Lecture 13 -18:

Fundamentals of Photogrammetry

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ACKNOWLEDGEMENT

These slides are aggregations for better understanding of the topic mentioned in the previous slide . I acknowledge the contribution of all the authors and photographers from where I tried to accumulate the info and used for better presentation.

Topics to be Covered by this Presentation

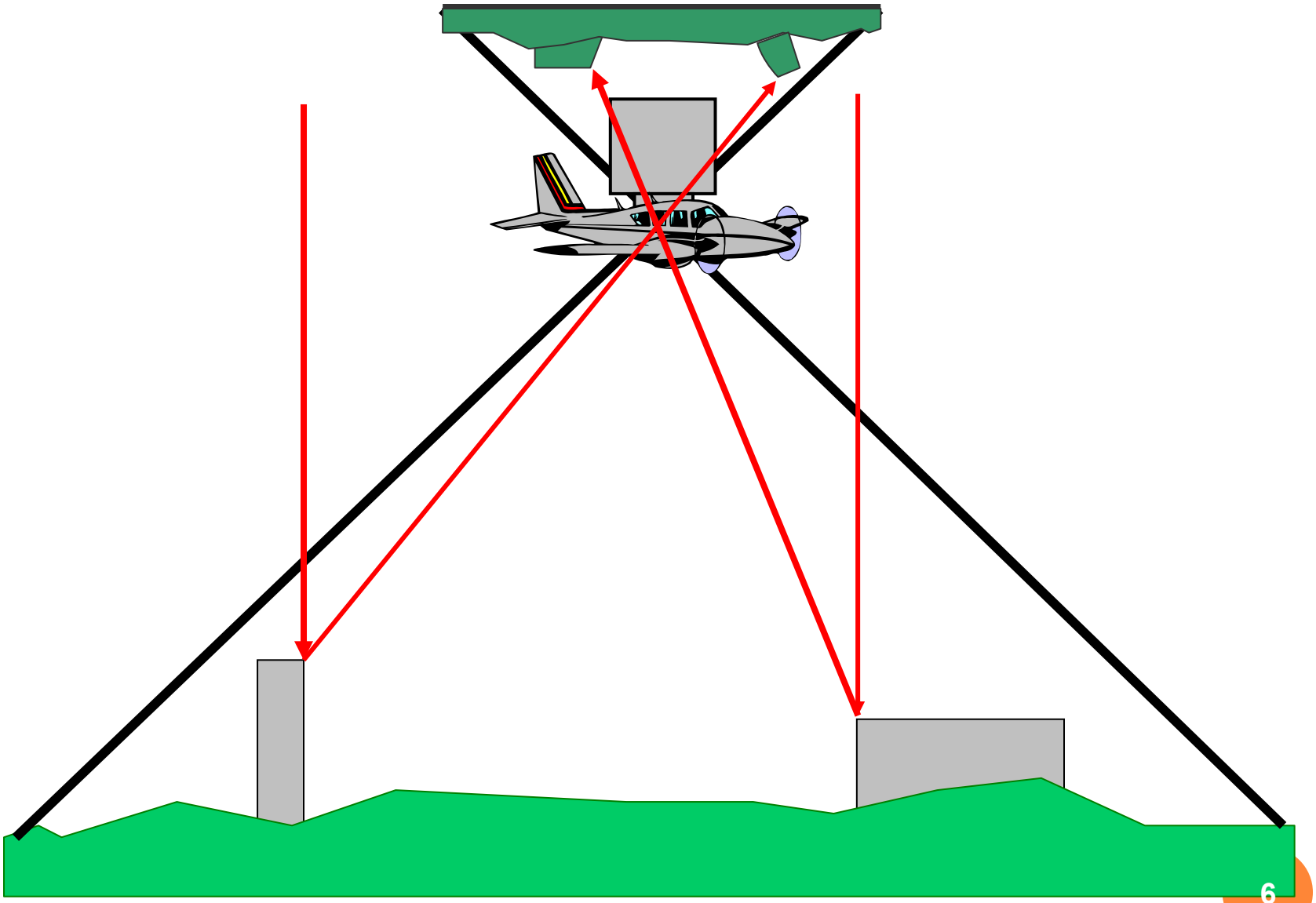
- What is Photogrammetry
- Single Photograph Approximations
- Multiple Photograph Measurements
- Brief History of Photogrammetry
- Origins of Photograph and Remote Sensing
- Color Science
- Types of photographs
- Satellite photographs
- Basic Information on photogrammetry
- Types of Aerial Photographs
- Some Basic Definitions
- Scale of Photograph
- Parallax
- Orthophotographs and digital orthoimagery
- Orthorectification
- Photographic Interpretation
- Applications of Photogrammetry

PHOTOGRAMMETRY

Photogrammetry is…

A means of obtaining information from aerial photographs

Photogrammetry is the Science



PHOTOGRAMMETRY

- Photo = "Picture",
- Grammetry = "Measurement",

therefore

- Photogrammetry = "photo-measurement"

- Definition of Photogrammetry: the art, science, and technology of obtaining information about physical objects and the environment by photographic and electromagnetic images, in order to determine characteristics such as size, shape and position of photographed objects.

