with one eye and methods of judging distances with one eye are termed **monoscopic.** Studying the aerial photographs with out aid of stereoscope

Distances to objects, or depth can be perceived monoscopically on the basis of

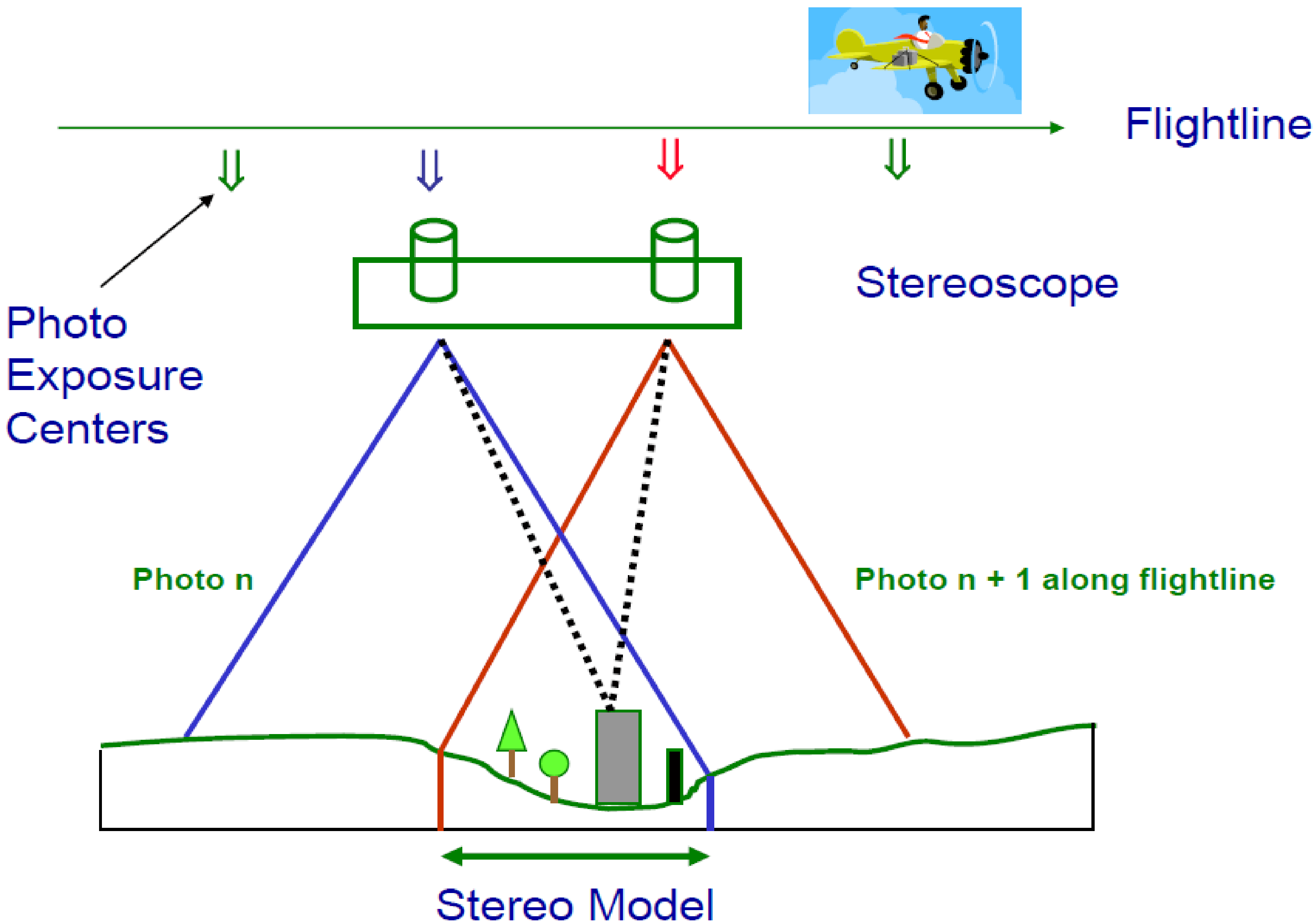
1) Relative sizes of objects, 2) Hidden objects, 3) Shadows and 4) Differences in focusing of the eye for viewing objects at varying distances.



Monoscopic methods of depth perception - Enable only rough impressions to be gained of distances to objects.

