BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024
Tamil Nadu, India

Programme : **M.Tech., Remote Sensing and GIS**

Course Title : **PHOTOGRAMMETRY**
Course Code : **24MTRS-02**

UNIT I : Basics of Aerial photography and Photogrammetry:

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UNIT I : Basics of Aerial photography and Photogrammetry:

History and definition - geometry of aerial photographs, principal point, conjugate principal point, nadir point, iso-centre, fiducial marks, overlap and side lap - Types of Photographs, Classification – Photogrammetric Films - Use of Filters - Photographic Resolution - Radiometric Characters of Aerial Photographs - Types based on - Camera Axis, Altitude, Film, Lens and angle of Coverage - Parts of Simple Camera - Aerial Cameras - Camera Calibration - Lens System - Distortions and Aberrations - Spectral Sensitivity of Aerial Cameras.

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.

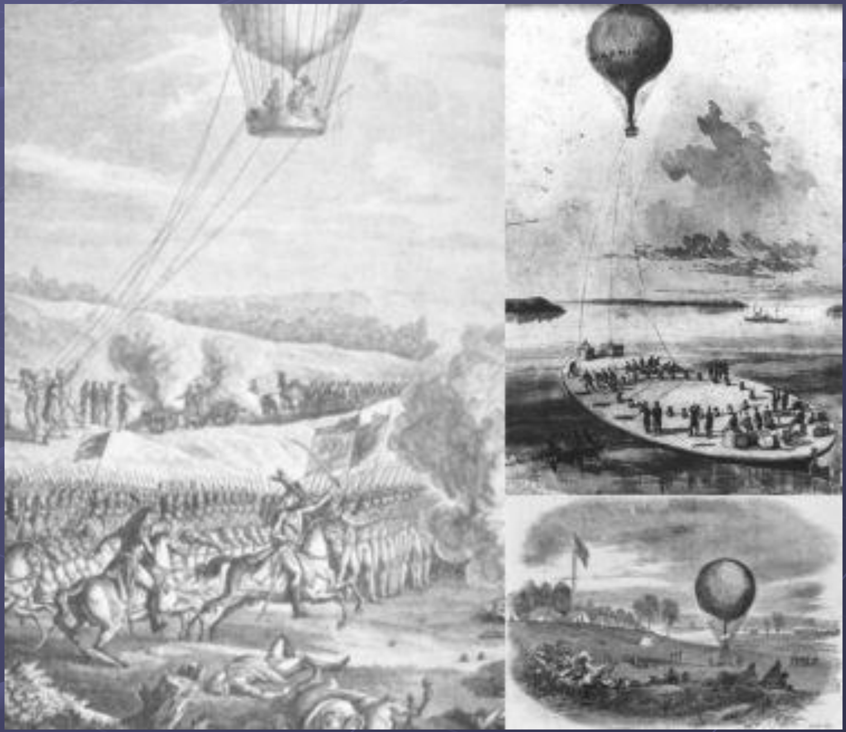
Photographic interpretation is an art of examining these photographic images for the purpose of identifying objects and judging their significance

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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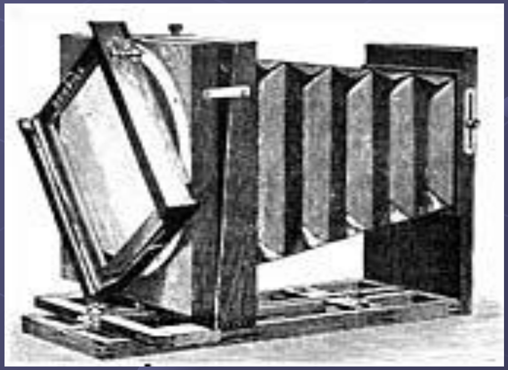
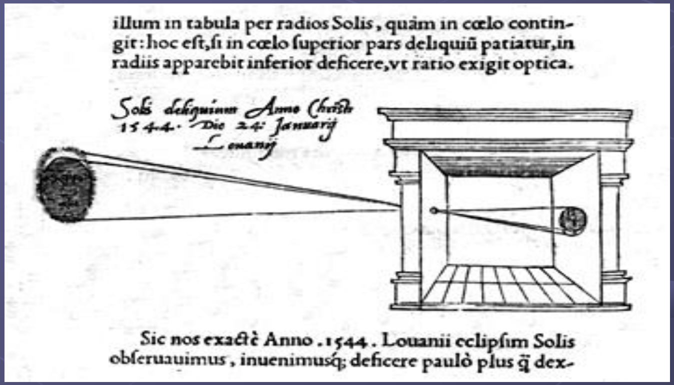
Some Important Dates in the Chronological History of Remote Sensing

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).



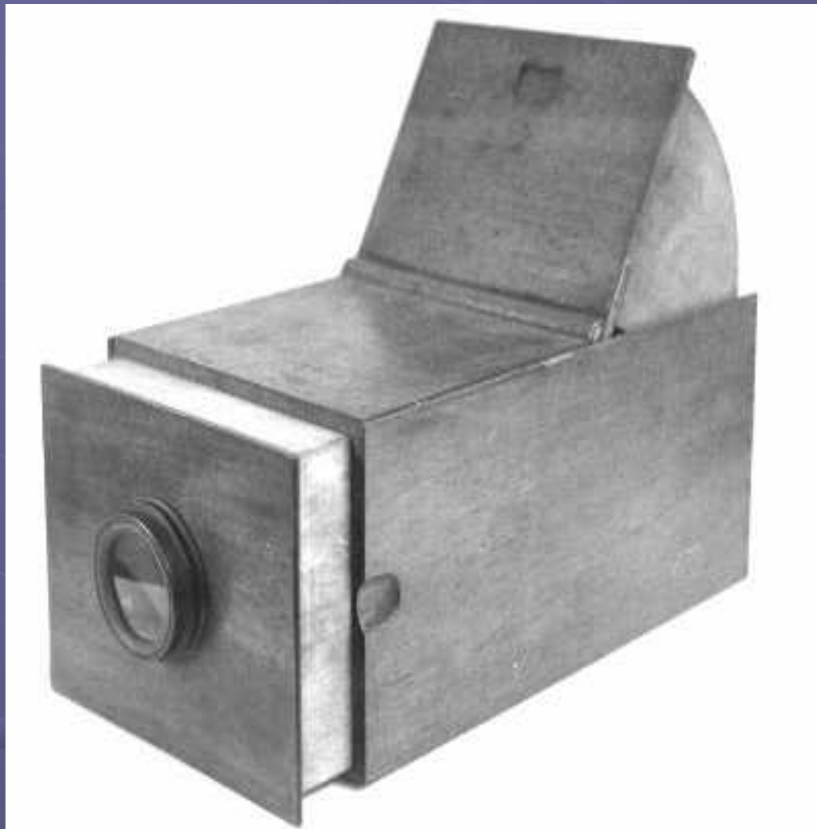
- 1038 AD - Al Hazen an Arabian mathematician explained the principle of the camera obscura to observe sun eclipse.

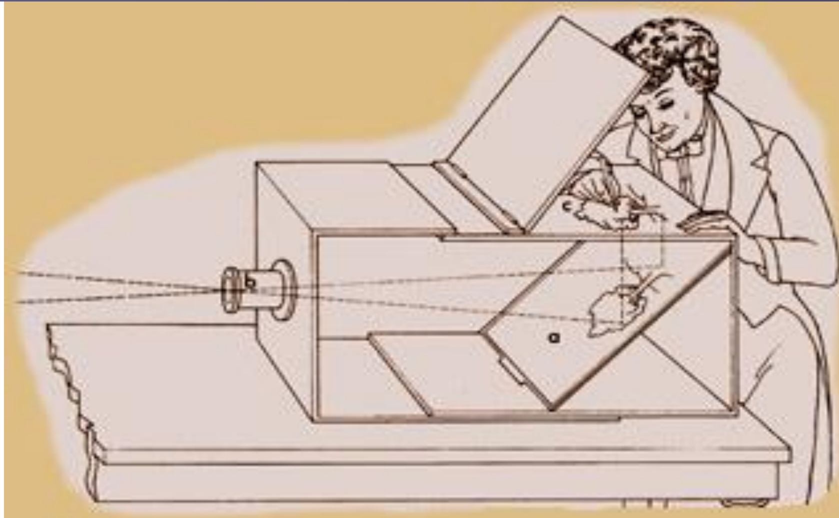


illum in tabula per radios Solis, quàm in cœlo contingit: hoc est, si in cœlo superior pars deliquiũ patiatur, in radiis apparebit inferior deficere, vt ratio exigit optica.

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

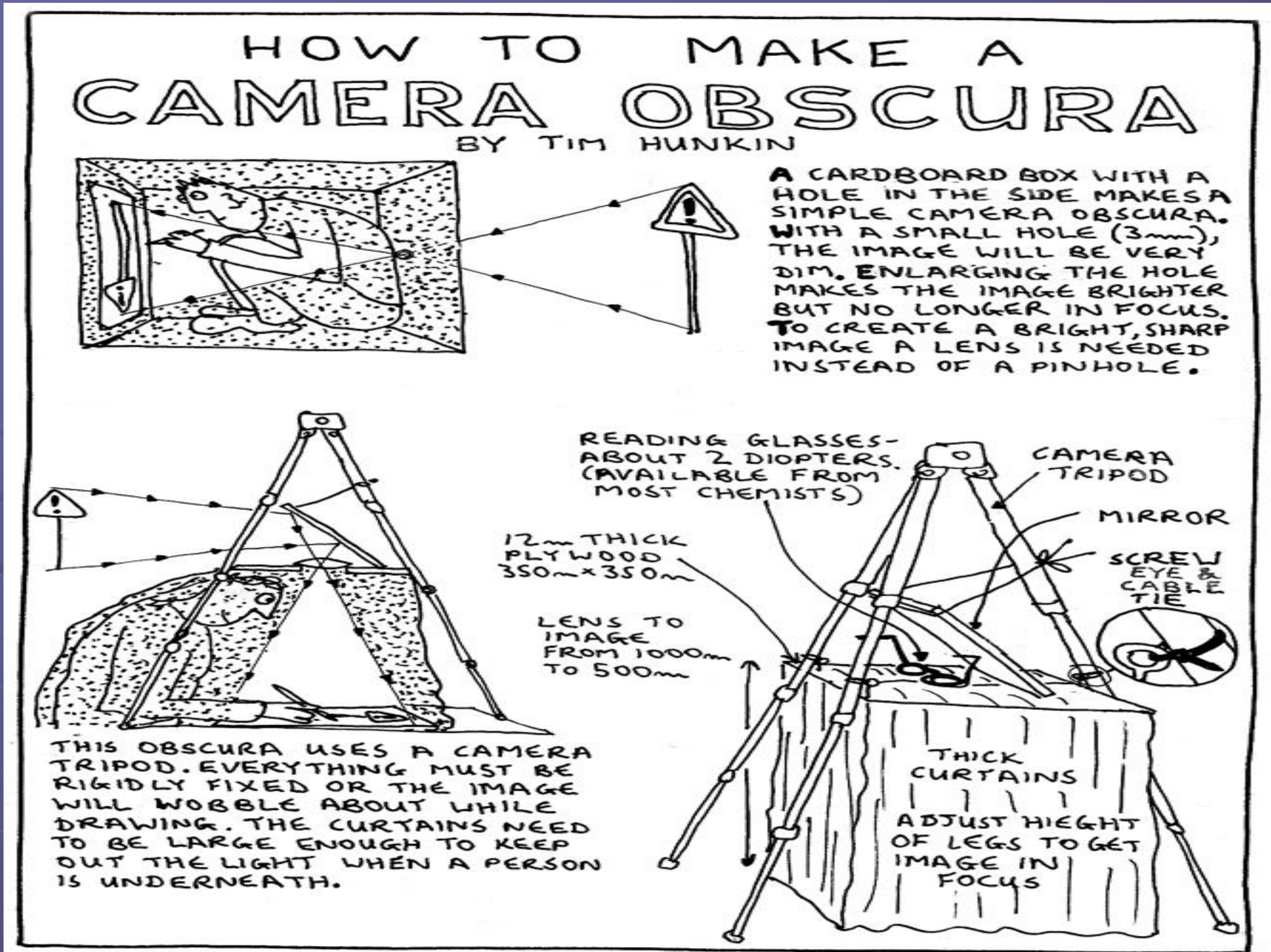
Camera Obscura





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.
READING GLASSES - ABOUT 2 DIOPTERS. (AVAILABLE FROM MOST CHEMISTS)
CAMERA TRIPOD
MIRROR
SCREW EYE & CABLE TIE
12mm THICK PLYWOOD 350mm x 350mm
LENS TO IMAGE FROM 1000mm TO 500mm
THICK CURTAINS
ADJUST HIEGHT OF LEGS TO GET IMAGE IN FOCUS
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

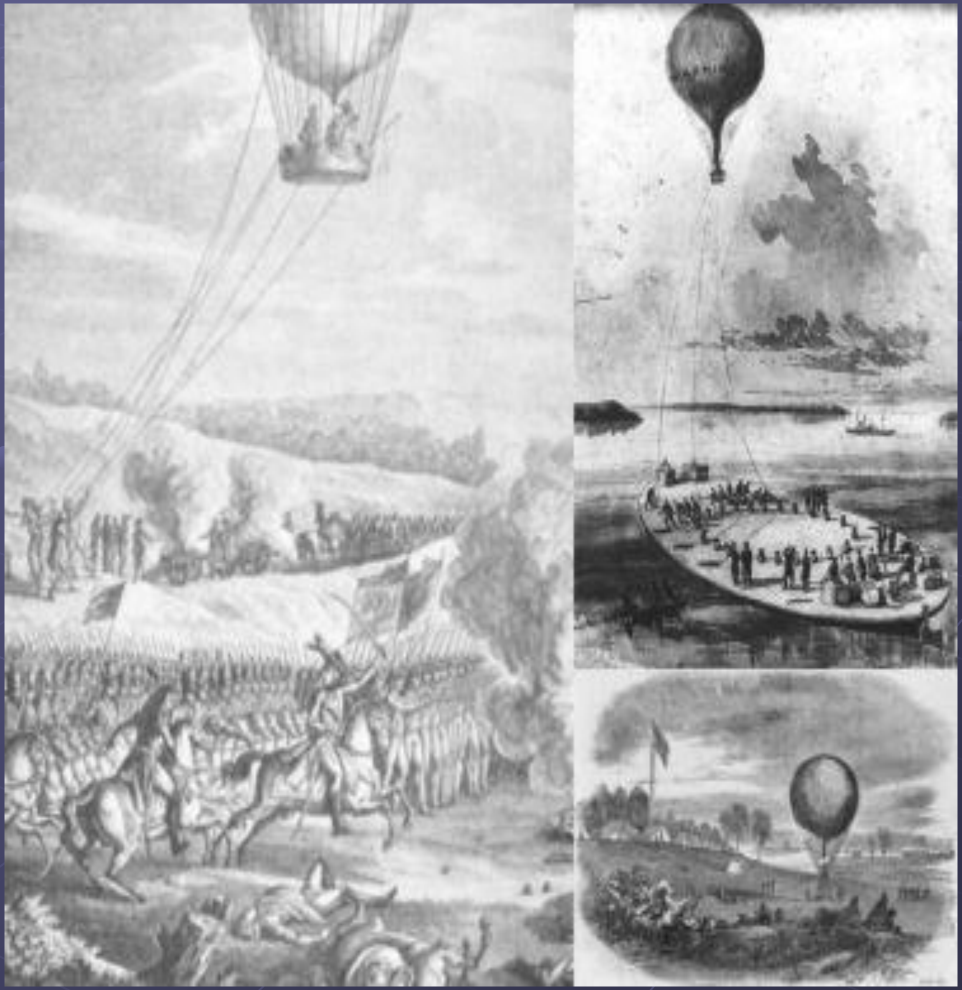
- The pictures used in the stereo views where in the form of "stereographs" which were two pictures of the same scene that were slightly offset and mounted side-by-side.

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.

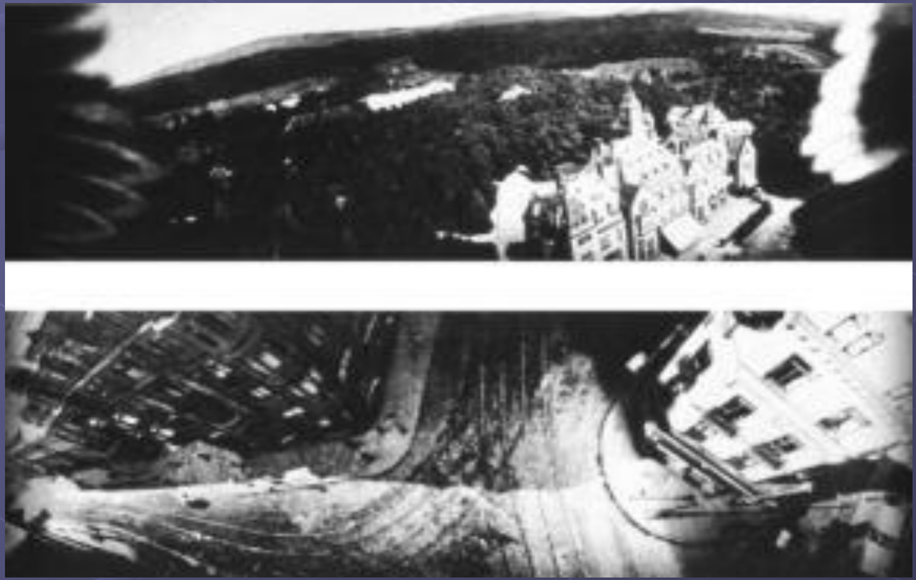
- 1860's - Aerial observations, and possible photography, for military purposes were acquired from balloons in the Civil War. Balloons were used to map forest in 1862, but not used to acquire aerial photographs as far as scholars can tell



- 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.

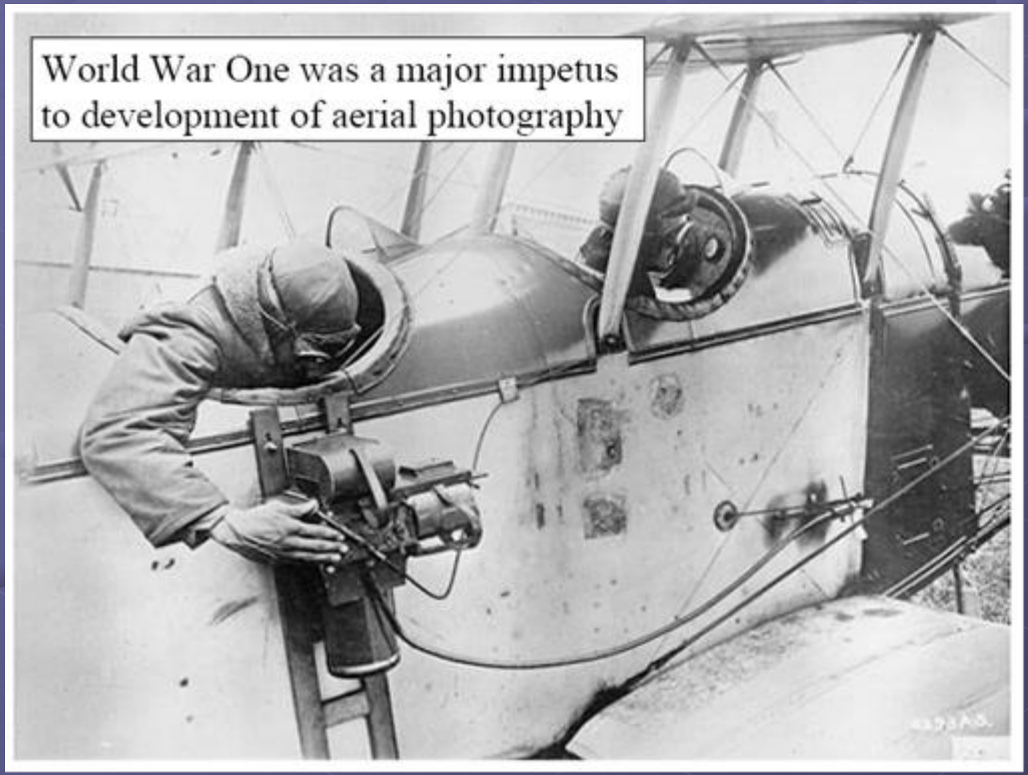
- 1899 - George Eastman produced a nitro-cellulose based film type that retained the clarity of the glass plates which were in use at the time and introduced the first Kodak camera.
- 1900 - Max Planck's revelation of 'quanta' and the mathematical description of the 'black body' lays the foundation for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

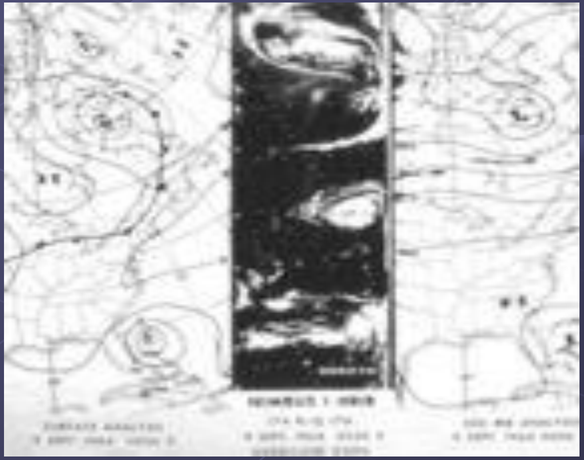
1946 - First space photographs from V-2 rockets.