What is Photogrammetry

- **Photogrammetry** is the art and science of making accurate measurements by means of aerial photography:
  - Analog photogrammetry (hard-copy photos)
  - Digital photogrammetry (digital images)

- Aerial photographs were the first form of remote sensing imagery.

- Differences between photogrammetry and Remote Sensing are that photographs are:
  - Black and white (1 band) or color (blue, green, red, and IR)
  - Wavelength range of 0.3-1.0 μm
  - Use cameras
  - One type of remote sensing imagery

Photogrammetry

- Science (or art) of deducing the physical dimensions of objects from measurements on photographs
- Mapping the earth or other bodies in the solar system
- Sometimes used to indirectly measure the geometry of buildings, dams, archeological sites using photographs.
- Sometimes the same principles are applied to digital imagery from satellite-based RS platforms.

Photogrammetry

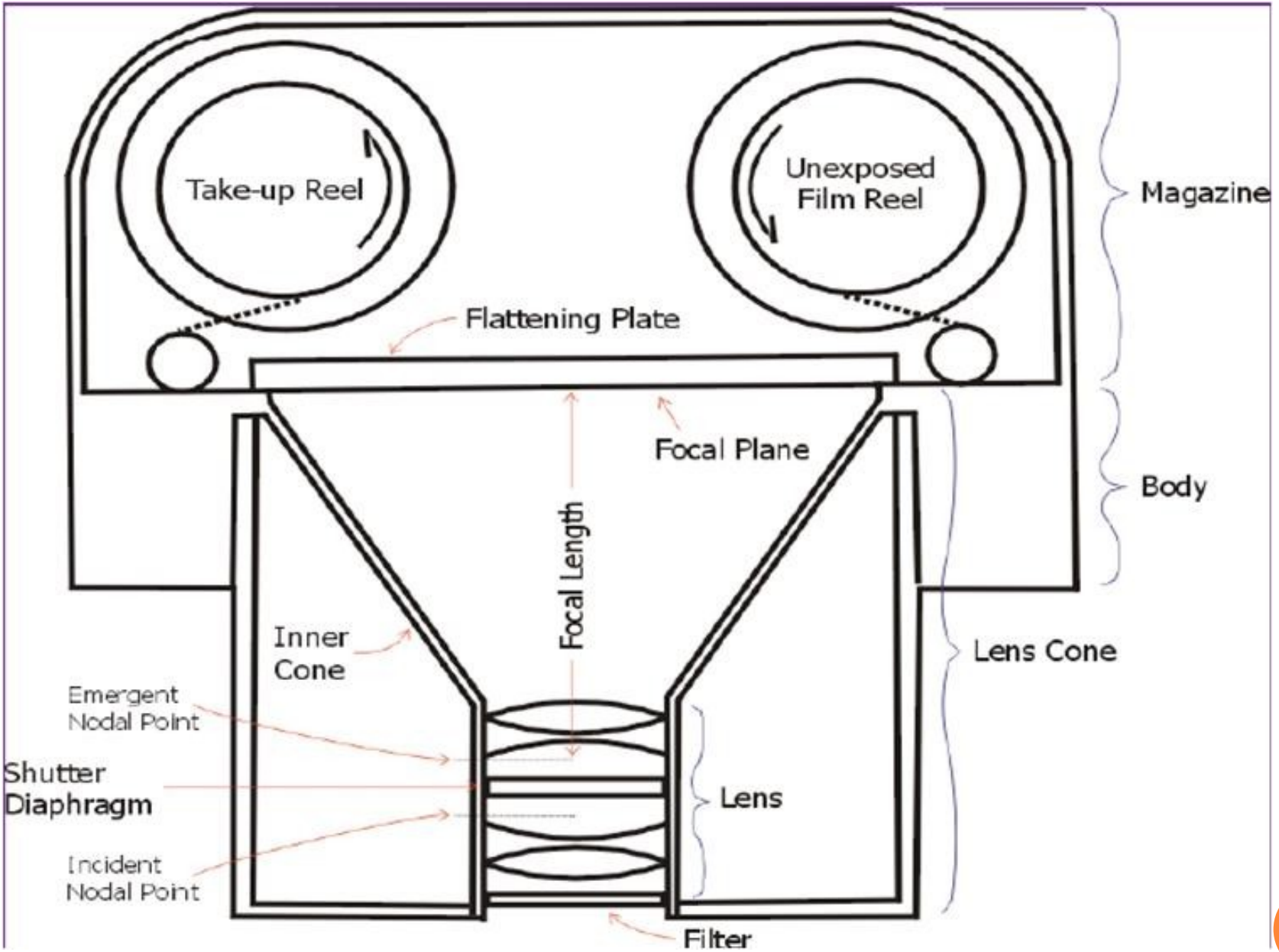
Photogrammetry is the technique of measuring objects (2D or 3D) from photographs.