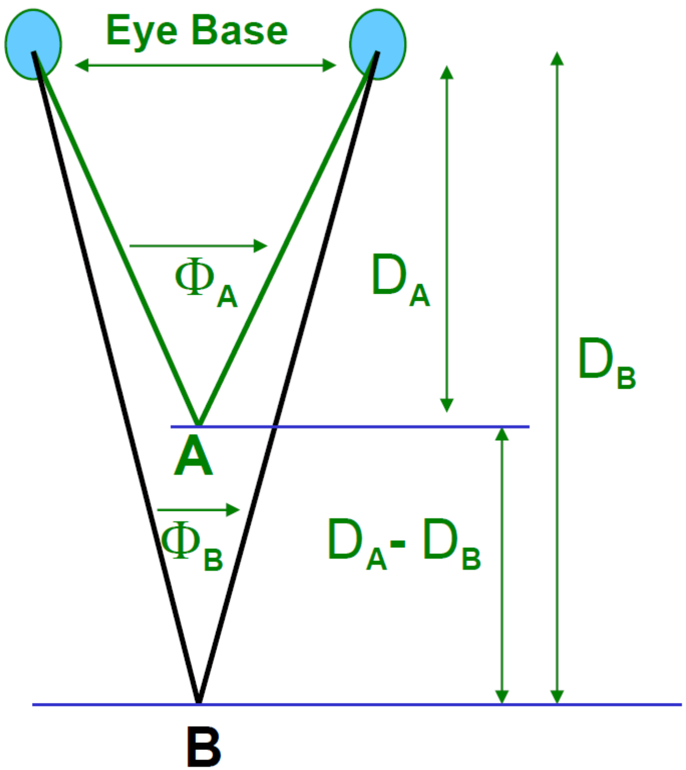
Much greater degree of accuracy in depth perception can be achieved by – stereoscopic vision.

Formation of Stereoscopic Model



STEREOSCOPIC DEPTH PERCEPTION

With binocular vision, when the eyes fixate on a certain point, the optical axes of the two eyes converge on that point, intersecting at an angle called the parallactic angle. The nearer the object, the greater the parallactic angle and the object with long distance having the low parallactic angle.



Φ = Parallactic Angle

The optical axes of the two eyes L and R are separated by a distance b_e called the eye base. For the average adult, the distance is between 63 and 69 mm or approximately 2.6 in.

When the eyes fixate on point A, the optical axes converge, forming parallactic angle ϕ_a. Similarly, when sighting an object at B, the optical axes converge, forming parallactic angle ϕ_b.

The brain automatically and unconsciously associates distances D_A and D_B with corresponding parallactic angles ϕ_a and ϕ_b. The Depth between objects A and B is D_B - D_A and is perceived from the difference in these parallactic angles.

The ability of human beings to detect changes in parallactic angles and thus judge differences in depth is quite remarkable. Although it varies some what among individuals. The photographic procedures for determining heights of objects and terrain variations based on depth perception by comparisons of parallactic angles can be highly precise.