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.

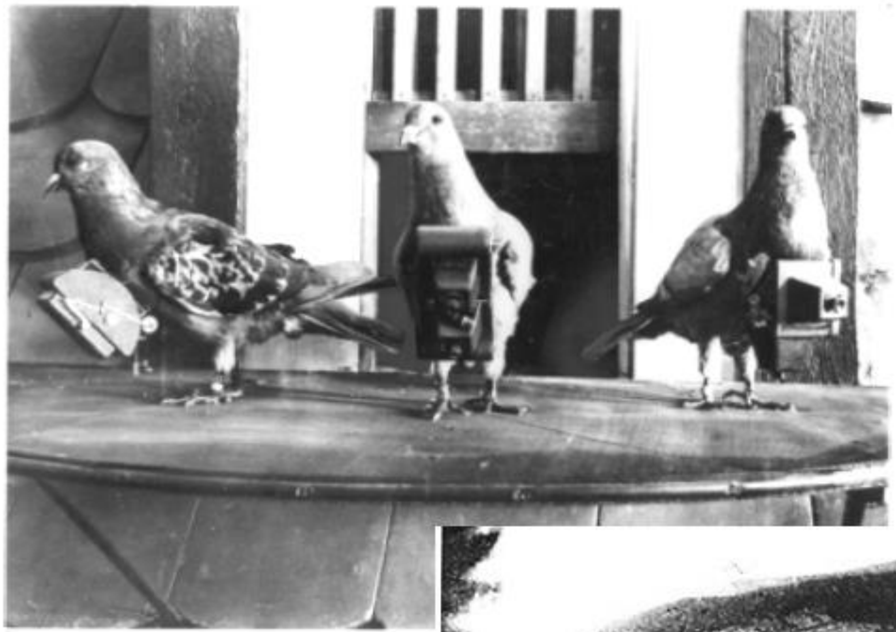
Google earth

2007 – Expected launch of RapidEye...

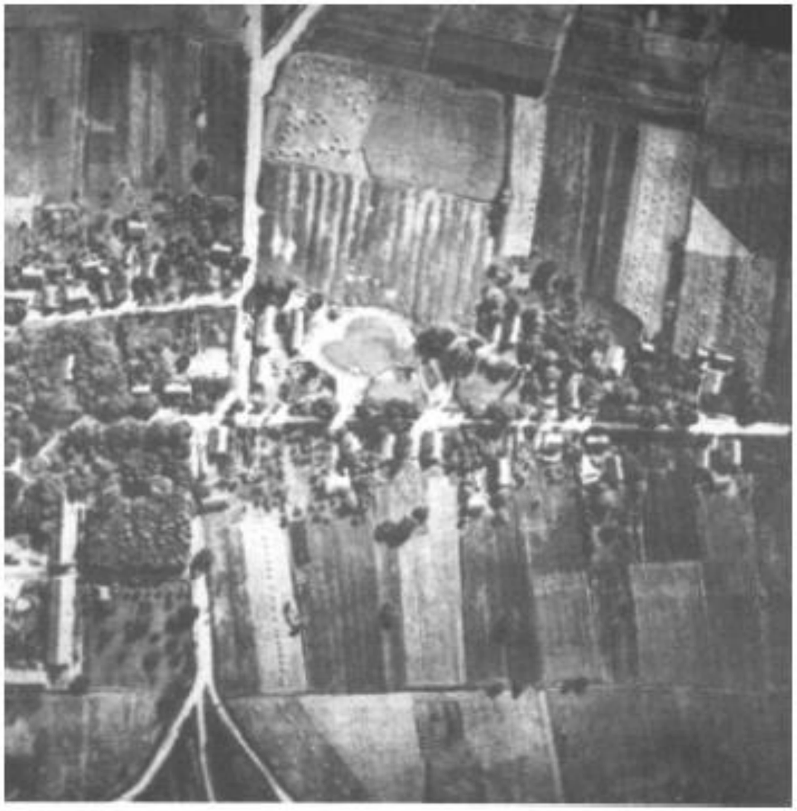
Aerial Platforms for Cameras

- ➔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.

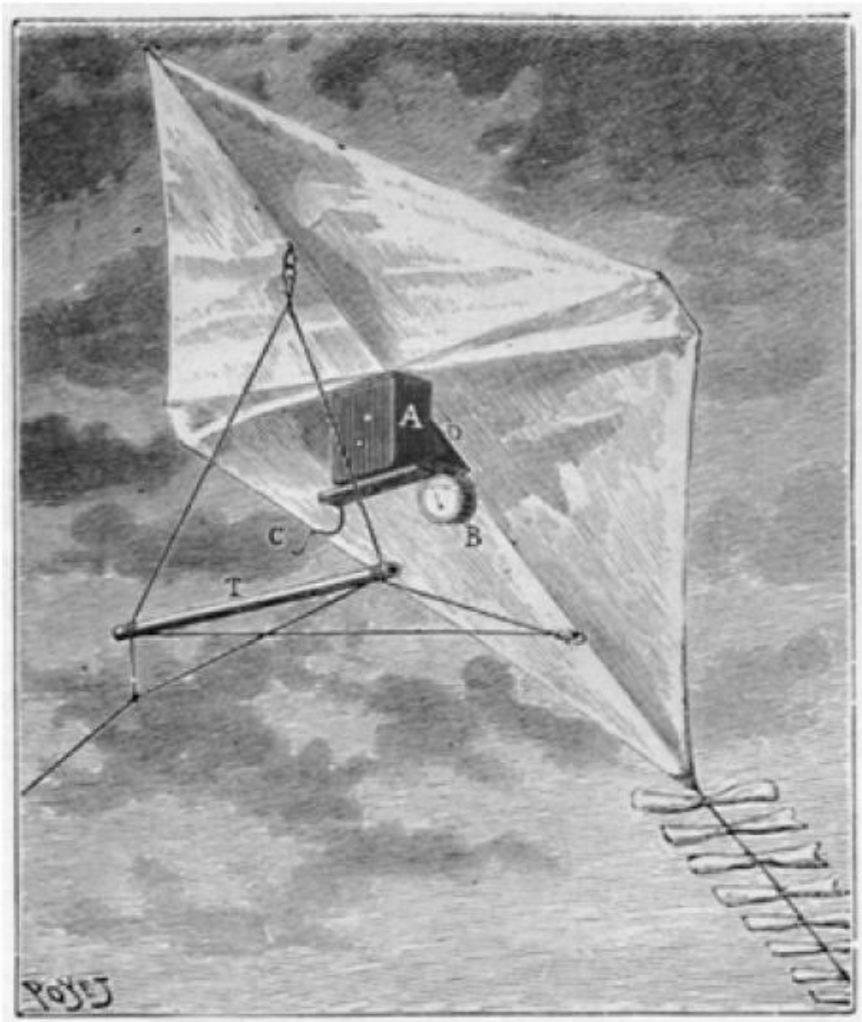


Balloons used to map forest in 1860th not aerial photo though. Pictures taken from greater heights, 33,000-34,000 feet, from free balloons.



Kites

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



http://latteier.com/pigeoncam/

Paris by Nadar, circa 1859

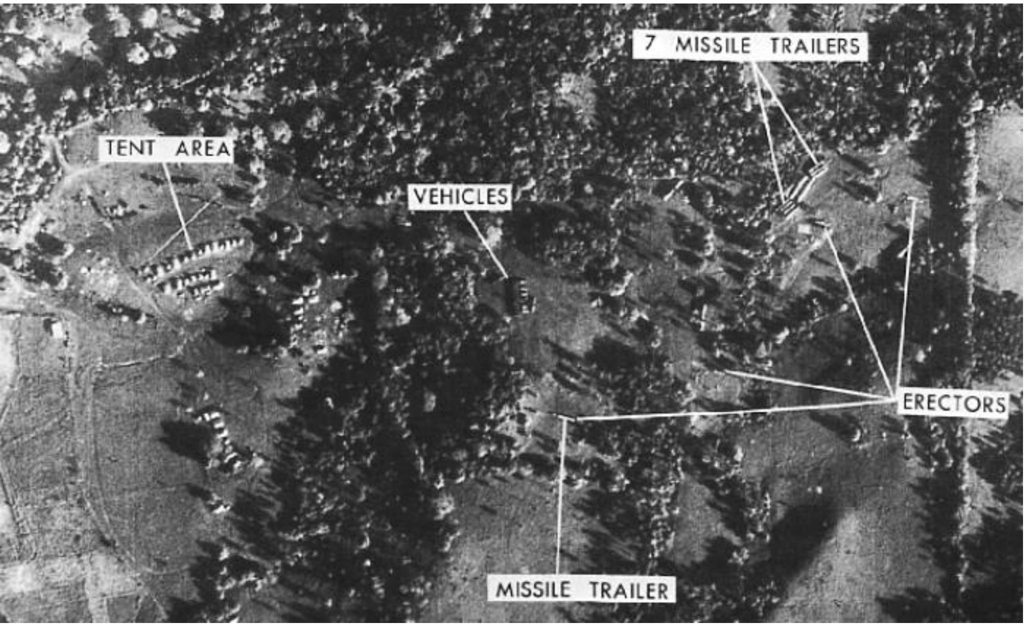
Aerial photograph of San Francisco earthquake damage –5 May 1906 - collected from a kite

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



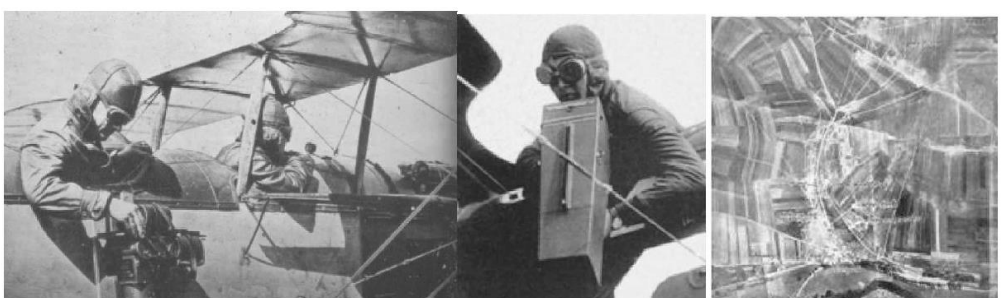


Figure 3-5: Reconnaissance during the World War-I (left), Graflex camera (middle) and an annotated photo of military locations in France during the World War-I, 1918 (right).

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

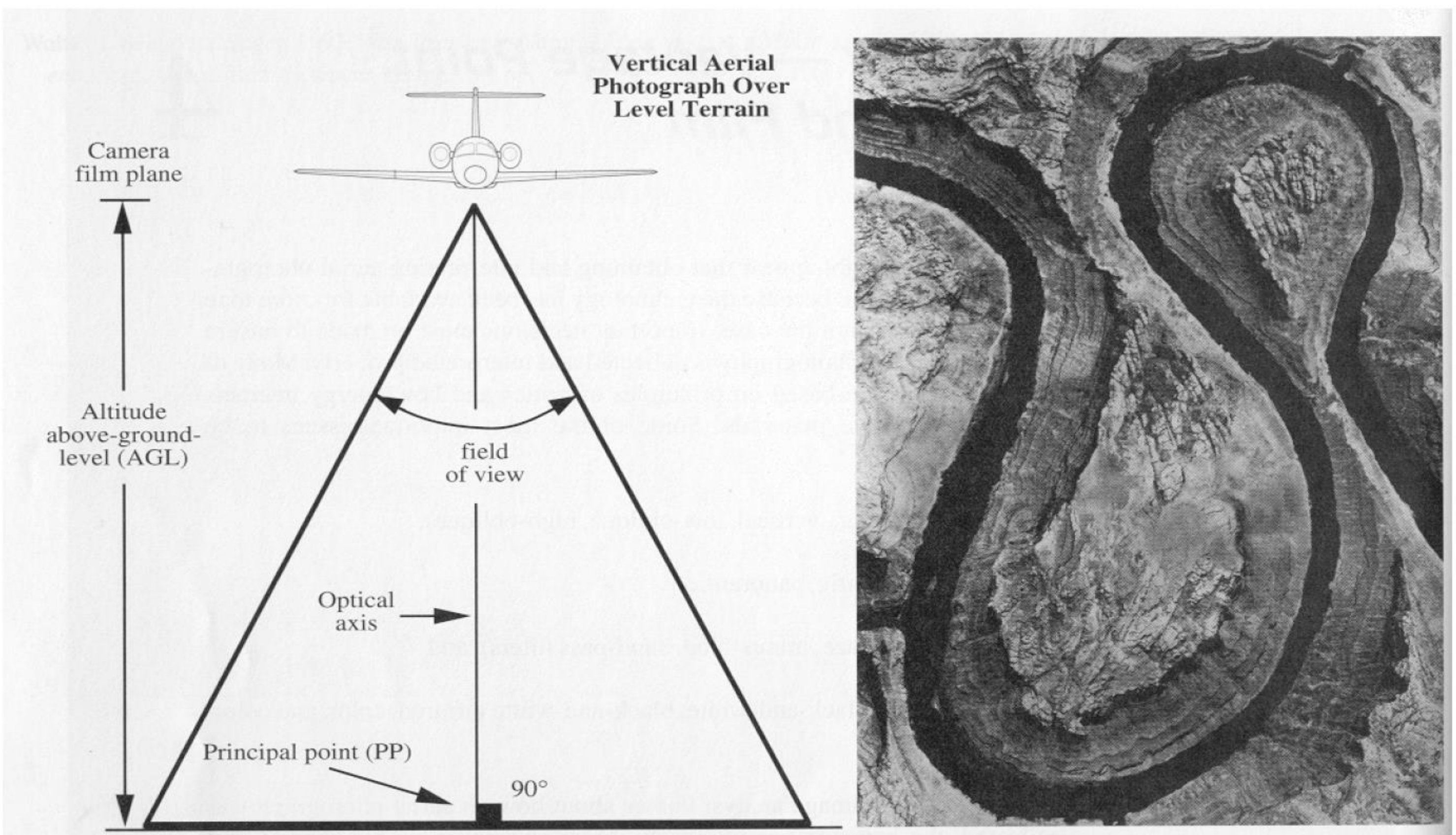
Terrestrial photographs

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**

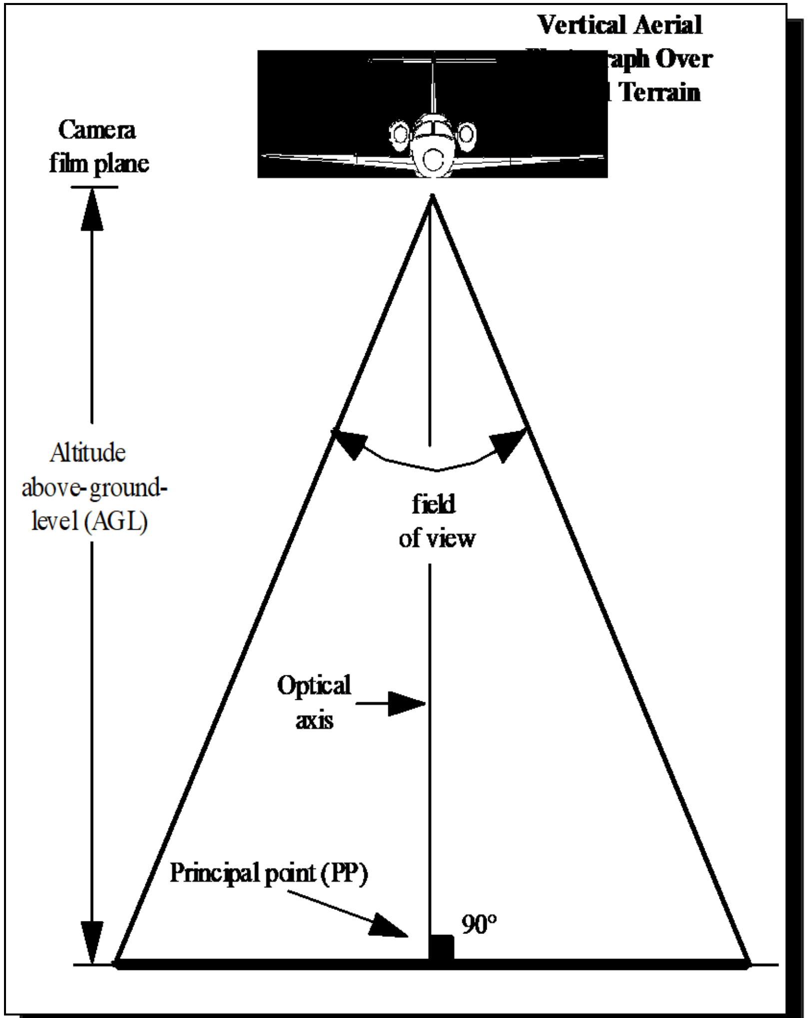
1	According to orientation of camera axis	A) Vertical photography B) Low oblique Photography C) High oblique Photography
2	According to lens system	A) Single lens photography B) Three lens photography (Trimetrogon photography) C) Four lens photography D) Nine lens photography E) Continuous strip photography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