Its most important feature is the fact, that the objects are measured **without being touched**.

PHOTOGRAMMETRY

- Objects are measured WITHOUT TOUCHING.
- It is a REMOTESENSING technique.
- It is a close range method of measuring objects.
- It is a 3-dimensional coordinate measuring technique that uses PHOTORAPHS as the fundamental medium for measurement.
- Modern Photogrammetry also uses radar imaging, radiant electromagnetic energy detection and x-ray imaging – called remote sensing.

AERIAL CAMERA



Photogrammetry

- Has many uses
- Very economical as opposed to on site surveying

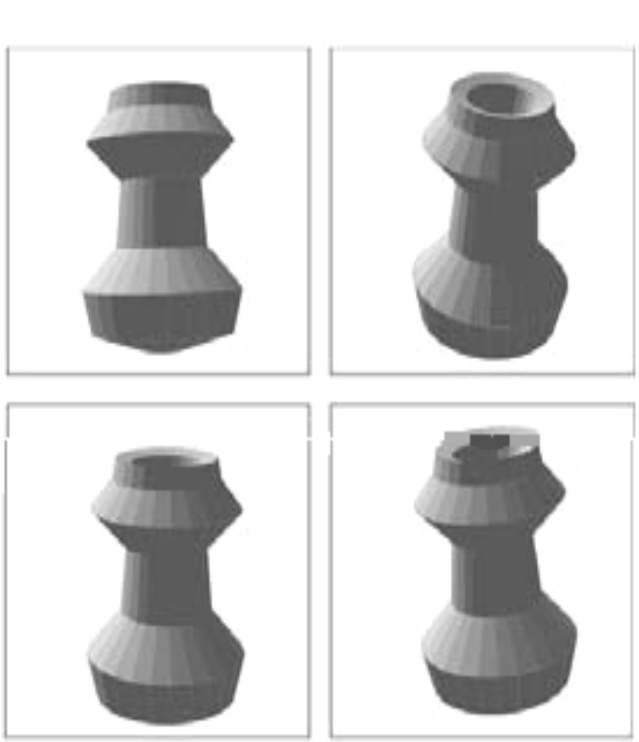
PHOTOGRAMMETRY PRINCIPLE

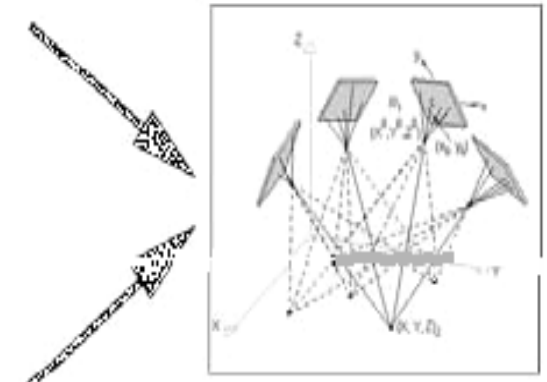
- The main principle is "TRIANGULATION".
- Eyes use the principle of TRIANGULATION to gauge distance (depth perception).
- TRIAGULATION is also the principle used by theodolites for coordinate measurement.
- By taking photographs from at least two different locations, so-called "lines of sight" can be developed from each camera to points on the object. These lines of sight (sometimes called rays owing to their optical nature) are mathematically intersected to produce the 3-dimensional coordinates of the points of interest.

IS THIS A REAL CAR ? ?