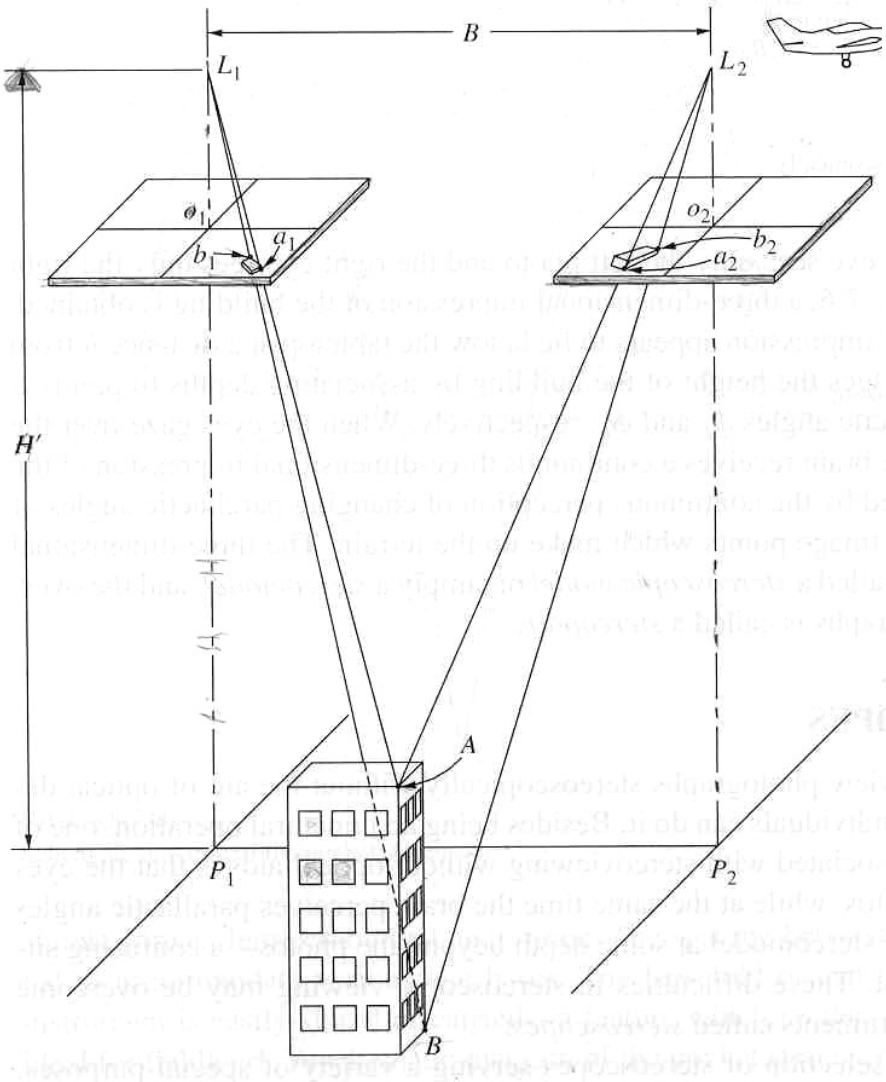


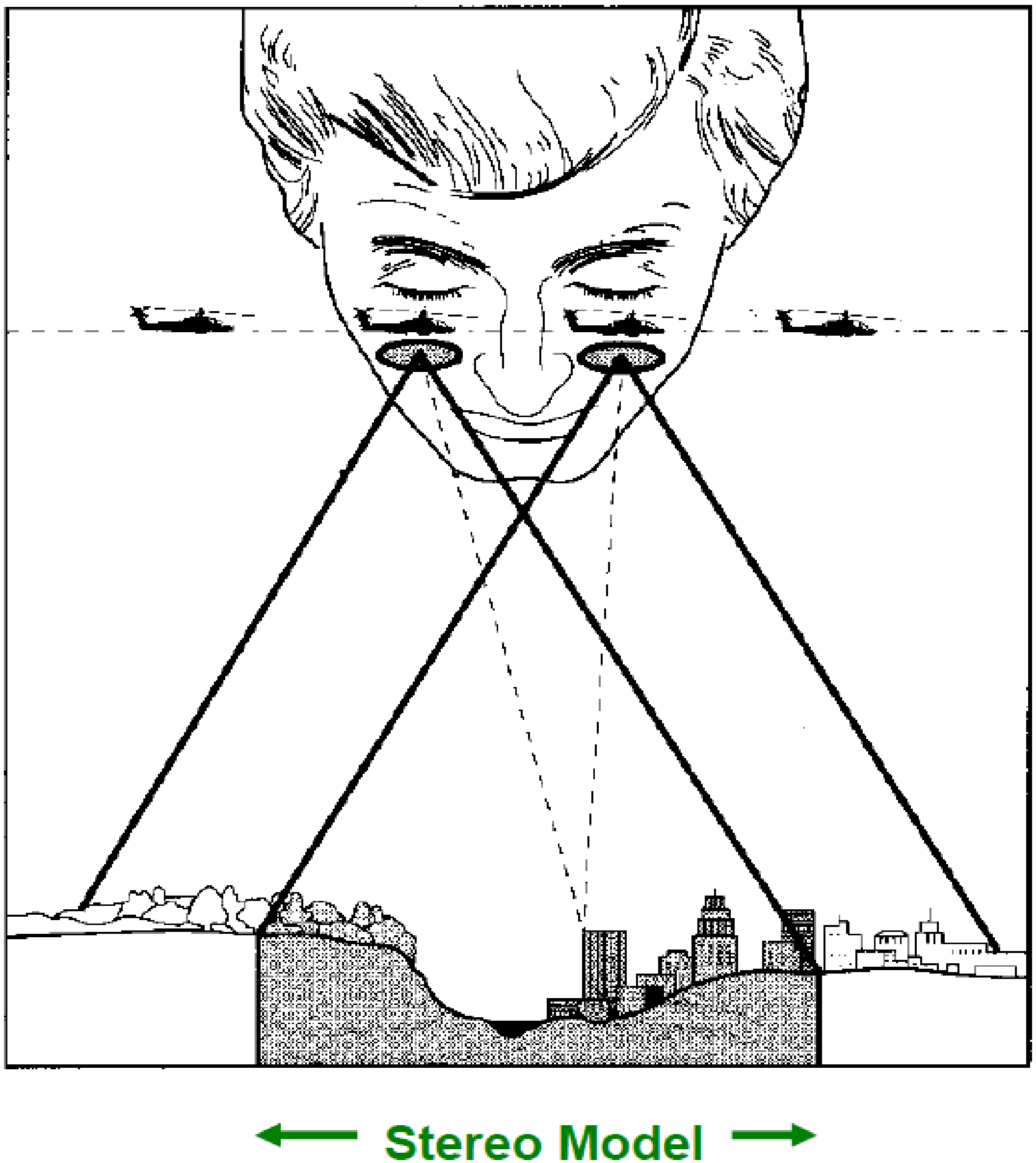
FIGURE 7-5
Photographs from two exposure stations with building in common overlap area.

A pair of aerial photographs is taken from exposure station L_1 and L_2 so that the building appears on both photos.
Flying height above ground is H' and the distance between the two exposures is B, the air base.
Object point A and B at the top and bottom of the building are imaged at a_1 and b_1 on the left photo and at a_2 and b_2 on the right photo.

If these two photos are laid on a table and viewed so that the left eye sees only left photo and the right eye sees only the right photo so that three dimensional impression of the building is obtained