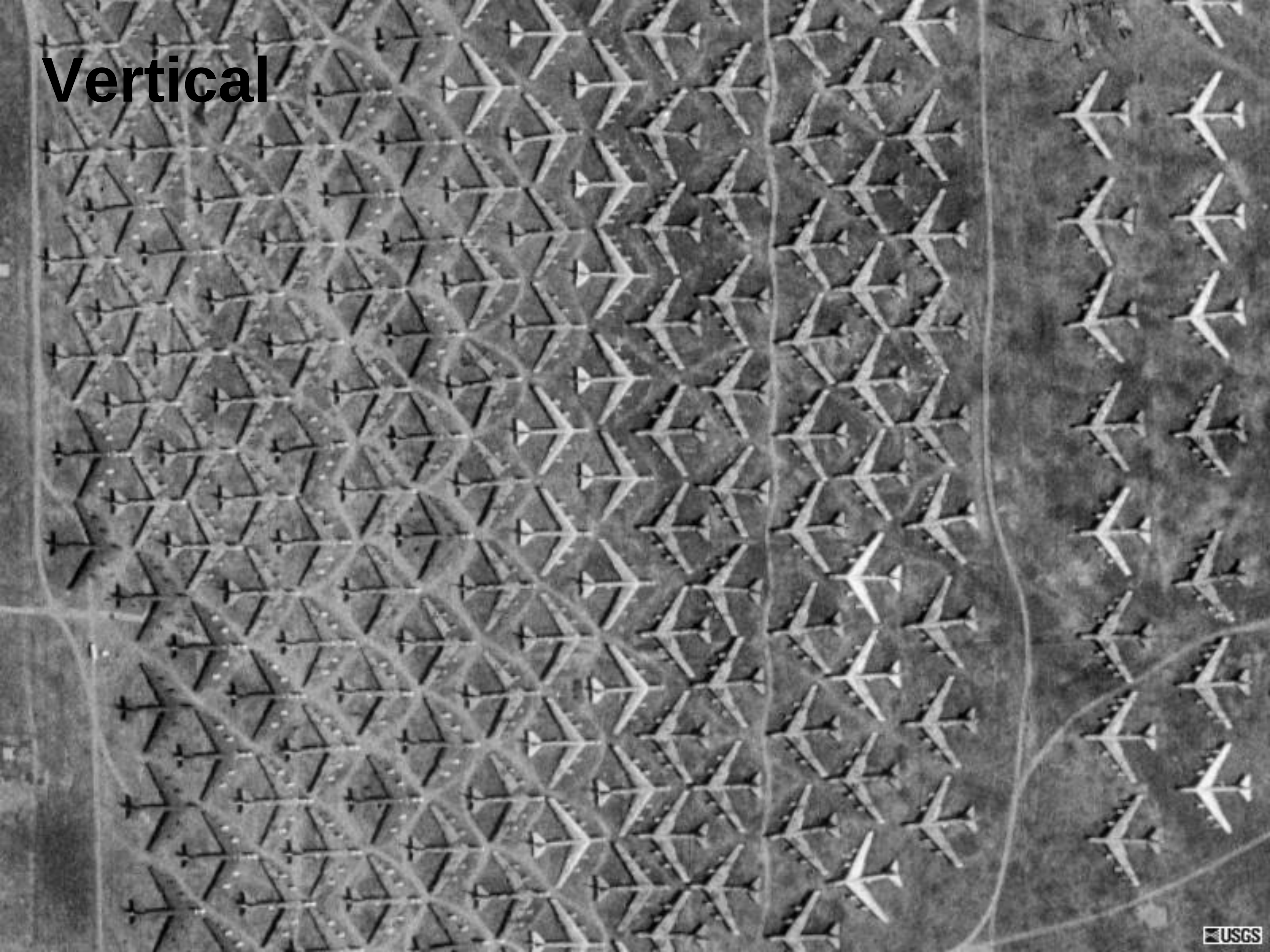


Goosenecks of the San Juan River in Utah

Jensen, 2000

Most are vertical aerial photography

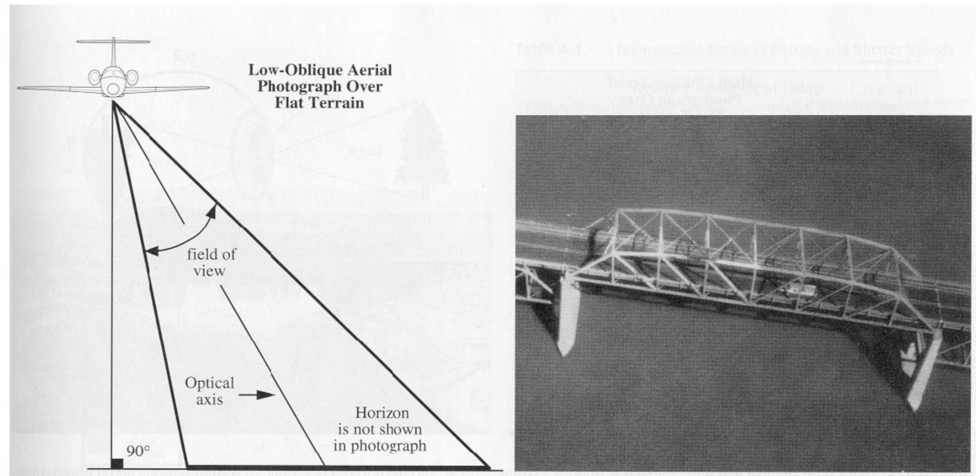
Vertical



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

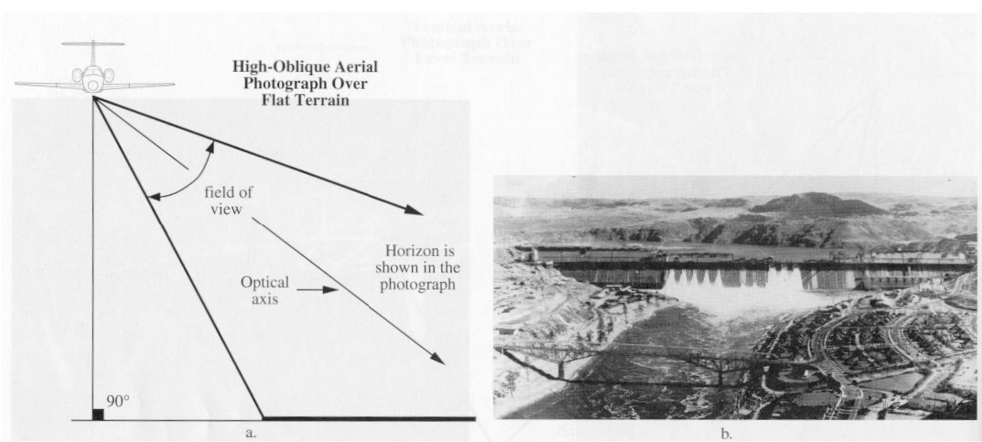
i) Low oblique photography:

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^o)

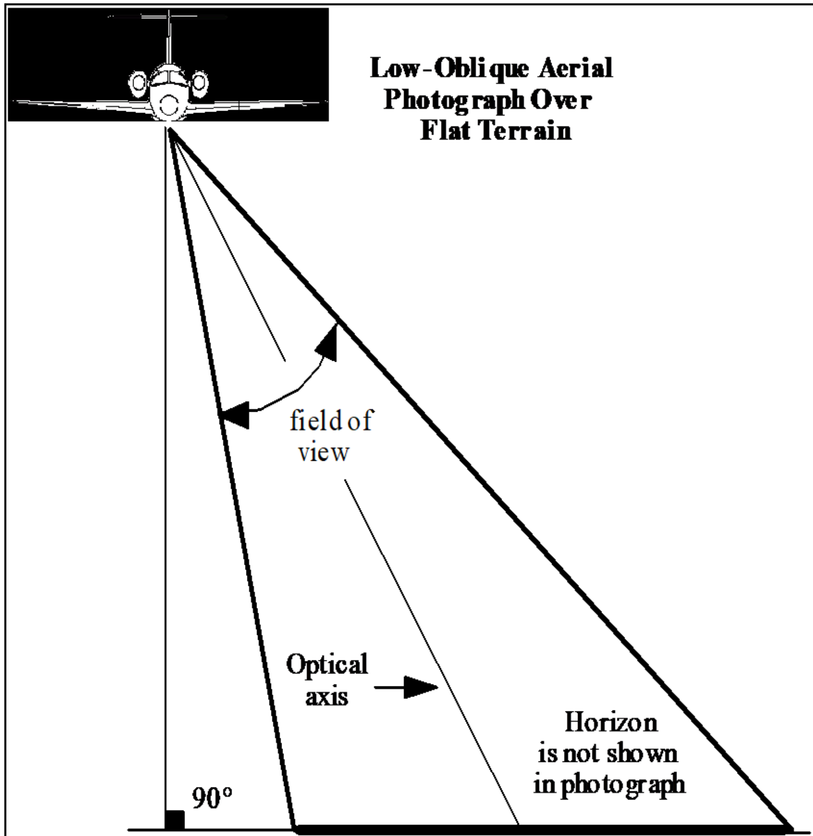


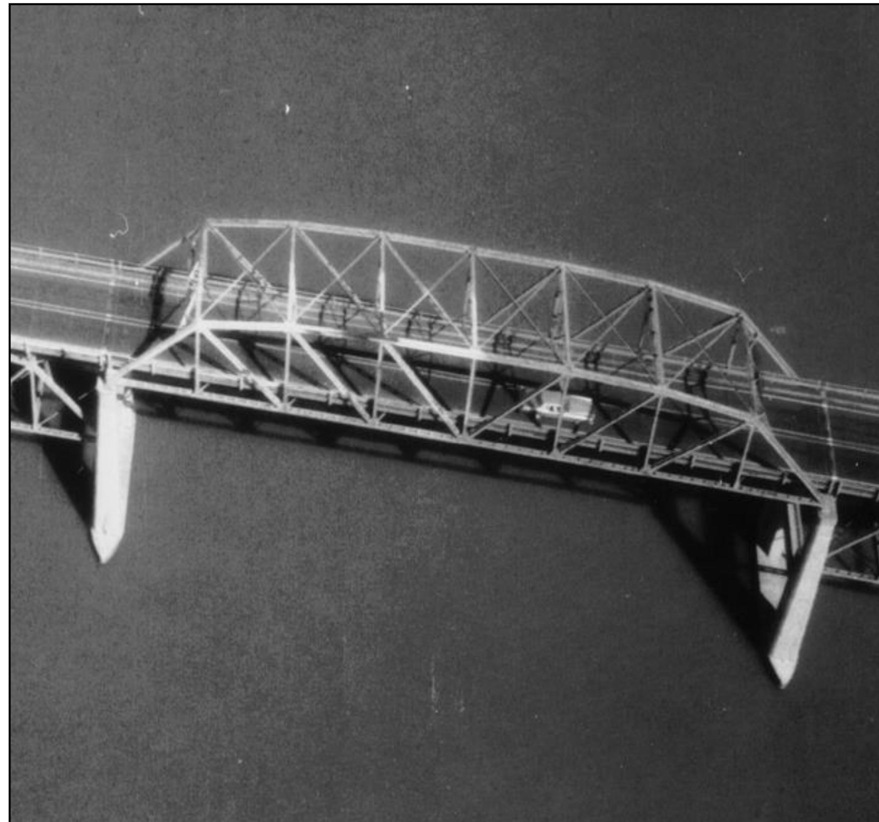
ii) High oblique photography:

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

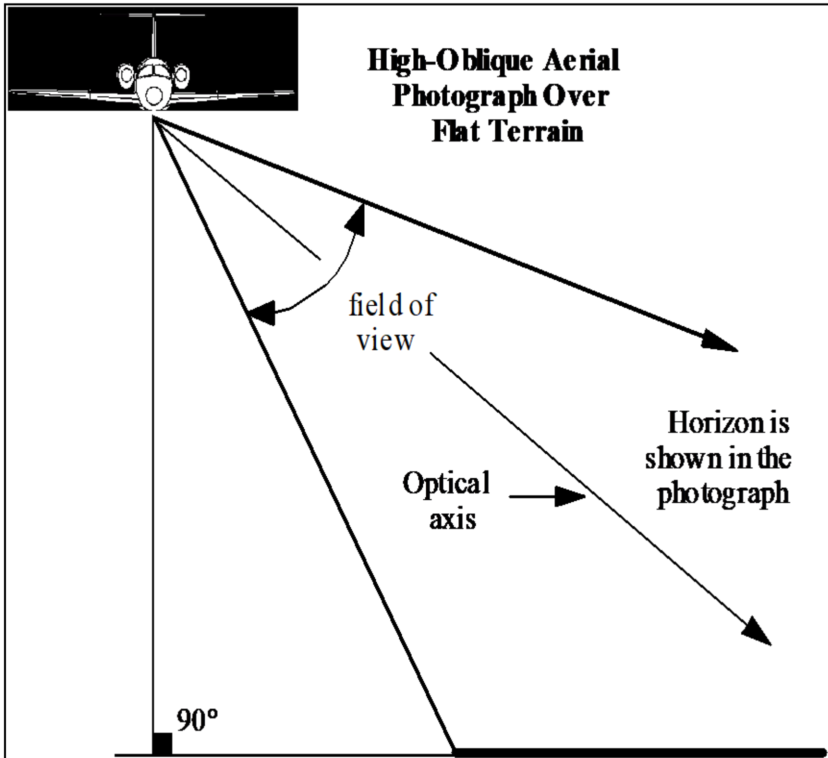




Low-oblique photograph of a bridge on the Congaree River near Columbia, SC.

Jensen, 2000

High-oblique Aerial Photography



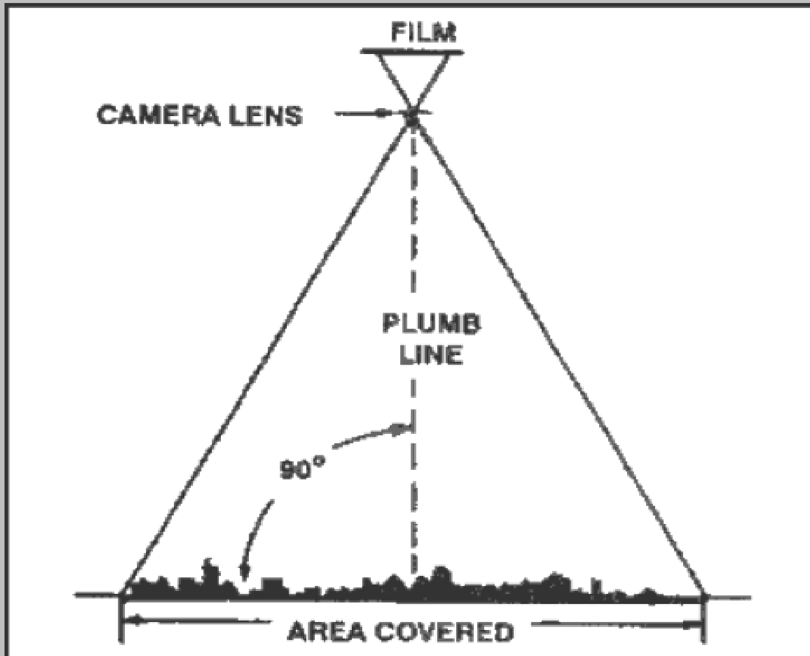
High-oblique photograph of the grand Coulee Dam in Washington in 1940