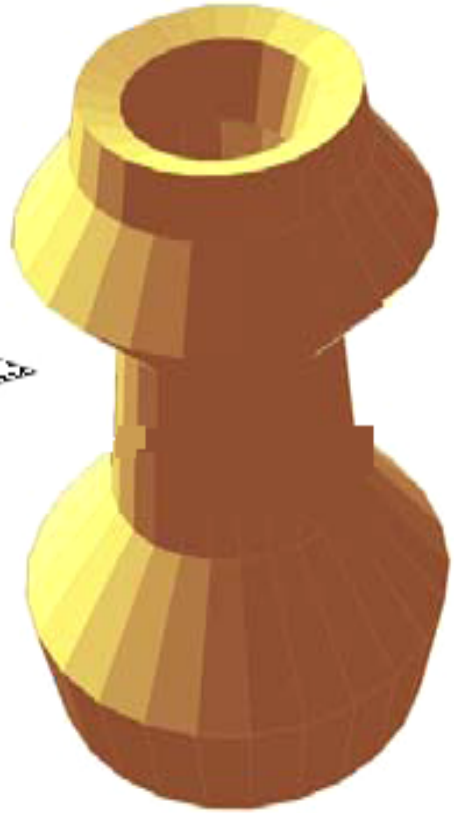
NOW YOU CAN TELL !!

PHOTOGRAPHY THE FIRST PART…





Photogrammetry



2D

3D

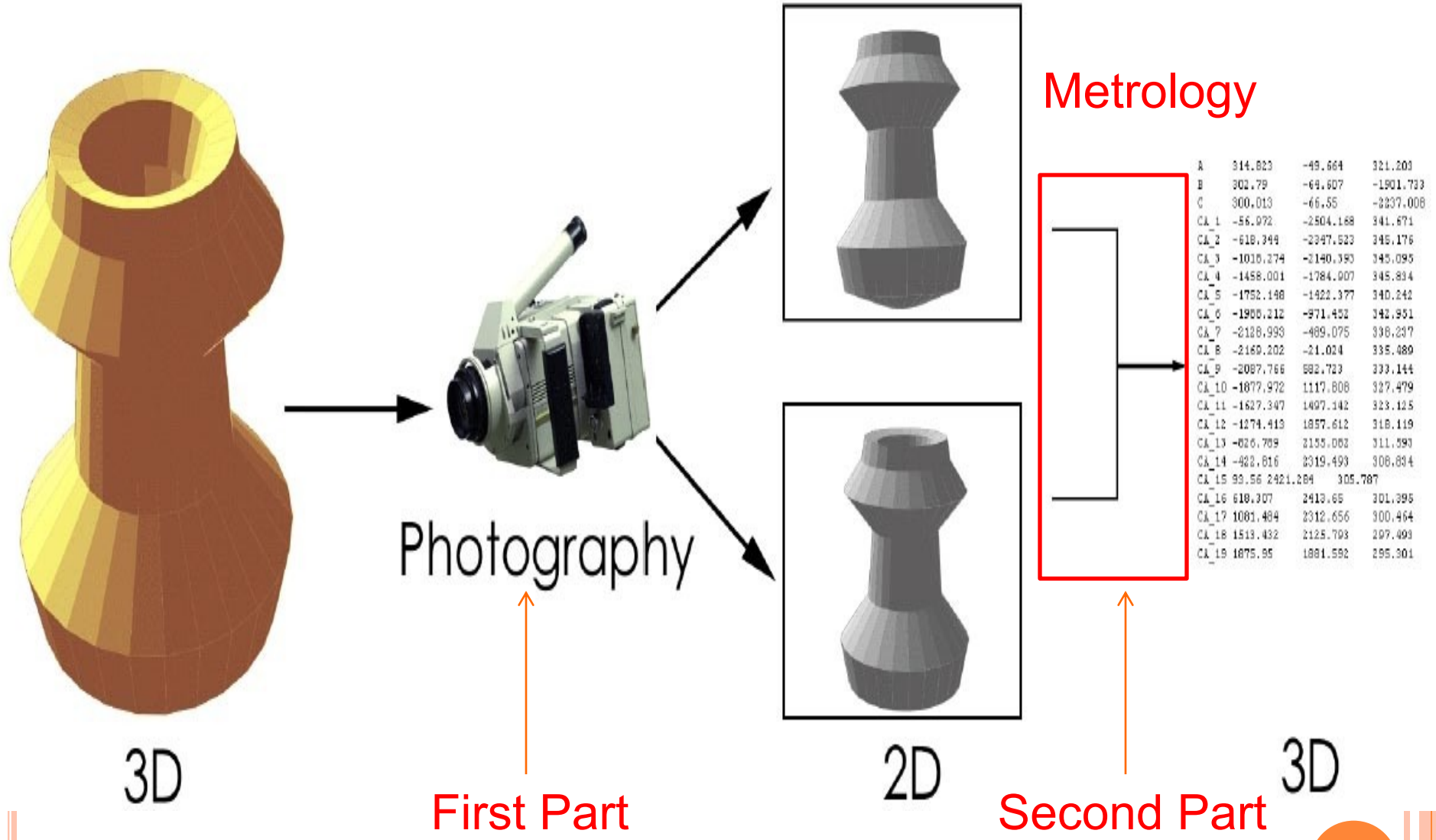
Photography - The First Part of Photogrammetry

Taking photographs is, of course, essential for making a photogrammetric measurement. To obtain the high accuracy, reliability and automation the system is capable of, photographs must be of the highest quality.