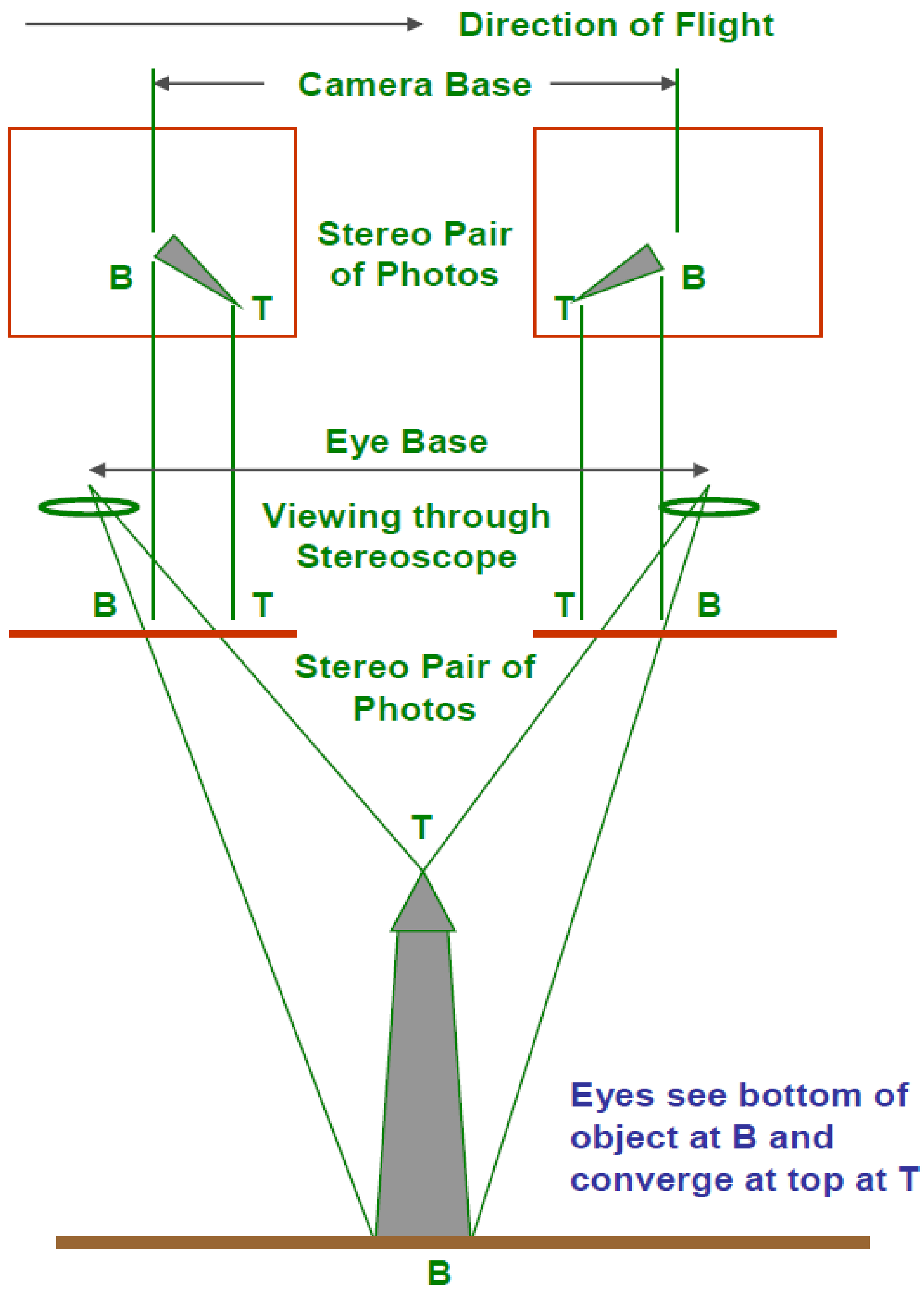
The brain judges the height of the building by associating depths to points A and B with the parallactic angles ϕ_a and ϕ_b respectively.
When the eyes gaze over the area entire overlap area, the brain receives a continuous three dimensional impression of the terrain. The three dimensional model thus formed is called a stereoscopic model or simply **stereomodel** and the overlapping pair of photograph is called a **stereopair**

The "giant" eyebase of stereo photography



After Jensen, 2004

Principles of Stereo Viewing



Base Height Ratio – Vertical Exaggeration

Under the normal conditions, the vertical scale of a stereomodel will appear to be greater than the horizontal scale i.e an object in the stereomodel will appear to be toll. This apparent scale disparity is called vertical exaggeration.

The vertical exaggeration is caused primarily by the lack of equivalence of the photographic base-height ratio, B/H' and the corresponding stereo viewing base-height ratio, b_e /h.

The term B/H' is the ratio of the air base (distance between the two exposure stations) to flying height above average ground.

b_e /h is the ratio of the eye base (distance between the two eyes) to the distance from the eyes at which the stereomodel is perceived.

For topographic mapping and other precise quantitative photogrammetric measurements, photography preferably taken with a wide or super wide angle (short focal length) camera so that a large base – height ratio (B/H') is observed

The larger the b/h' ratio, the greater the intersection angles or parallactic angles.