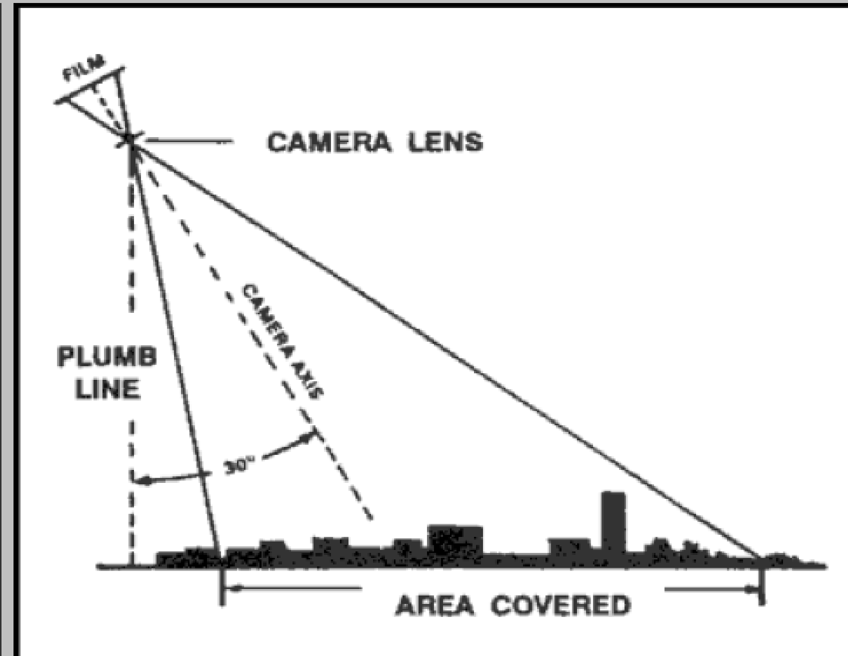
Jensen, 2000

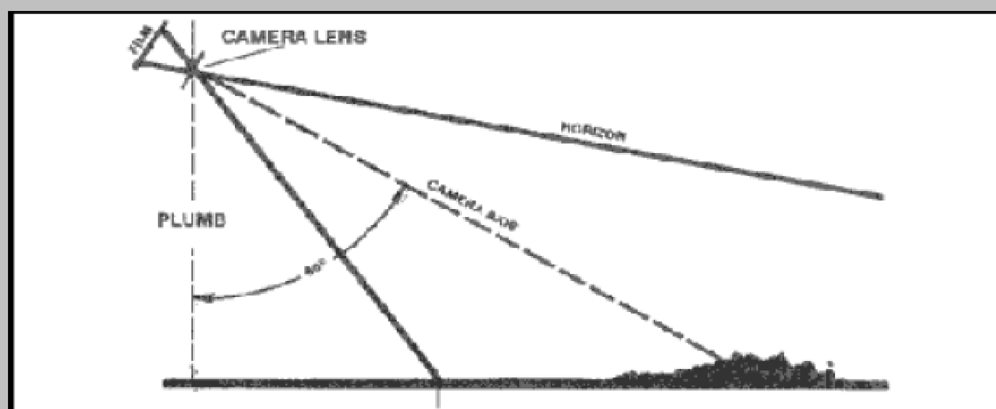
High oblique

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

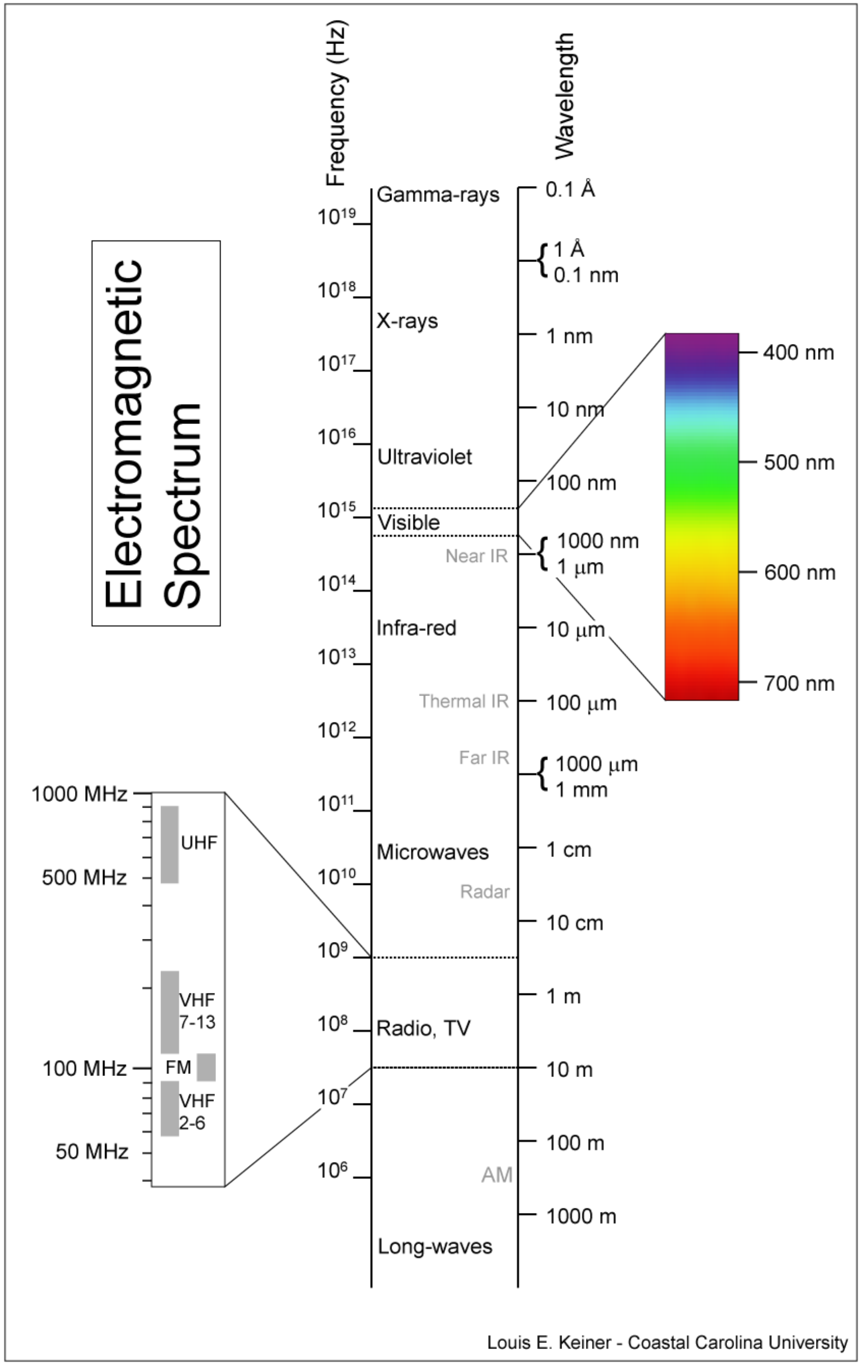
Photography according to Lens System

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

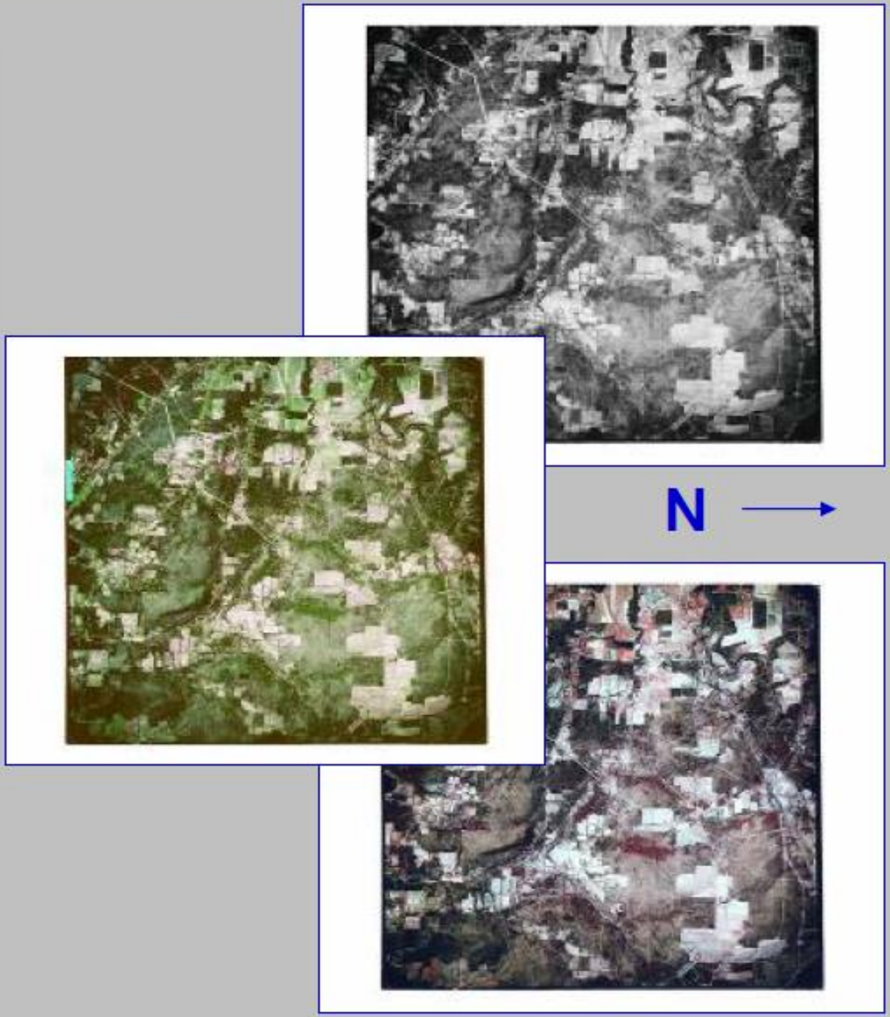


EM Spectrum Regions Used in Remote Sensing

- 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

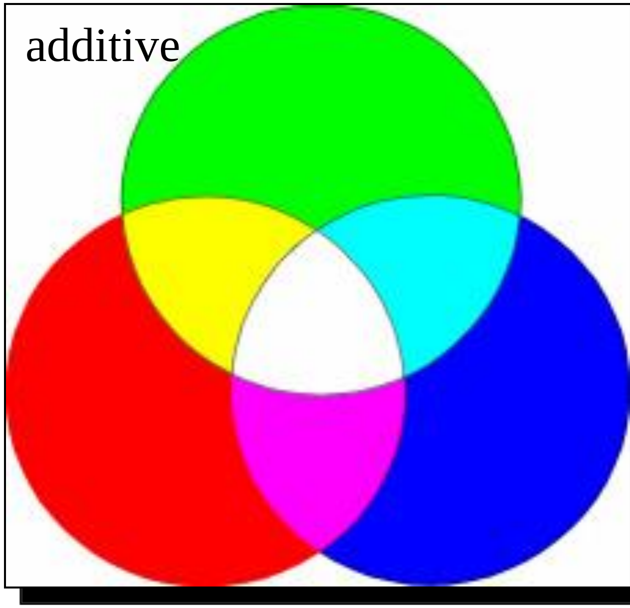
Common Types of Aerial Film

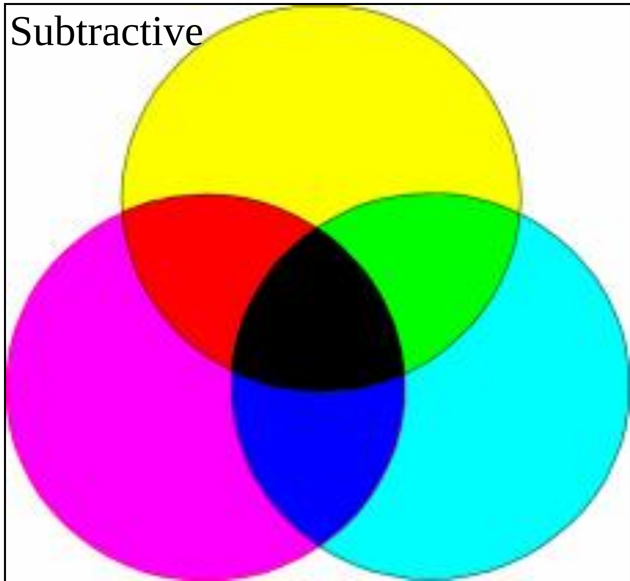
- Panchromatic
  - Sensitive to blue through red wavelengths
- Color
  - Three emulsion layers
- Color Infrared
  - Generally three layers sensitive in green, red, and IR



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

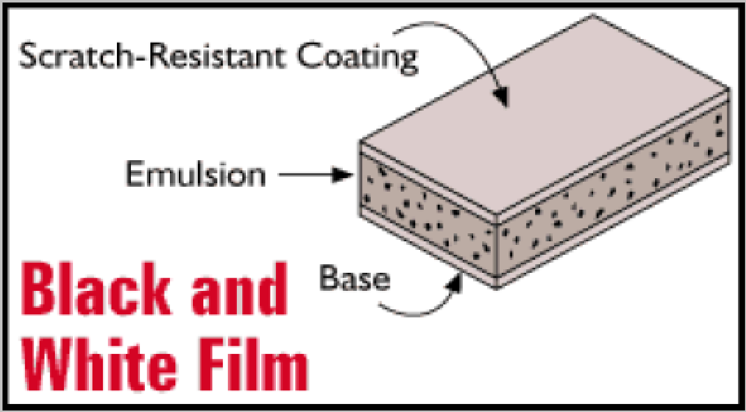
False-color infrared

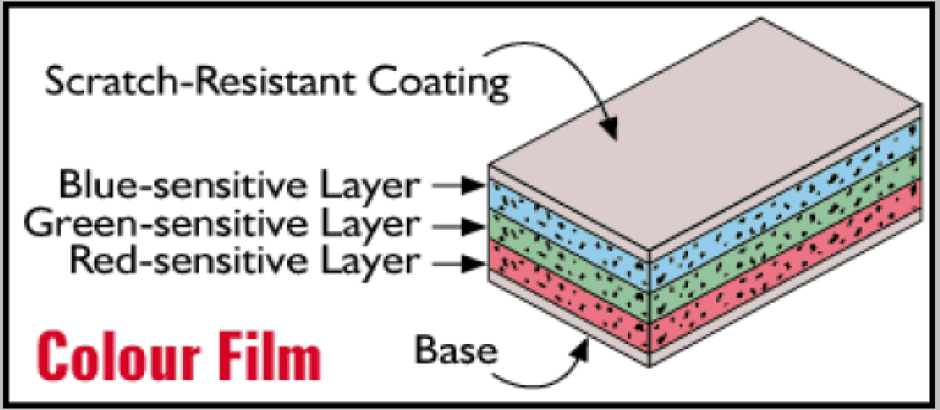
Normal color

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

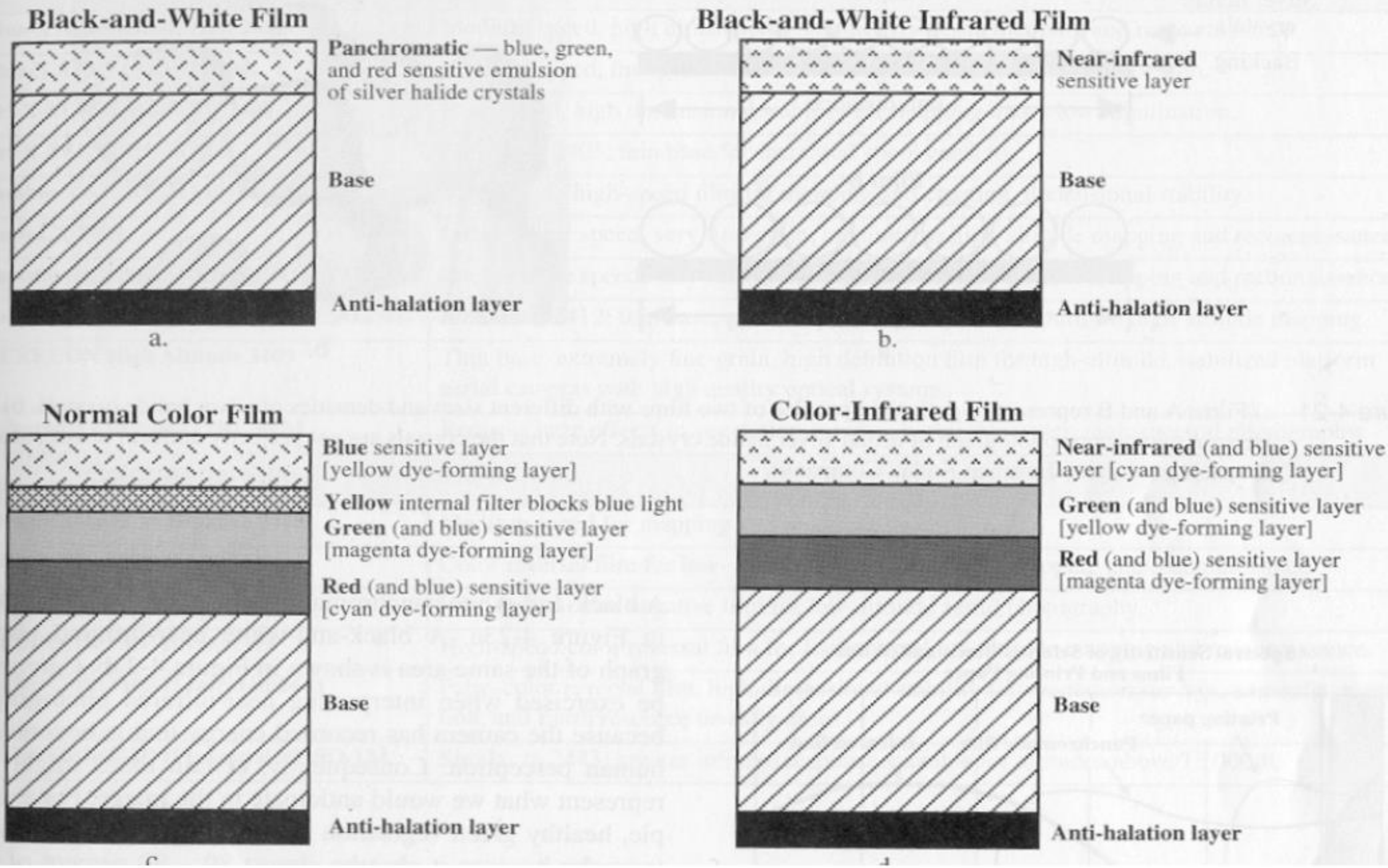
0.4 to 0.5 μm: blue region of the EM spectrum

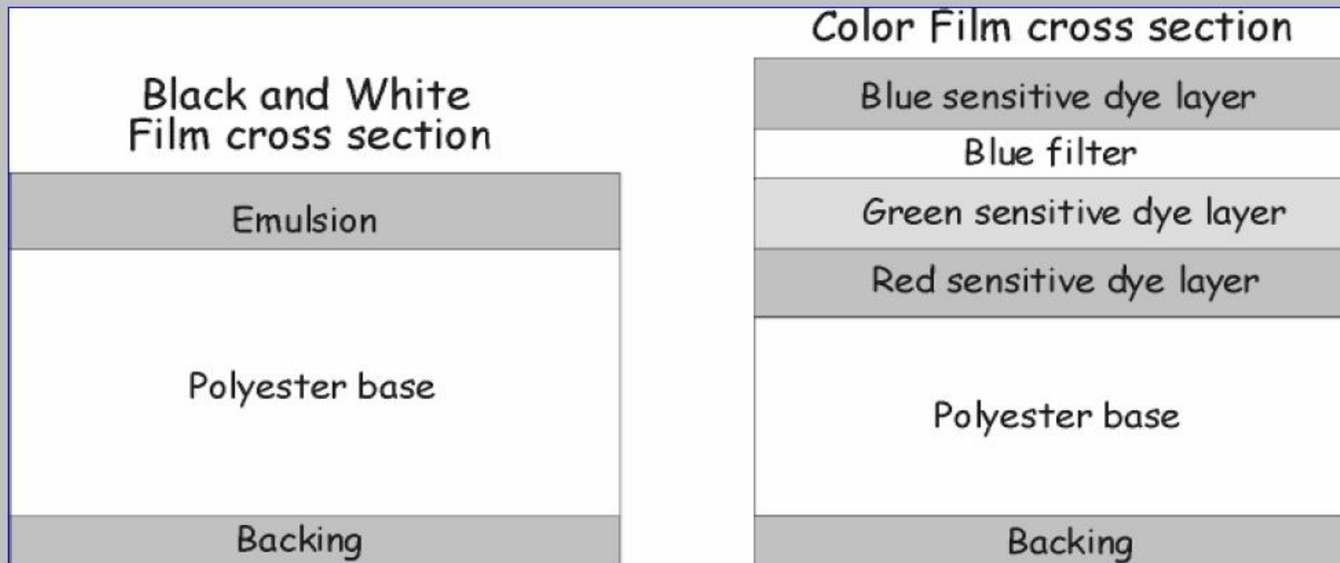
0.5 to 0.6 μm: green region of the EM spectrum

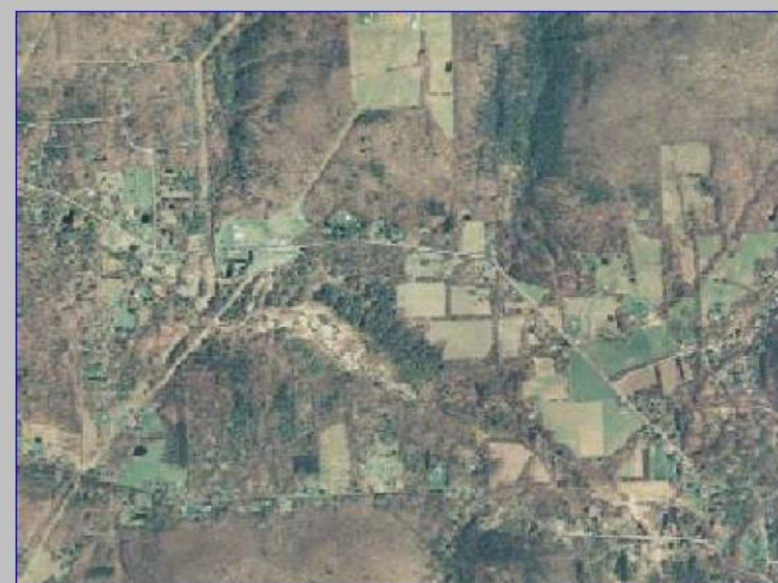
0.6 to 0.7 μm: red region of the EM spectrum

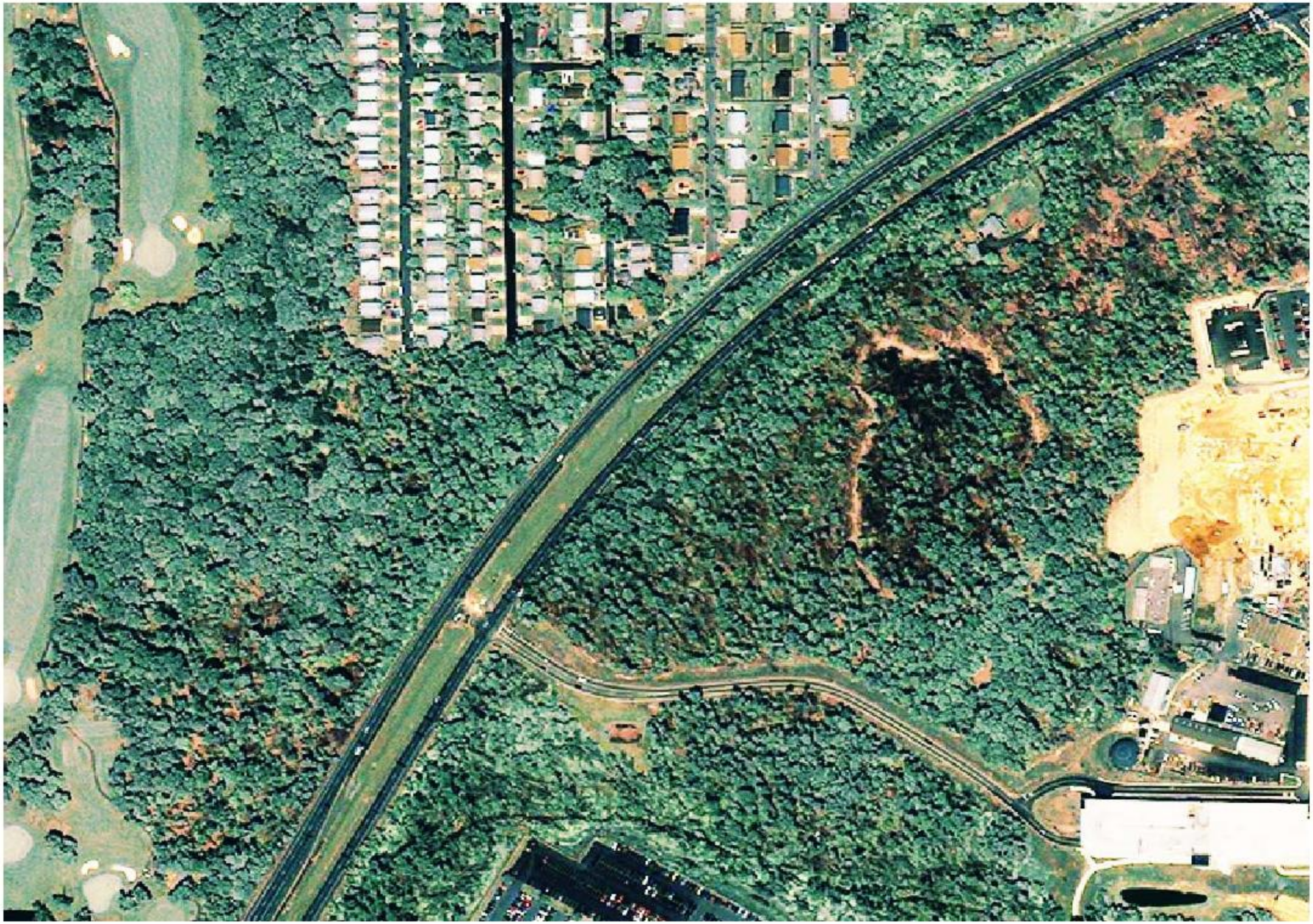
0.7 to 1.1 μm: near infrared region of the EM spectrum