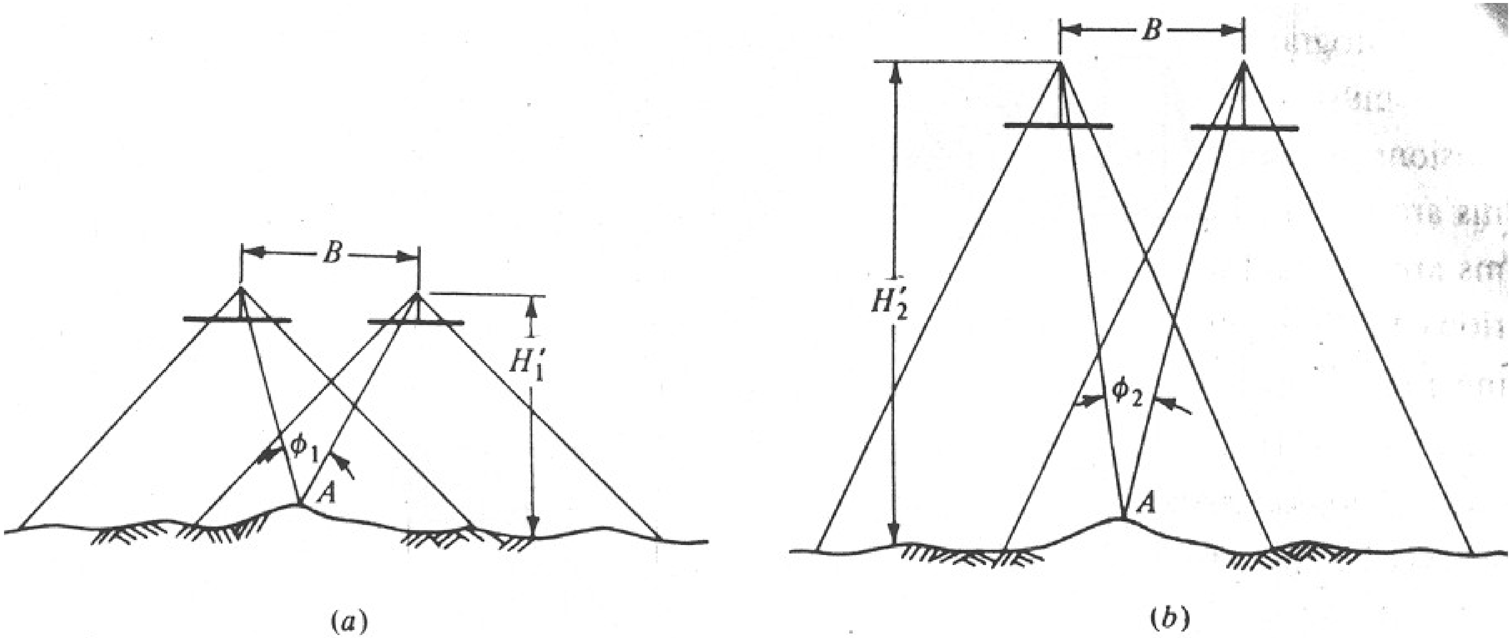


FIGURE 10-6
Parallactic angles increase with increasing B/H' ratios.

The air bases are equal in these two cases. But the focal length and flying height are half those of right side figure
Decreased b/h' ratio can be attained by increasing flying height and now by using a longer focal length camera to compensate the scale reduction, this can be done.

Aerial photographs with Decreased b/h' ratio is more desirable for

- Mosaic construction because
- Scale variations
- Image distortions / displacement due to
- Relief, tilt and flying height variations
- Are much less.

VERTICAL EXAGGERATION IN STEREOVIEWING

The condition of increased vertical scale of the photo object than its normal height is known as vertical exaggeration.

- **Scale disparity**
- **Vertical scale is greater than the horizontal scale**

Although other factors are involved, Vertical Exaggeration is caused primarily by the lack of equivalence of the B/H' ratio in obtaining the photography and the corresponding (be / h) ratio in stereoviewing.

- **Ratio of the air base to flying height above the ground (B/H')**
- **b_e /h – is the ratio of the eye base to the distance from the eyes at which the stereomodel is perceived.**

The product of the B/H' ratio and the inverse of the be/h ratio gives an approximation of vertical exaggeration, or

$$V = \frac{B}{H'} * \frac{h}{be}$$

STEREOSCOPIC PARALLAX

Apparent shift in the position of an object, with respect to a frame of reference, caused by a shift in the position of observation

Change in position of an image from one photo to the next is caused by aircraft's motion

- **Called stereoscopic parallax, x parallax, or simply parallax**

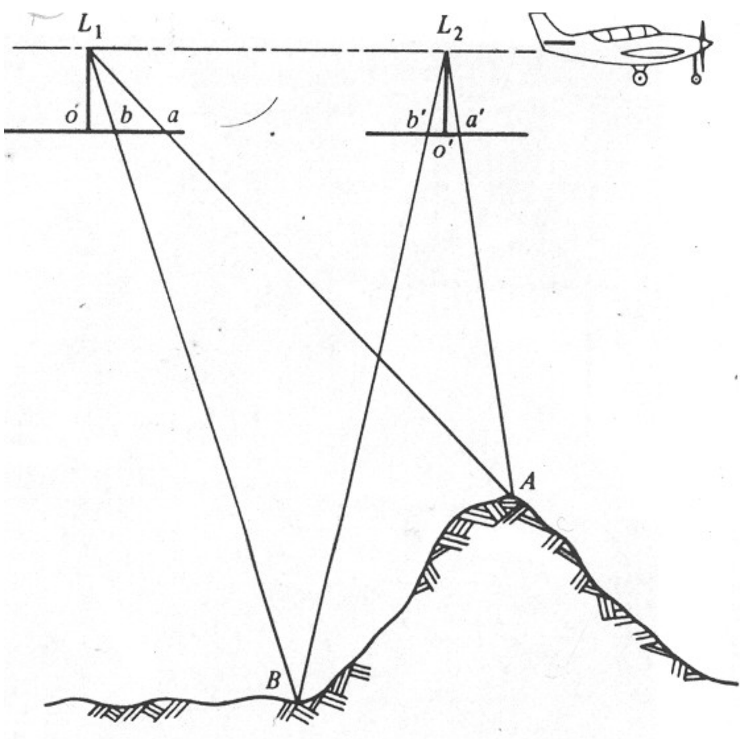
Two important aspects of stereoscopic parallax

- **Parallax of any point is directly related to the elevation of the point**
- **Parallax is greater for high points than for low points**

Images of object point A and B appear on a pair of overlapping vertical photographs which were taken from exposure station L_1 and L_2.

Point A and B are imaged at a and b on the left hand photograph. Because of forward motion of the air craft between exposure, these points appear at a' and b'.

Because Point A is higher than B, in other words the parallax of point A is higher than point B.



This lead to two important aspects of stereoscopic parallax such as

1. The parallax of any point is directly related to the elevation of the point

2. Parallax is greater for high points than low points

Variation of parallax with elevation provides the fundamental basis for determining elevations of points from photographic measurements.

Also, X,Y and Z ground coordinates can be calculated for points based upon their parallaxes

Parallaxes of object points A and B are pa and pb respectively. Stereoscopic parallaxes for any point such as A expressed in terms of flight line photographic coordinates is

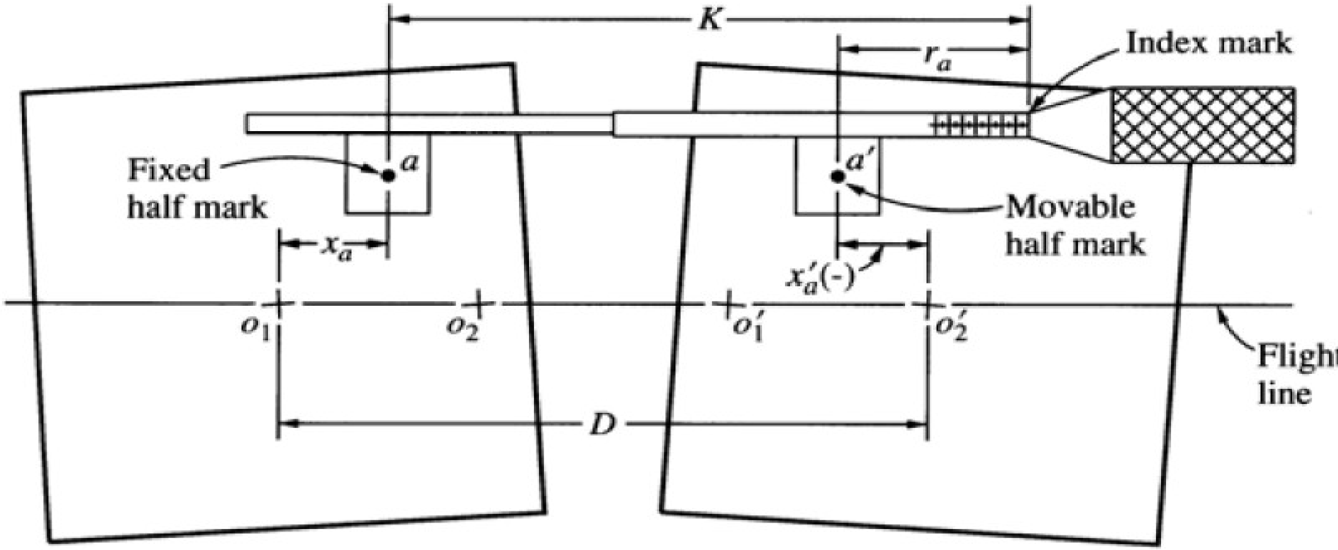
$$p_a = x_a - x'_a$$

pa is the stereoscopic parallax of object point A, xa is the measured photo coordinate of image a on the left photograph of the stereopair and x'a is the photo coordinate of image a' on the right photo.

Stereoscopic Methods of Parallax Measurement

Through the principal of the floating mark, parallaxes of points may be measured stereoscopically. This method employs a stereoscope in conjunction with an instrument called a **parallax bar** also called as **stereometer**.

A parallax bar consist of a metal rod to which are fastened two half marks. The right half mark may be moved with respect to the left mark by turning micrometer screw. Reading from the micrometer are taken with the floating mark set exactly on points whose parallaxes are desired. From the micrometer reading, parallaxes or differences in parallaxes are obtained.



When a parallax bar is used, the two photos of a stereopair are carefully oriented, flight line of each photo lies precisely along a common straight line as line AA'. The left half mark called the fixed mark is unclamped and the right half mark or moveable mark may be moved left or right with respect to the fixed mark (increasing or decreasing parallax) as required to accommodate high points or low points with out exceeding the run of the parallax bar graduation.