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



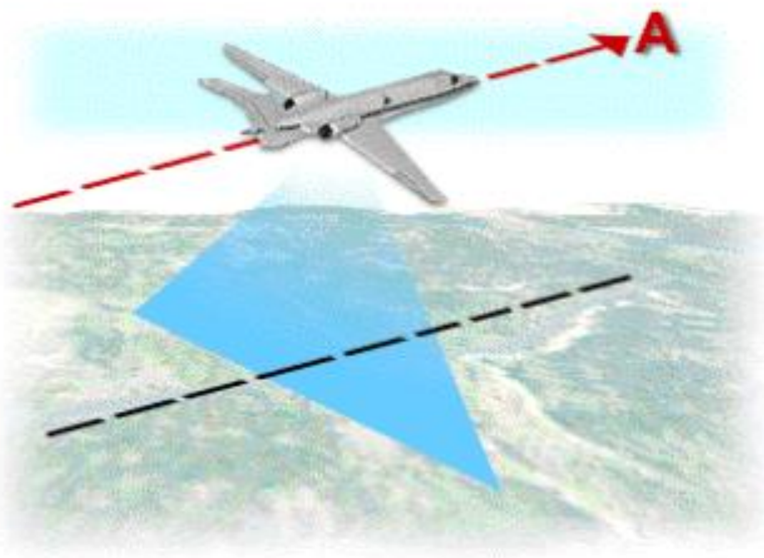


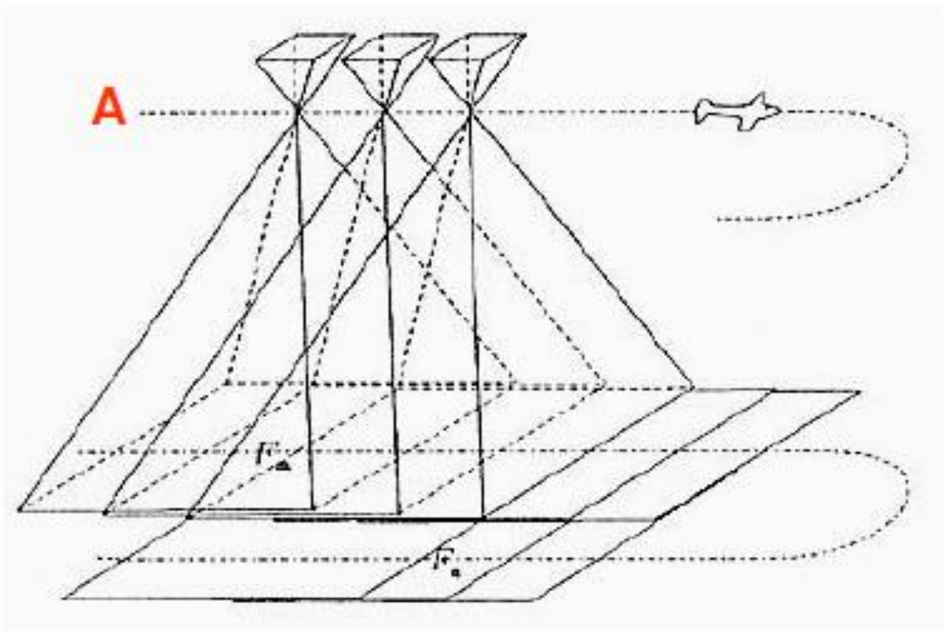
September 18, 2004

January 4, 2004

Flight runs

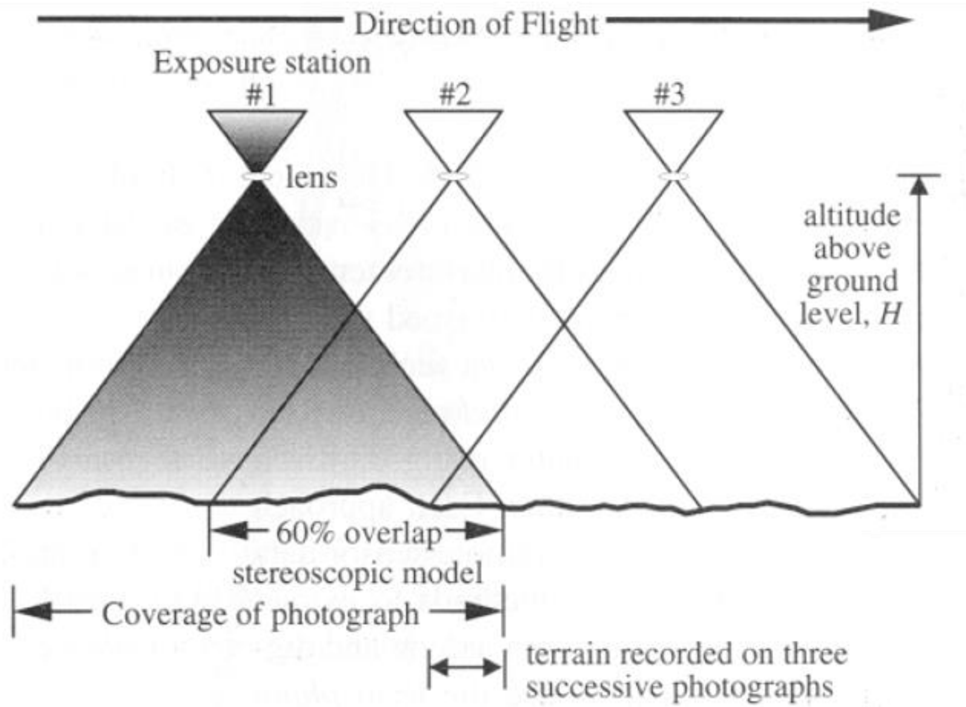
When obtaining vertical aerial photographs, the aircraft normally flies in a series of lines, each called a flight run (A).

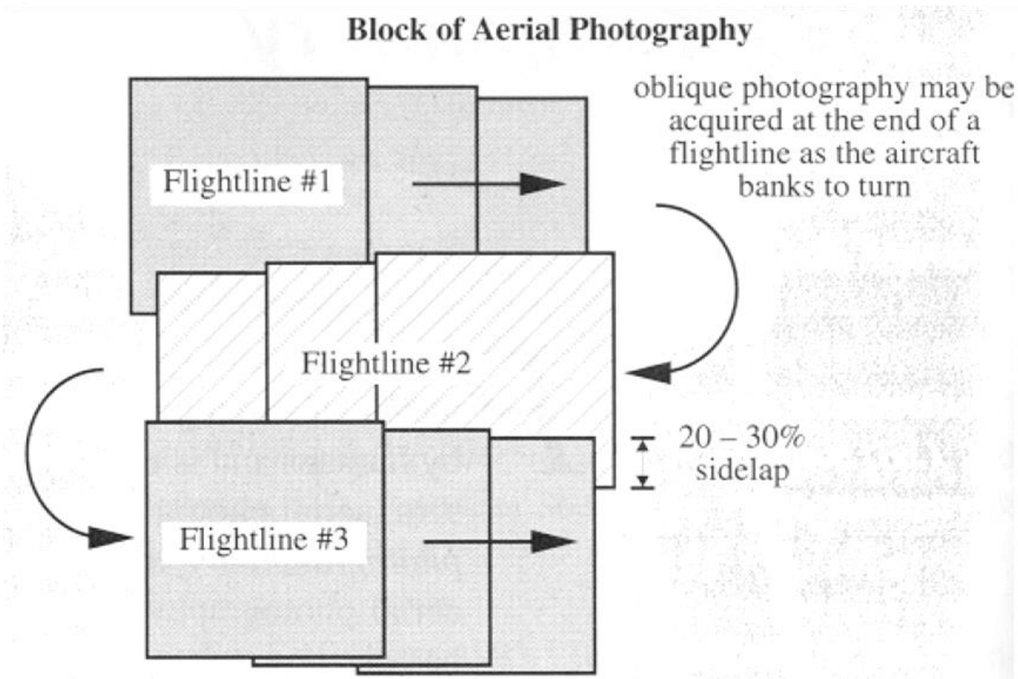


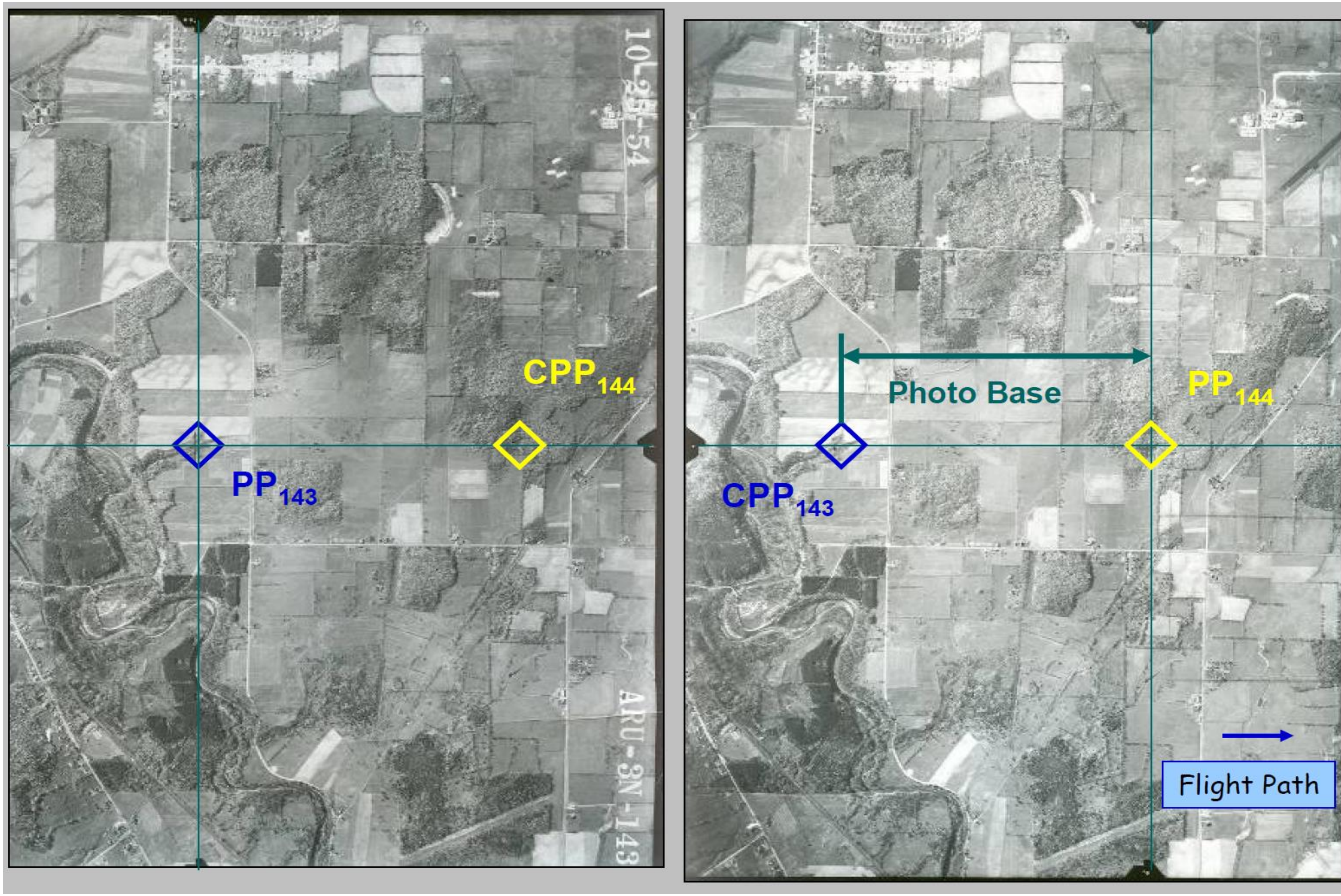


Acquisition of aerial photograph

Flightline of Aerial Photography



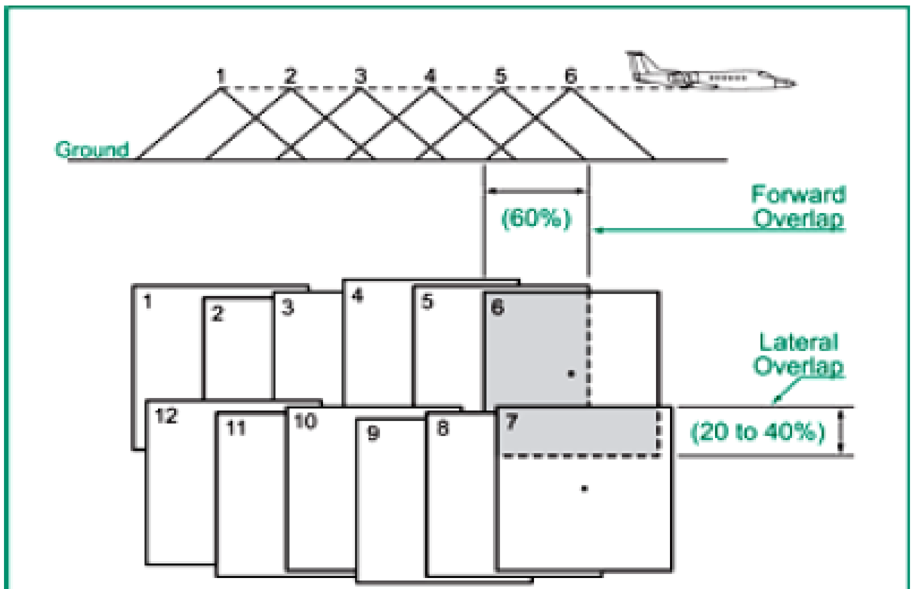




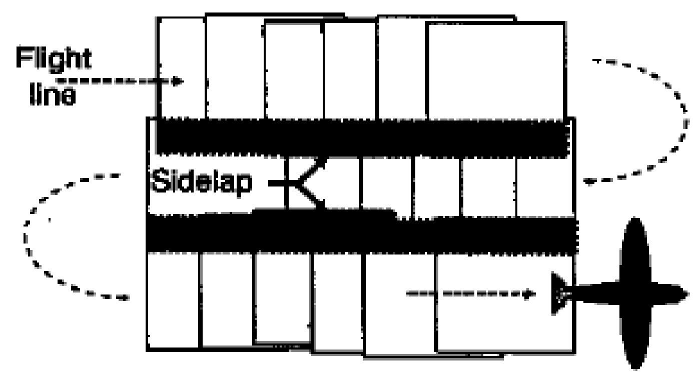
CPP$_{144}$
PP$_{143}$
Photo Base
PP$_{144}$
CPP$_{143}$
Flight Path

60 % overlap

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

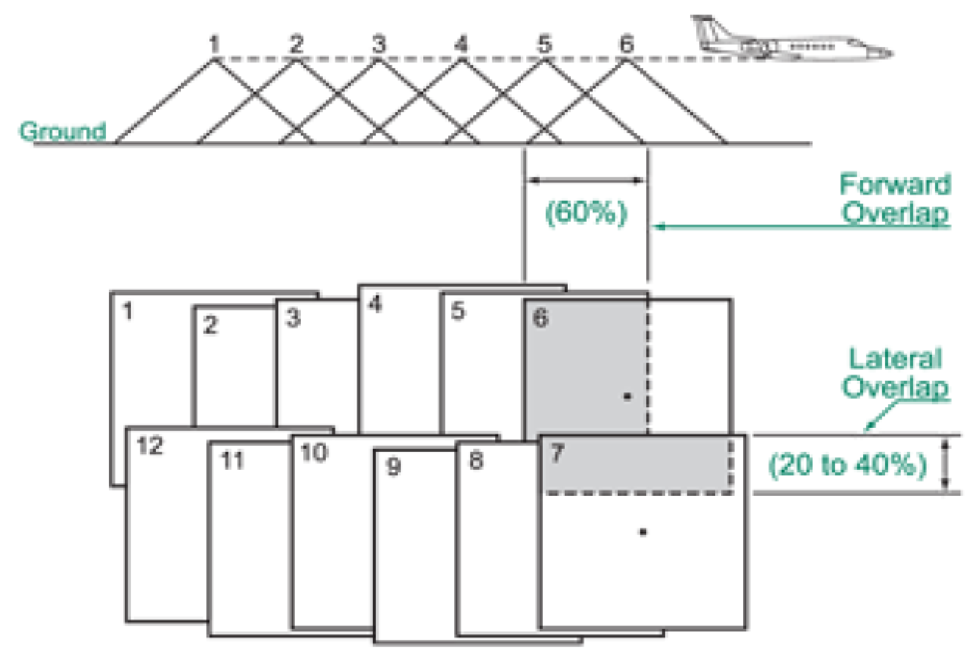


Photographic Overlap

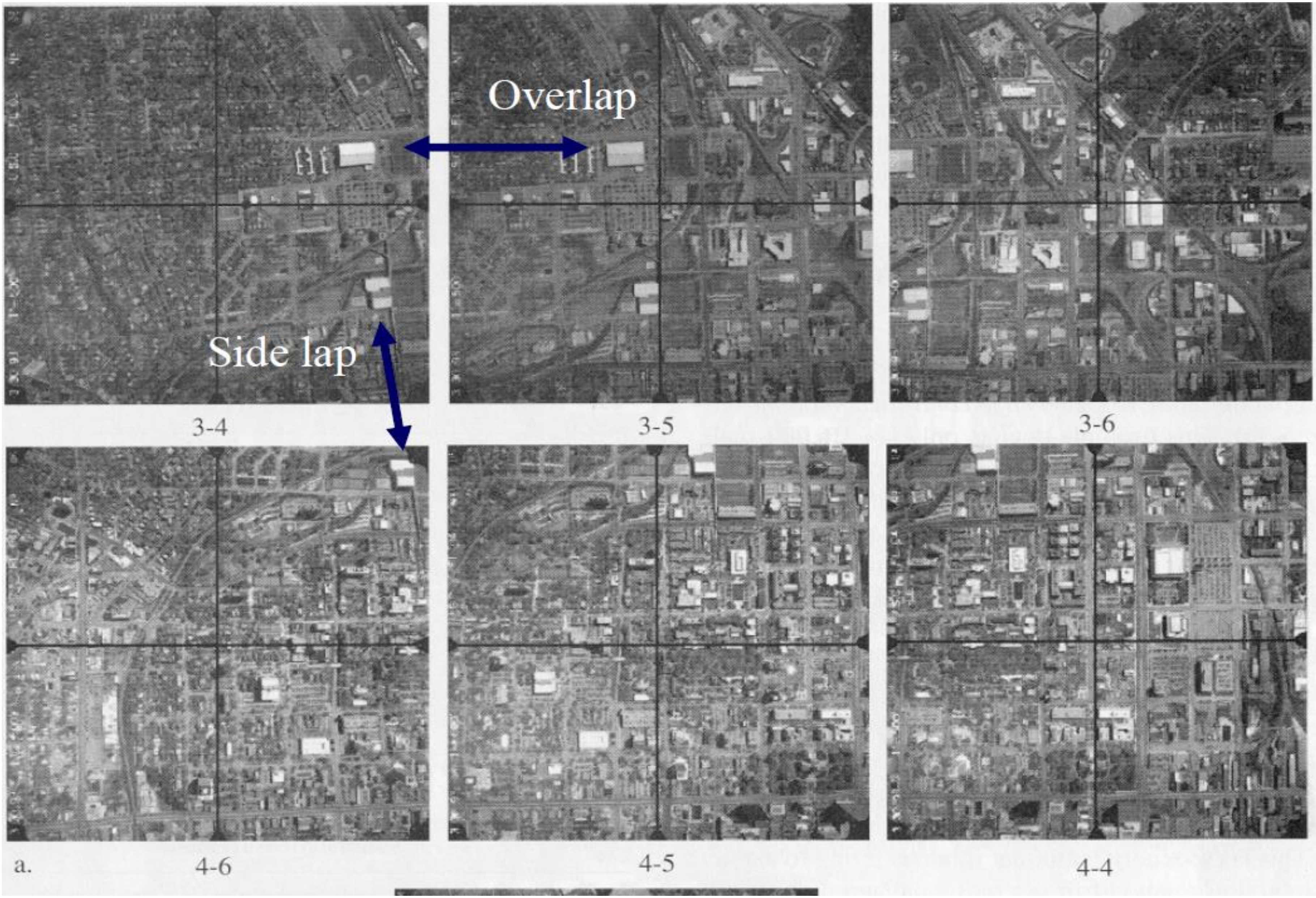


Vertical Photography

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

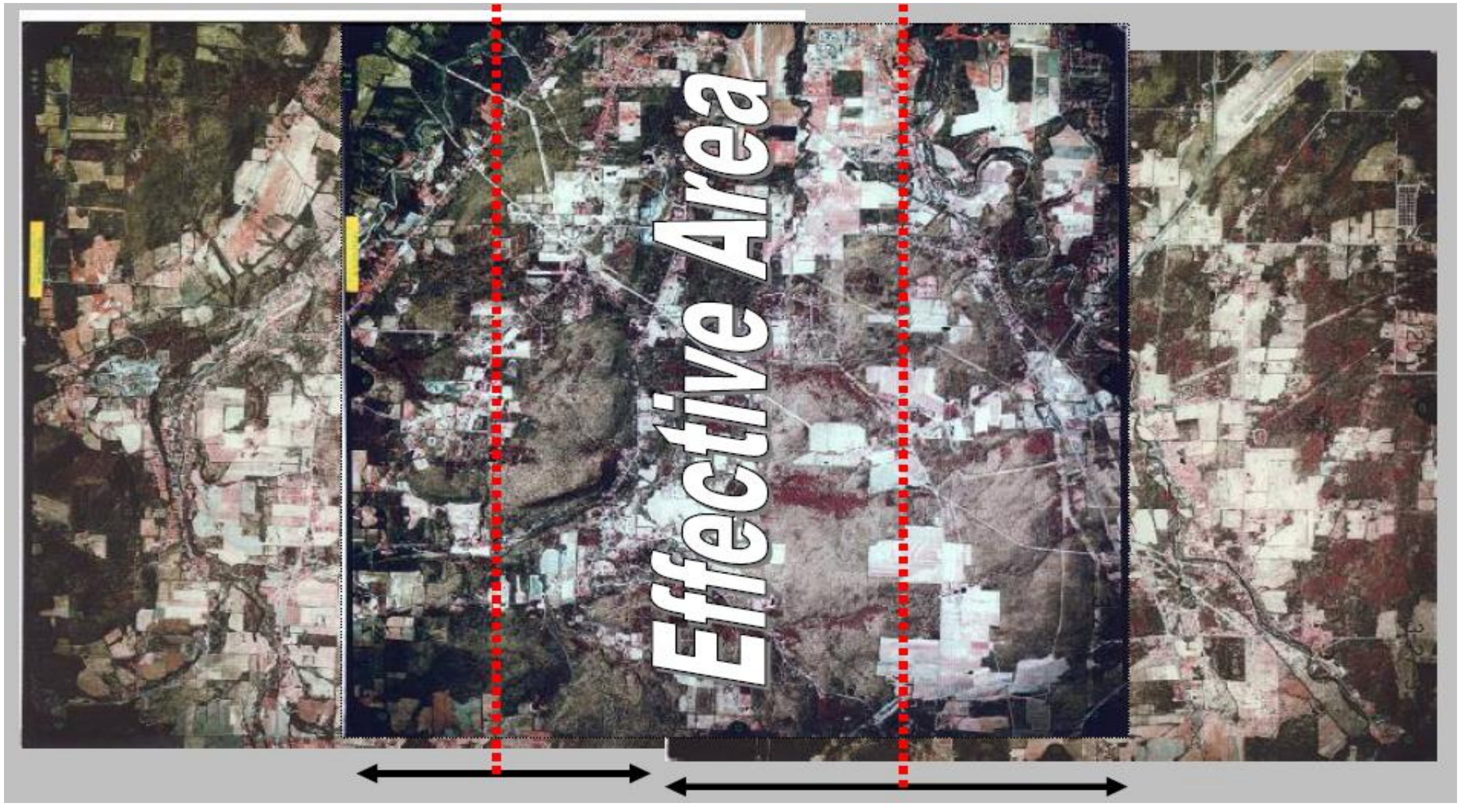


Photographic Overlap


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*

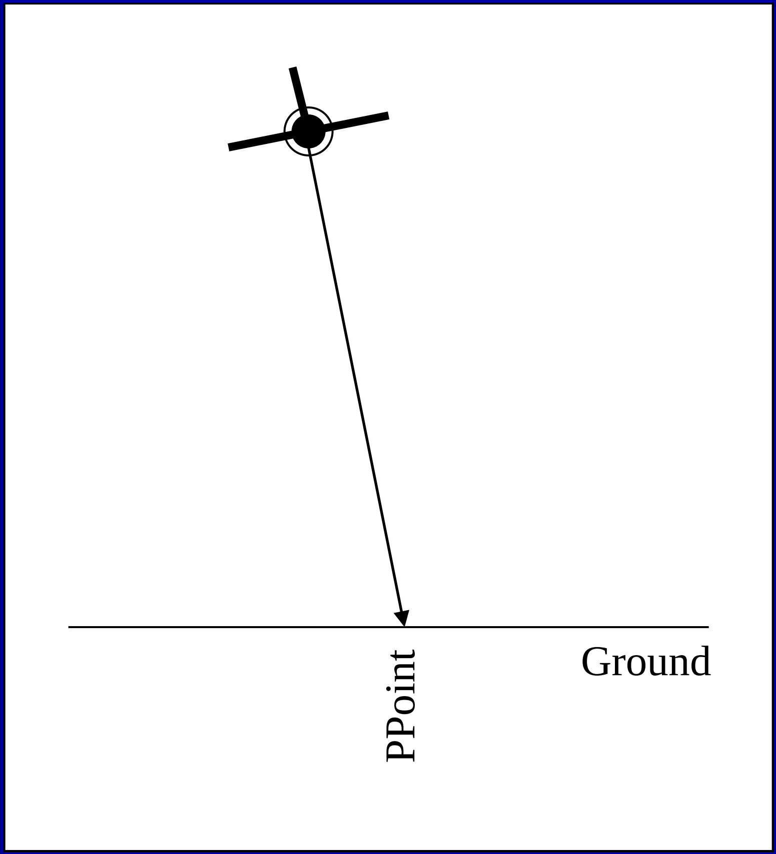
The three photo centers

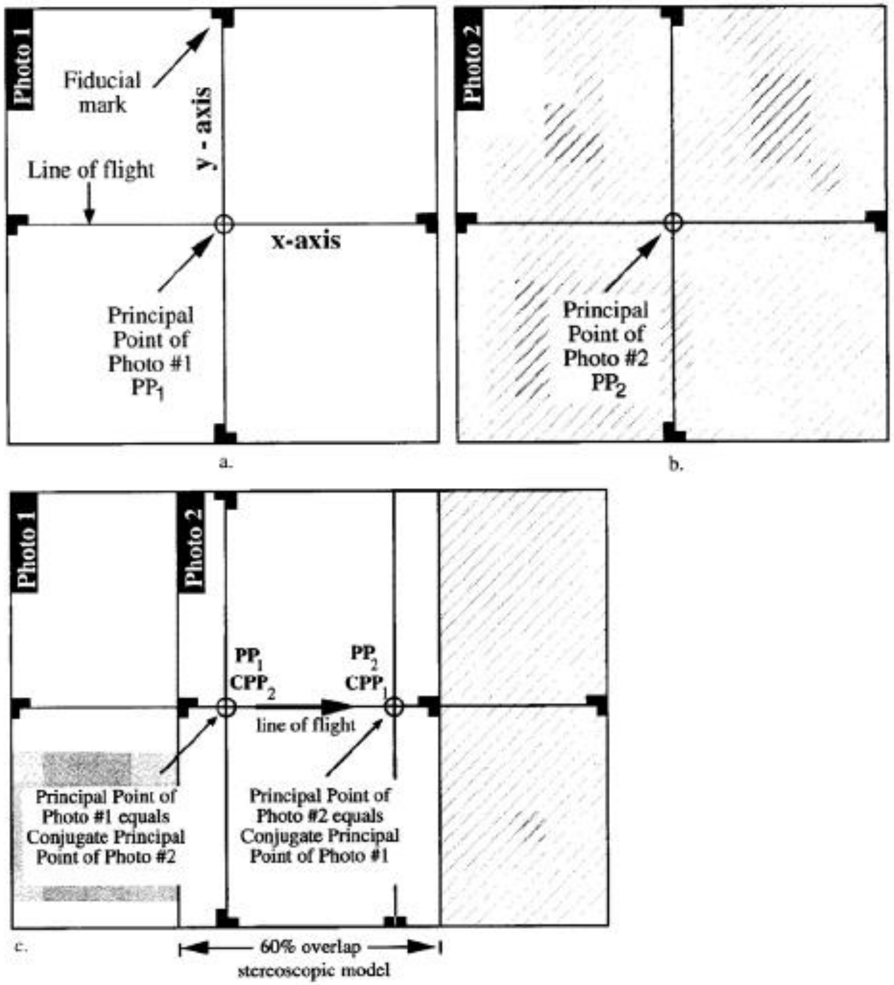
Different types of distortion and displacement radiate from each.

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.

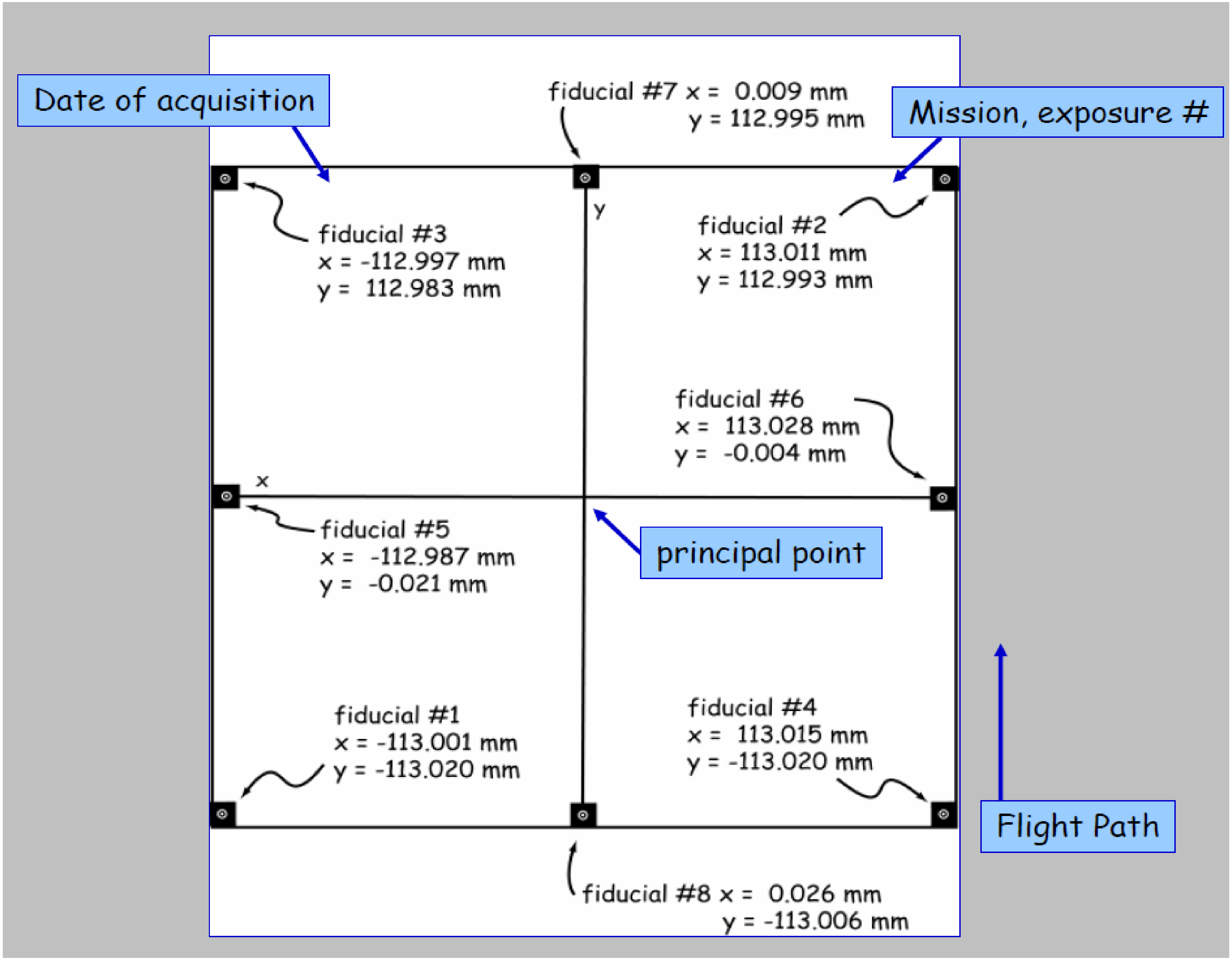
It is the intersection point between the projection of the optical axis (i.e., the perpendicular to the center of the lens) and the ground.

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*.

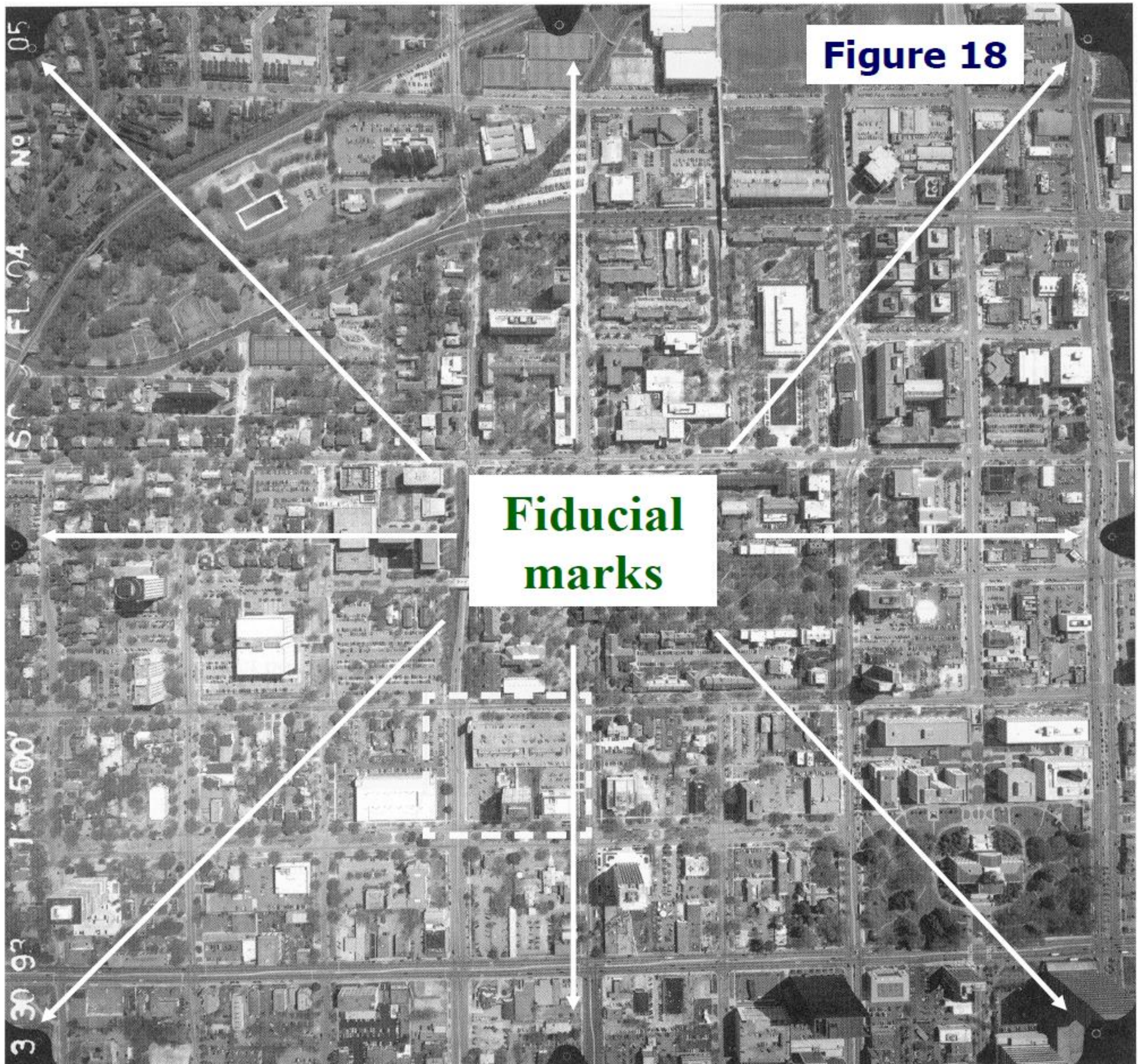
This PP is then transferred stereoscopically onto the adjacent (left and right) photographs of the same flight line