After the photos have been oriented and the left half mark is fixed in position as just described, the parallax bar constant C for the setup is determined

The spacing between principal points is a constant (D). Once fixed mark is clamped, the distance from the fixed mark to the index mark of the parallax bar is also a constant (K)

The parallax of point A is

$p_a = x_a – x'_a = D – (K - r_a) = (D – K) + r_a$

The term (D – K) is C, the parallax bar constant for the setup. Also r_a is the micrometer reading. By substituting C into the above equation

$p_a = C + r_a$

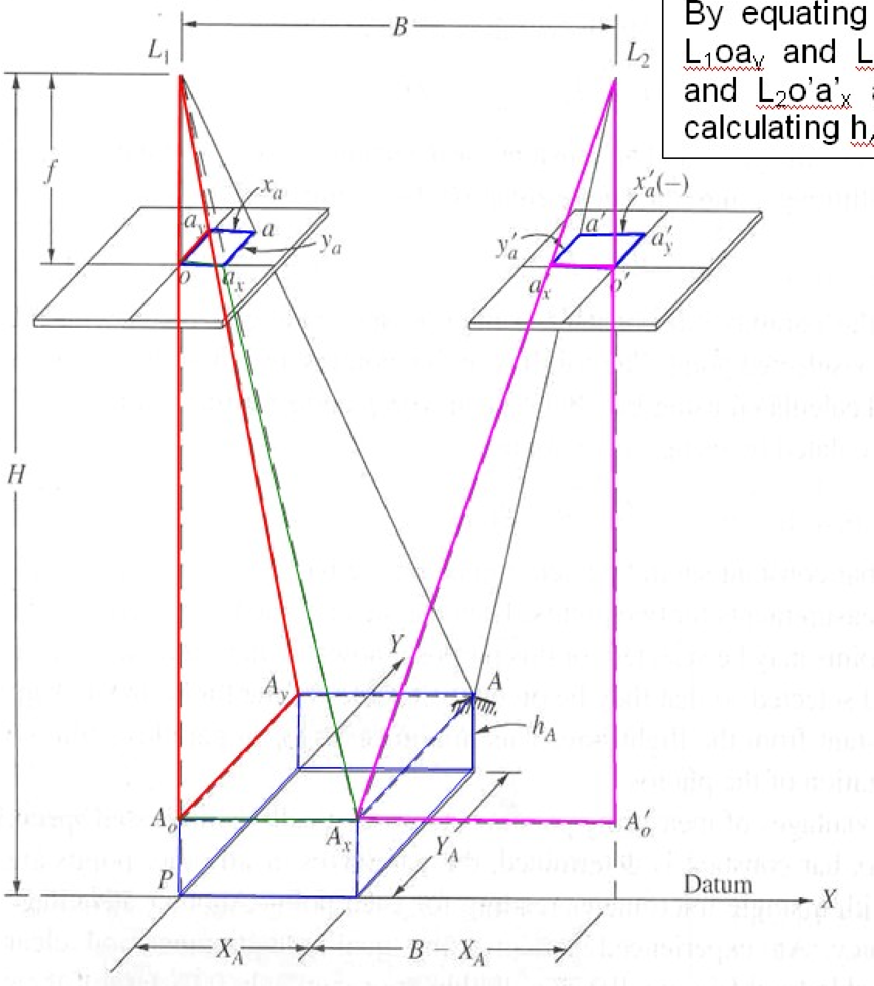
If p and r is known, the value can be calculated by

C = p + r

The parallax bar constant should be determined on the basis of micrometer readings and parallax measurements for two points.

Parallax Equation

X,Y and Z ground coordinates can be calculated for points based upon the measurements of their parallaxes. An overlapping pair of vertical photographs which have been exposed at equal flying heights above datum



By equating similar triangles such as L_1oa_y and $L_1A_0A_y$, L_1oa_x and $L_1A_0A_x$, and $L_2o'a'_x$ and $L_2A'_0A_x$, formulas for calculating h_A, X_A and Y_A

$$h_A = H - \frac{Bf}{p_a}$$

$$X_A = B\frac{x_a}{p_a}$$

$$Y_A = B\frac{y_a}{p_a}$$

hA is the elevation of point A above datum, H is the flying height above datum, B is the air base, f is the focal length of the camera. pa is the parallax of point A, XA and YA are the ground coordinates of point A, xa and yb are the photo coordinates of point 'a' measured with respect to flight line axes on the left photo.

These equations are called **parallax equations**.

Approximate Equation for Height of Objects from Parallax Differences

In many applications it is necessary to estimate heights of objects to a moderate level of accuracy

By modifying the above equation, we can calculate the approximate height of the object

$$\boxed{h_A = \frac{\Delta p H}{b + \Delta p}} \quad \text{or} \quad \boxed{h_A \approx \frac{\Delta p H}{b}}$$

h_A: Height of the point A above ground

Δp: = pa – pc is the difference in parallax between the top of the feature and the ground

H : is the flying height above ground

b: is the photo base for the stereopair

PHOTO MOSAICS

Mosaics:

An assemblage of two or more individual overlapping photographs to form a single continuous picture of an area.

Photographic reproduction of a whole series of aerial photographs assembled in such a manner that the detail of one photograph matches the detail of all adjacent photographs at a much smaller scale.