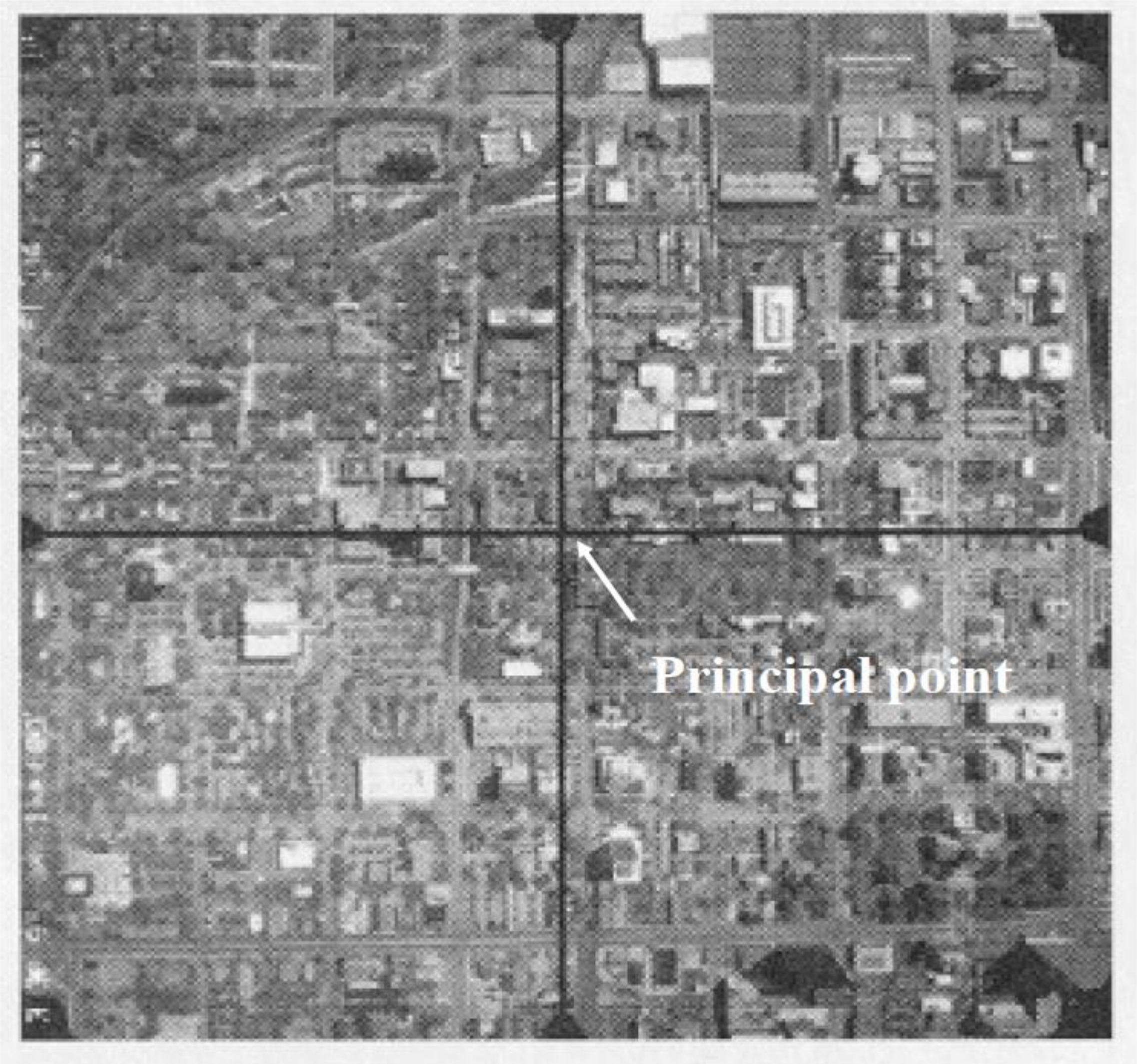
These transferred points are called transferred principal points or **conjugate principal points (CPP).** The line segment joining the principal points and the conjugate principal points constitute the flight line of the aircraft, also called base line or air base


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

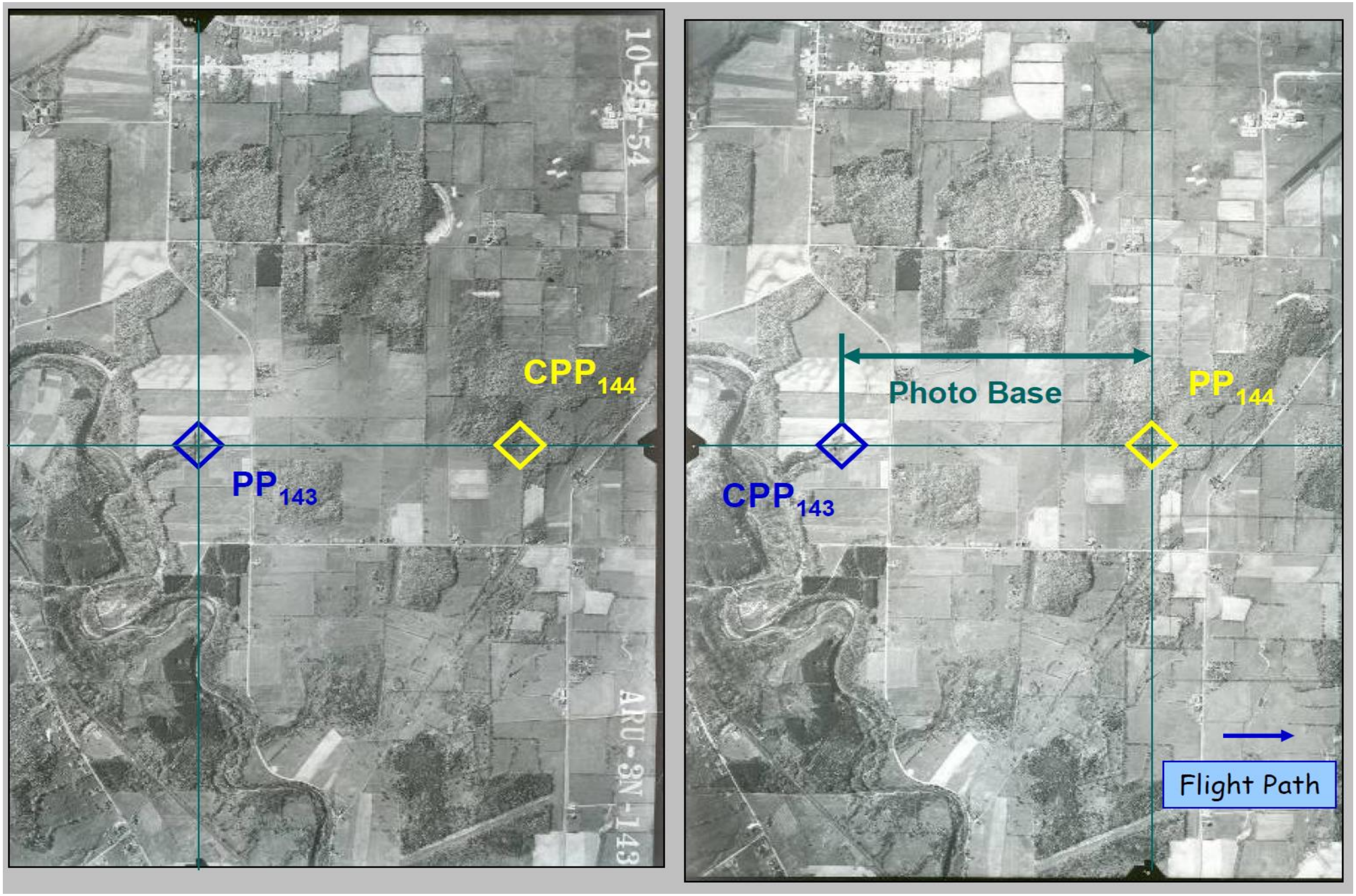
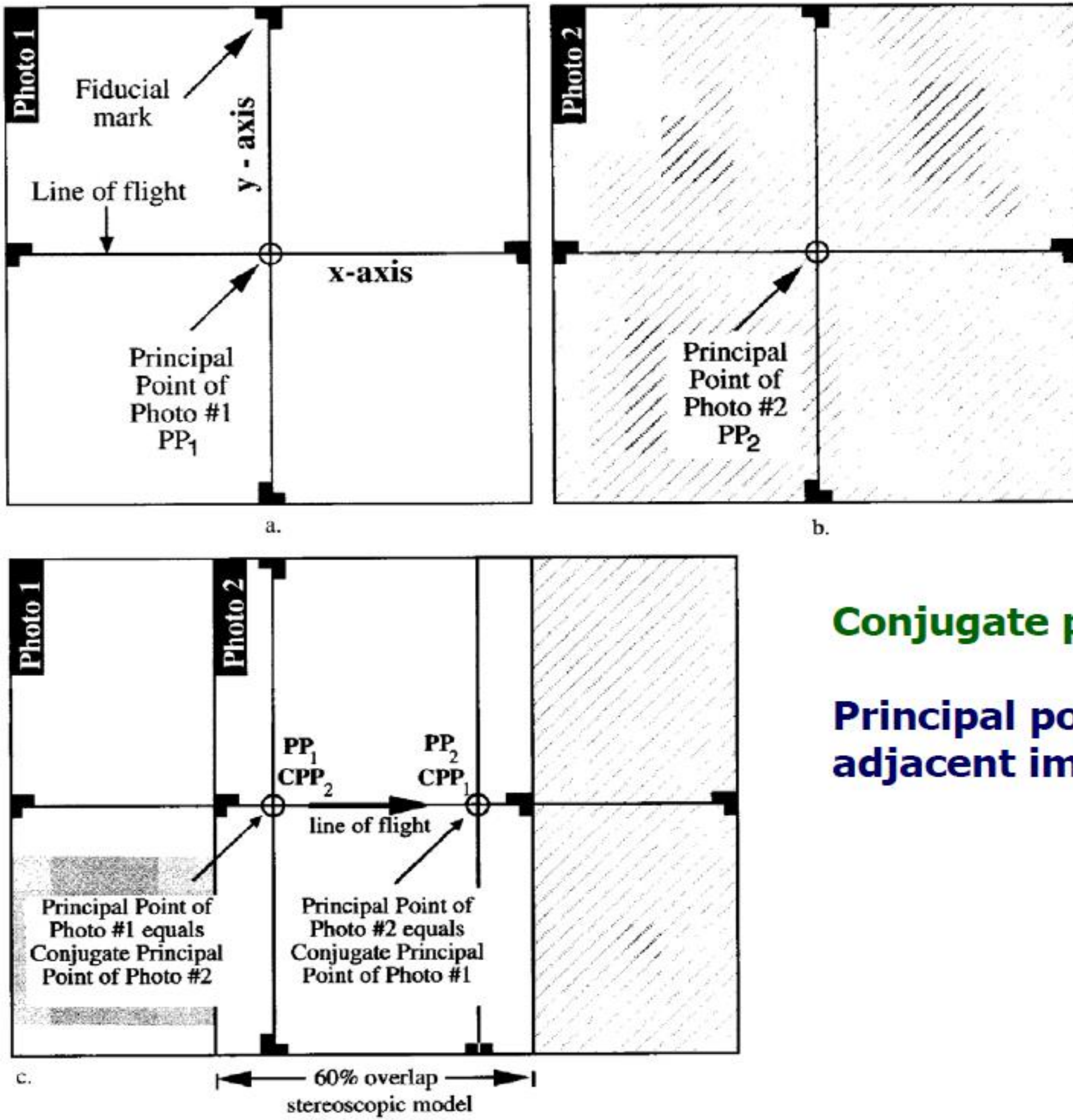

CPP$_{144}$
PP$_{143}$
ARU-8N-143
Photo Base
PP$_{144}$
CPP$_{143}$
Flight Path

Figure 20



Conjugate principal point

Principal point from an adjacent image

Nadir Point

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

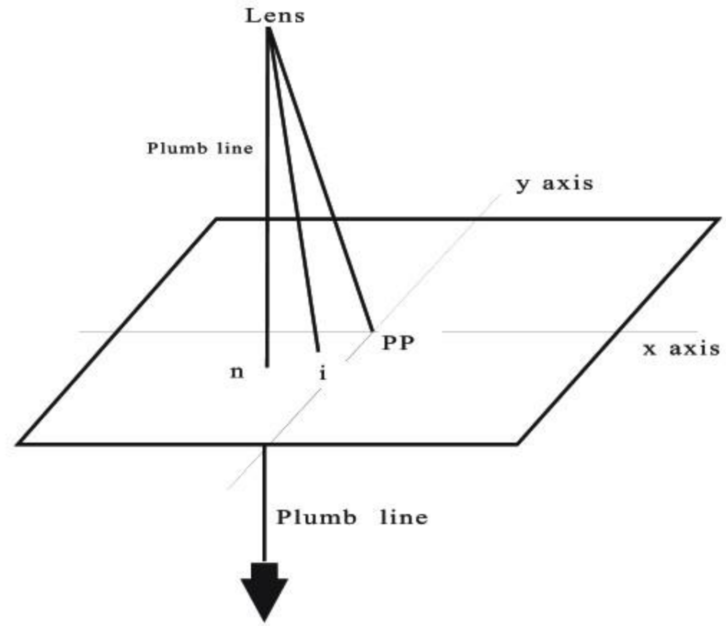
It is the intersection point between the plumb line directly beneath the camera center at the time of exposure and the ground.

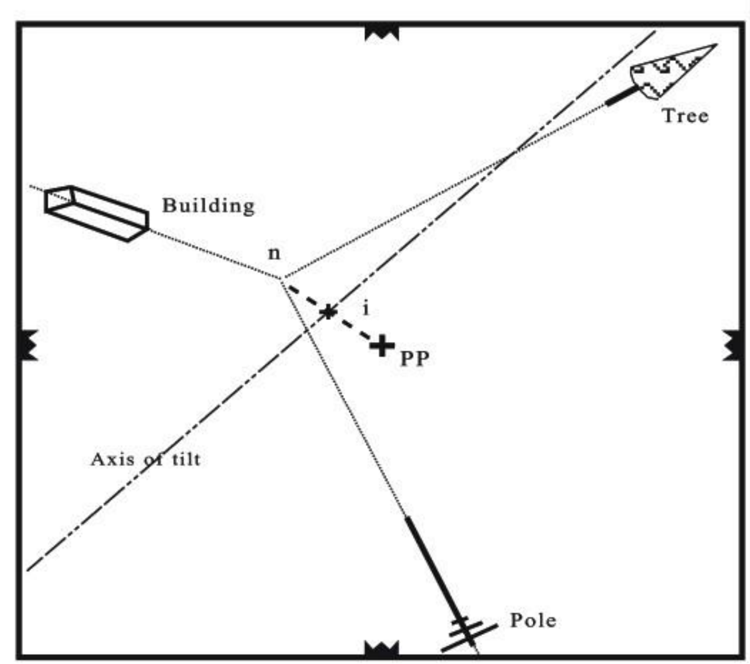
The nadir is important because relief displacement is radial from this point

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.





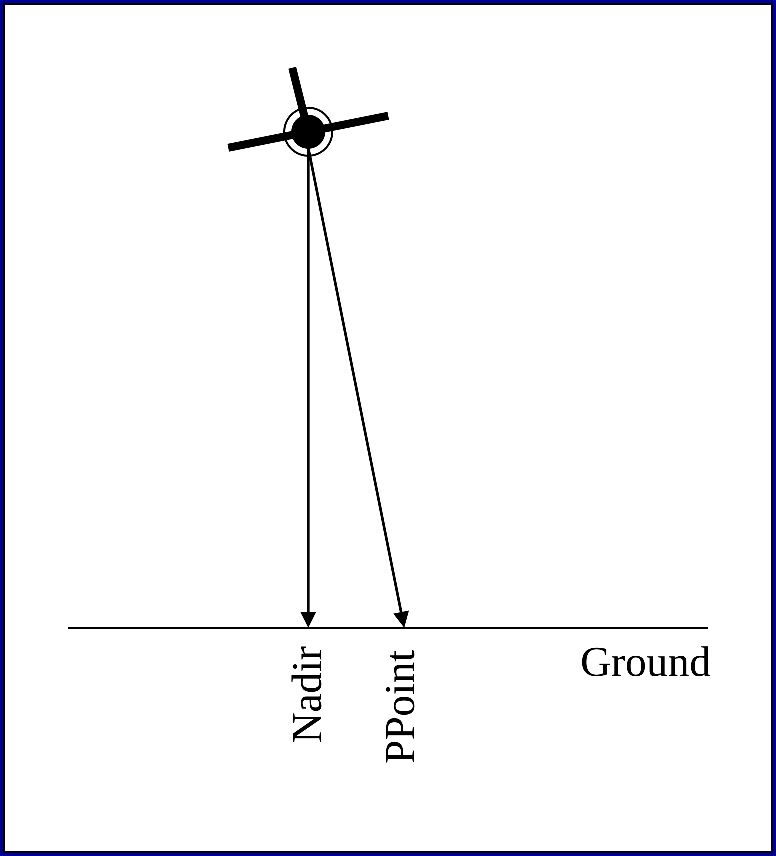
The three photo centers

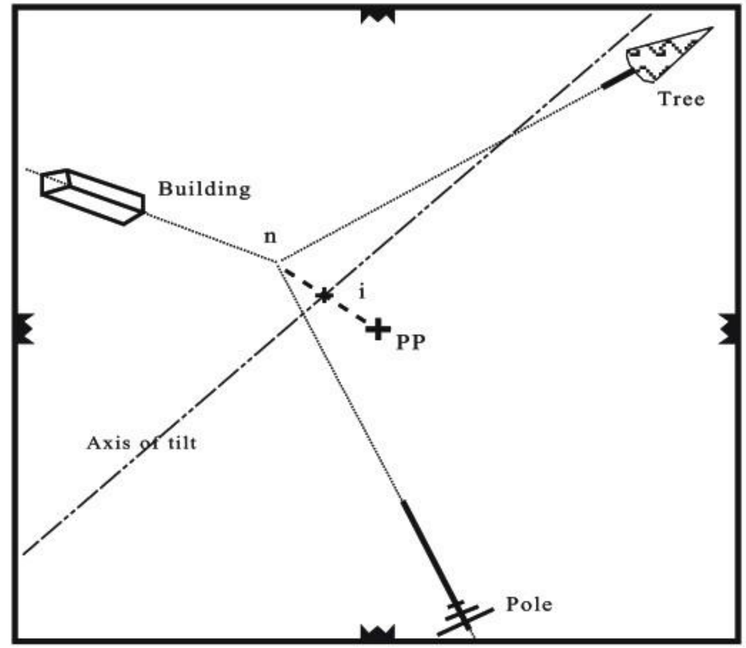
2

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.

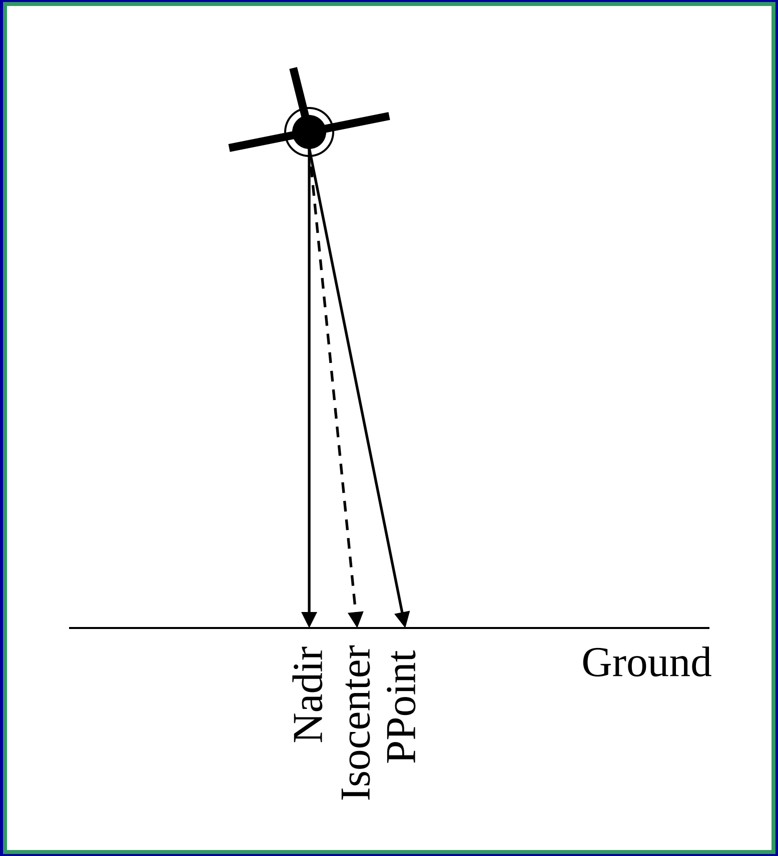
The isocentre is the point from which tilt displacement radiates.

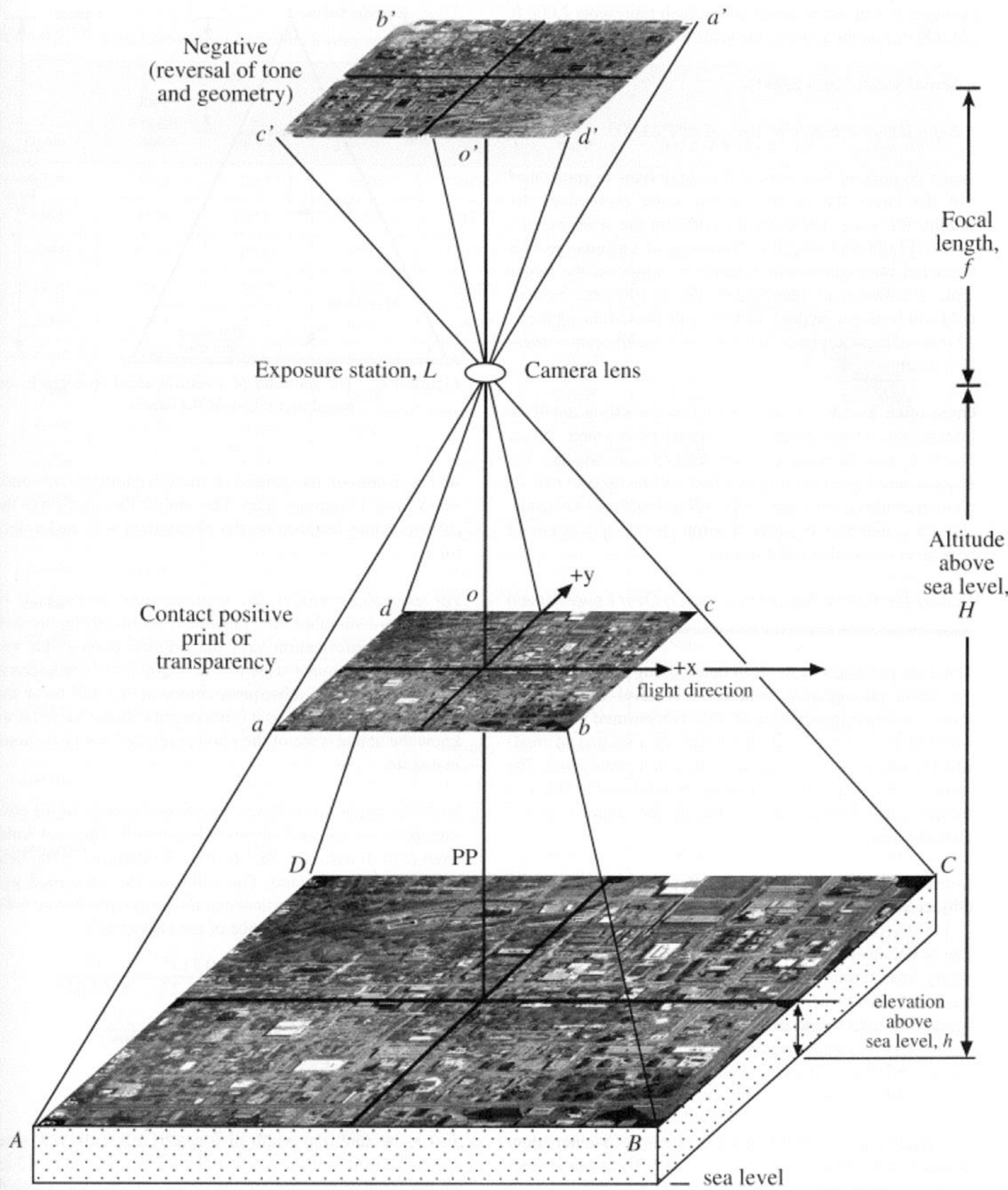
The three photo centers

3

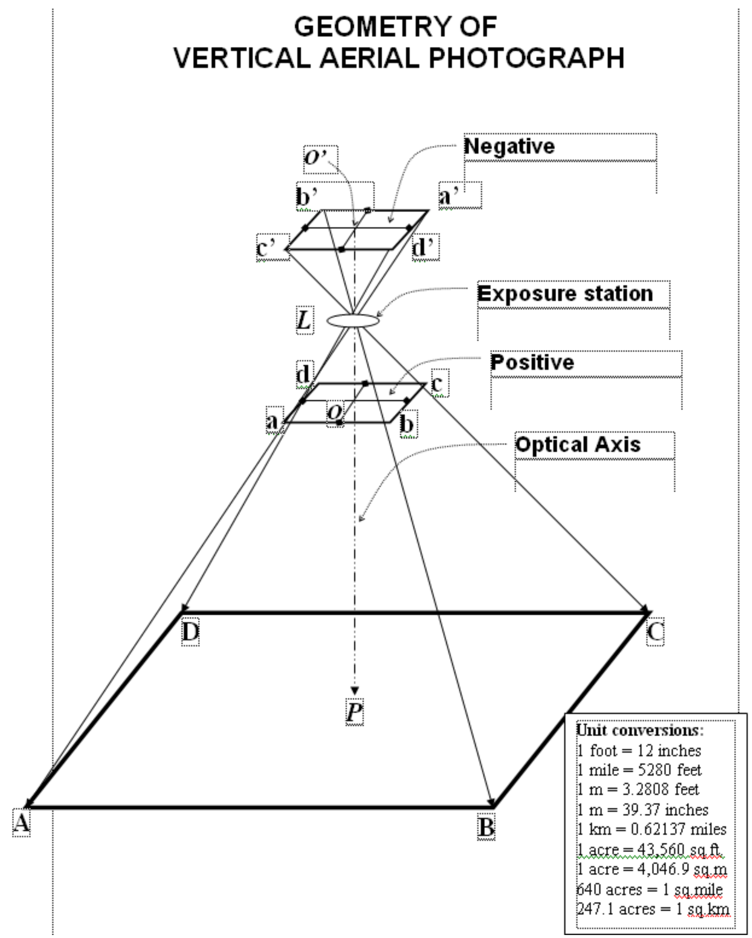
Isocenter: The point that falls on a line halfway between the Principal Point and the Nadir.

Tilt displacement radiates from the isocenter

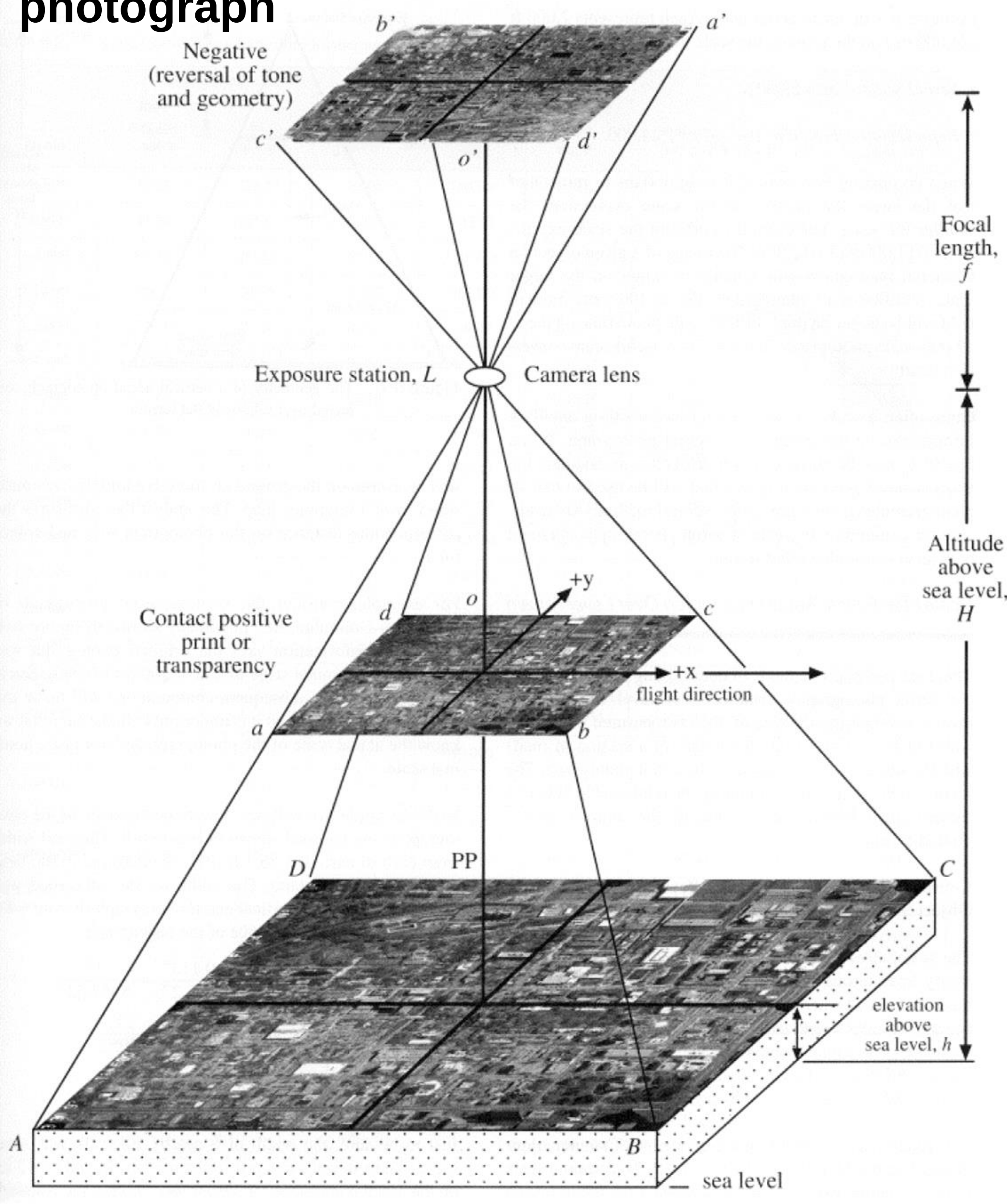




Geometry of a vertical aerial photograph



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)

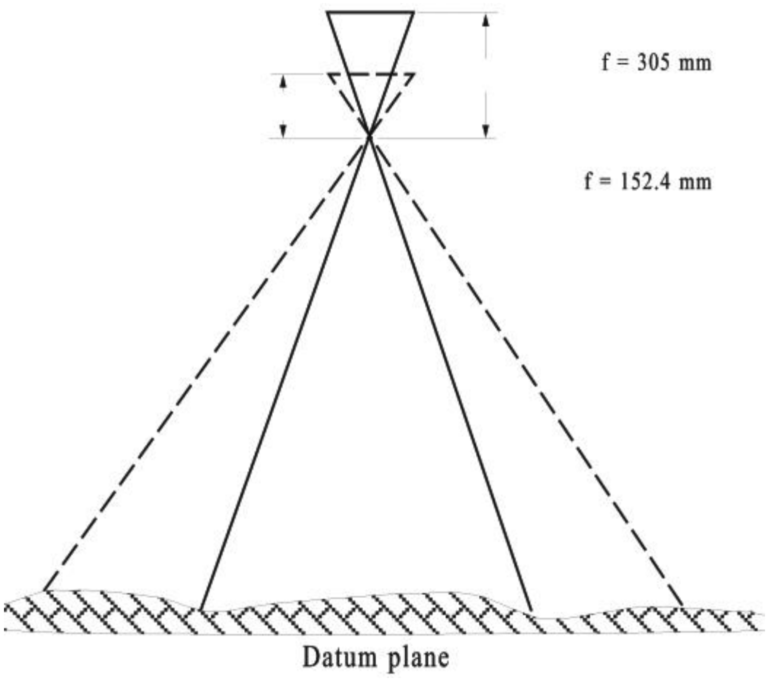
Field of View – The region which is collected in the photograph is often referred to as the camera system's field of view (FOV

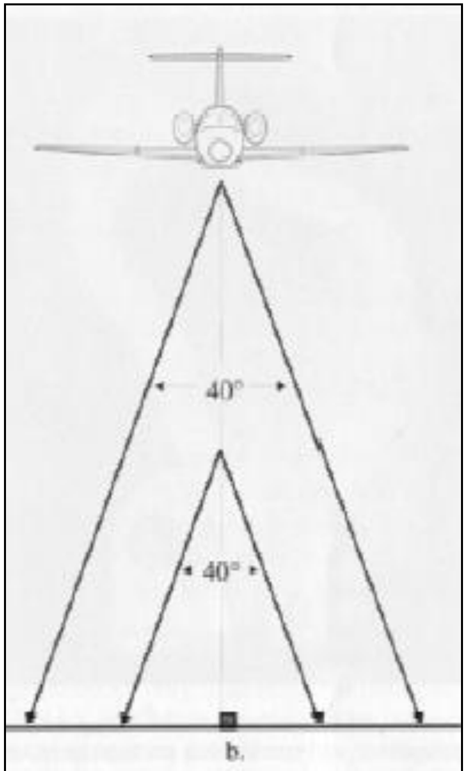
Relationship between aircraft altitude and ground coverage

➔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

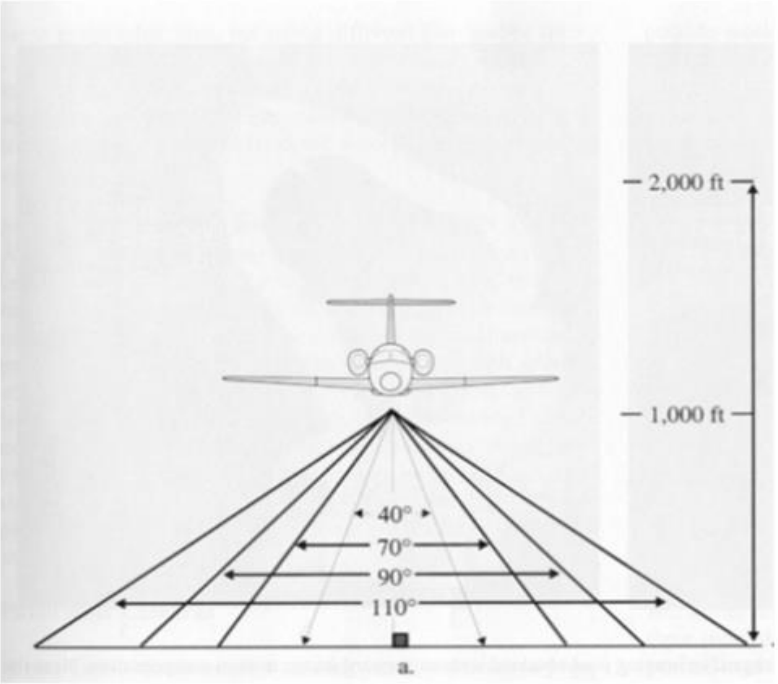
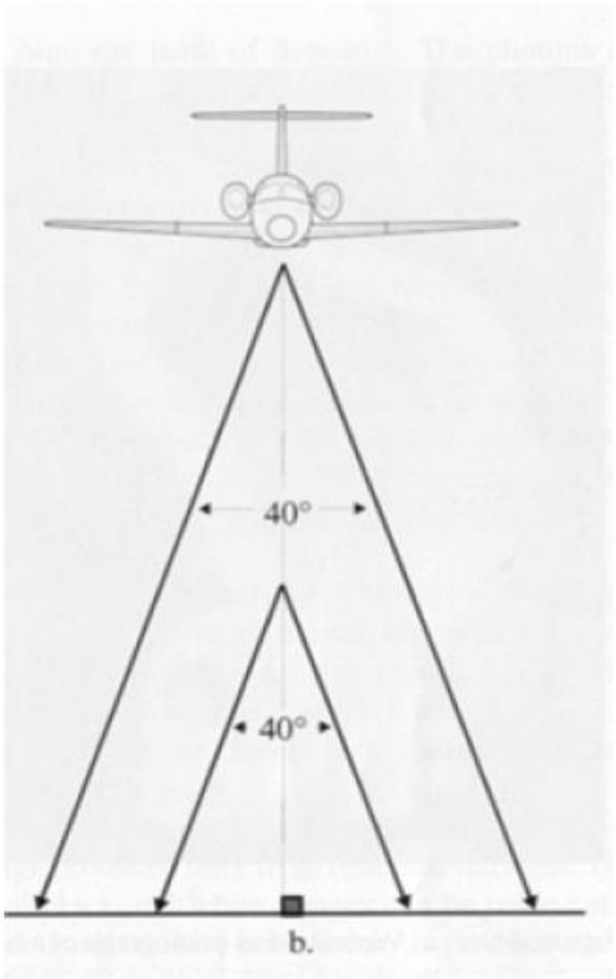


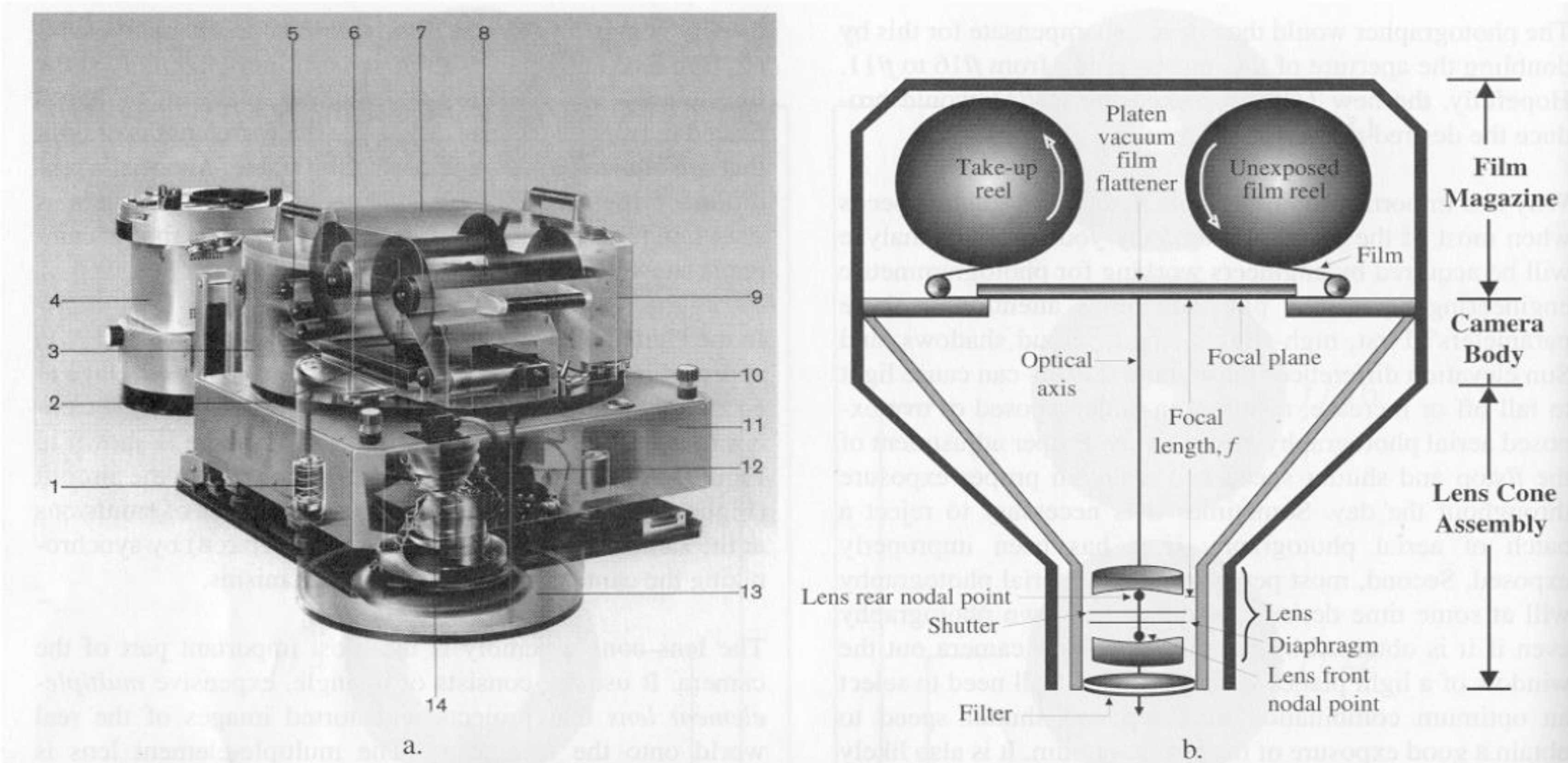
Figure 23

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

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



Aerial metric camera



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.

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.