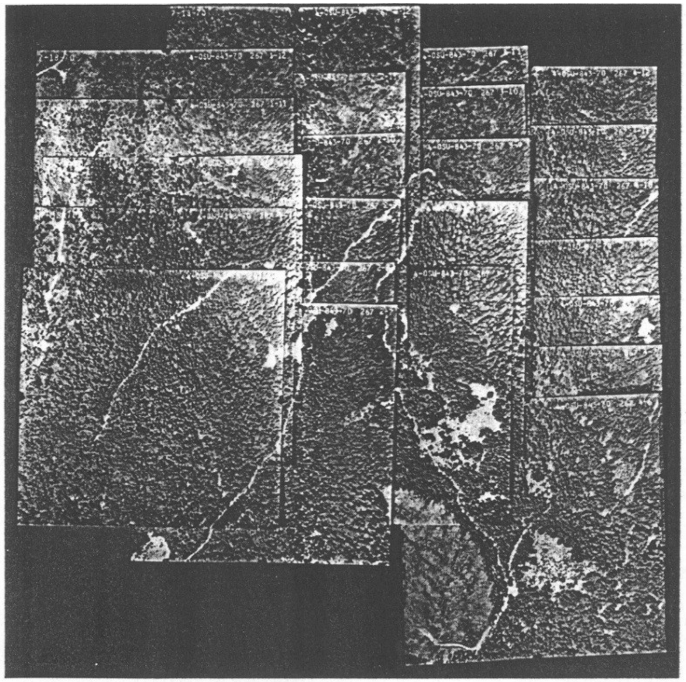
Uses of Mosaics:

- ➔ Useful in the field of planning – landuse / engineering
- ➔ Geological and natural resource inventory
- ➔ Many more interpretations and mapping them
- ➔ Shows areas completely and comprehensively
- ➔ Prepared rapidly and economically
- ➔ Alternate plans can be conveniently investigated
- ➔ Useful for detailed study and best overall plan can be finally adopted.
- ➔ Used as planimetric map substitutes for many engineering projects
- ➔ Eliminates most of the ground surveying and plotting
- ➔ Design drawings and construction specifications are superimposed directly over the mosaic as overlay
- ➔ Time and cost saving and
- ➔ Higher accuracy.

Types of Mosaics:

i. Index or photo index
ii. Strip
iii. Controlled
iv. Semi controlled
v. Uncontrolled
vi. Temporary and
vii. Orthophoto mosaic.

1. Photo indexing or index mosaics



Uncontrolled mosaic which has been laid to very rough specifications. Prepared immediately after the flight for the purpose of providing an index to individual photographs for correlating photo numbers and photo coverages.

The primary use

- for indexing
- for photo retrieval from the files
- to know the ground coverage and
- to check for any gaps or missed areas for any necessary reflights
- Least expensive type of mosaic – uncontrolled and
- Not permanently mounted on a backing.

2. Strip Mosaic:

A strip mosaic is the assembly of a series of photographs along a single flight strip. Useful in planning and designing linear engineering projects like, Rail roads, pipelines, etc.

May be controlled, uncontrolled or semicontrolled.

3. Controlled Mosaic

A compilation of rectified photographs, so assembled that their principal points and other selected intermediate points are located in their true horizontal positions.

Rectification – the process of projecting a tilted or oblique photo on to a horizontal plane.

This projection may be of graphic or by photography in a special camera called rectifier or rectifying camera.

Each photograph is oriented in position by matching the photographic images of selected control points to the corresponding plotted position of the pre-established points

The rectified photo will have

- **➔horizontality or free from tilt**
- **➔better uniformity of scale**
- **➔uniformity in tones and contrasts of the print.**

4.0 Uncontrolled mosaic

Prepared by simply matching the image details of adjacent photos.

- ➔ There is no ground control and
- ➔ Vertical photos which have not been rectified or ratioed are used.
- ➔ They are not as accurate as controlled mosaics
- ➔ But for quaitative uses they are completely satisfactory.
- ➔ Usually, the central portion of each photograph is taken which is relatively free from relief and tilt displacements, and scale distortions.
- ➔ The photos are laid out in strips in straight lines.
- ➔ Then the different strip mosaics are matched together to compile a mosaic for the entire area.

5.0 Semicontrolled mosaic:

Assembled utilizing some combination of the specifications for controlled and uncontrolled mosaics.

- ➔ **By using ground control but using**
- ➔ **Photographs that have not been rectified or ratioed (or)**
- ➔ **Use rectified and ratioed photos but no ground control**
- ➔ **These mosaics are a compromise between economy and accuracy.**

6.0 Temporary Mosaic:

Whenever the conditions do not permit to prepare a controlled or uncontrolled mosaic and a large area needs to be viewed within a short time, then a very temporary mosaic may be prepared.

- Save the photo from trimming and
- The same photos can be used for stereoscopic viewing for photo interpretation after this purpose
- Alternate photos in a strip are taken
- Their borders only are trimmed
- Used without rectification or ratioing
- Strips are laid in a soft board
- Multiple strips are assembled and pinned on the board and used.

7. Orthophoto Mosaic:

An assembly of two or more orthophotos to form a continuous picture of the terrain. Ortho photos are derived from vertical aerial photographs using a differential rectification instrument.

- **Have had no image displacements due to relief and tilt – they are removed**
- **So that they show features in their true planimetric positions**
- **Distances, angles and areas can therefore be measured directly**
- **They have the pictorial advantages of aerial mosaics and the geometric correctness of maps.**
- **They can usually be prepared more rapidly and economically than line and symbol maps.**