The three main considerations for good photography are:

1. Field of View
2. Focusing
3. Exposure

METROLOGY - THE SECOND PART OF PHOTOGRAMMETRY



Single Photograph Approximations

- Scale of Photograph
- Height of Objects (sometimes, based on shadow analysis)
- Length of Objects
- Areas of Regions
- Perimeter of Regions
- Tone of Objects

Multiple Photograph Measurements

- Object location
- Object height
- Contour Maps
- Orthophotoquads (Image orthorectification)
- Digital Elevation Models
  - Slope and Aspect from DEMs

Brief History of Photogrammetry

- 1851: **French officer Aime Laussedat develops the first photogrammetrical devices and methods**. He is seen as the initiator of photogrammetry.

- 1858: The German architect A. Meydenbauer develops photogrammetrical techniques for the documentation of buildings and installs the first photogrammetric institute in 1885 (Royal Prussian Photogrammetric Institute).

- 1885: The ancient ruins of Persepolis were the first archaeological object recorded photogrammetrically.

- 1889: The first German manual of photogrammetry was published by C. Koppe.

Brief History of Photogrammetry

- 1911: The Austrian Th. Scheimpflug finds a way to create rectified photographs. He is considered as the initiator of aerial photogrammetry, since he was the first succeeding to apply the photogrammetrical principles to aerial photographs

- 1913: The first congress of the ISP (International Society for Photogrammetry) was held in Vienna.

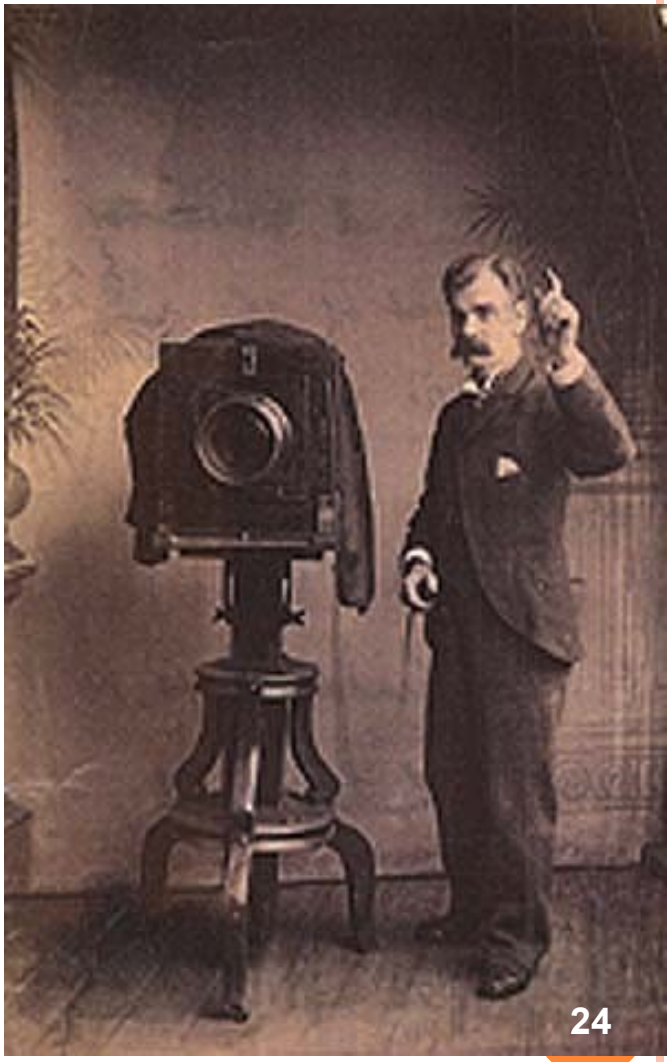
- 1980ies: Due to improvements in computer hardware and software, digital photogrammetry is gaining more and more importance.

- 1996: 83 years after its first conference, the ISPRS comes back to Vienna, the town, where it was founded.

Origins of Photograph and Remote Sensing

Remote sensing began with aerial photography

First photographs taken in 1839

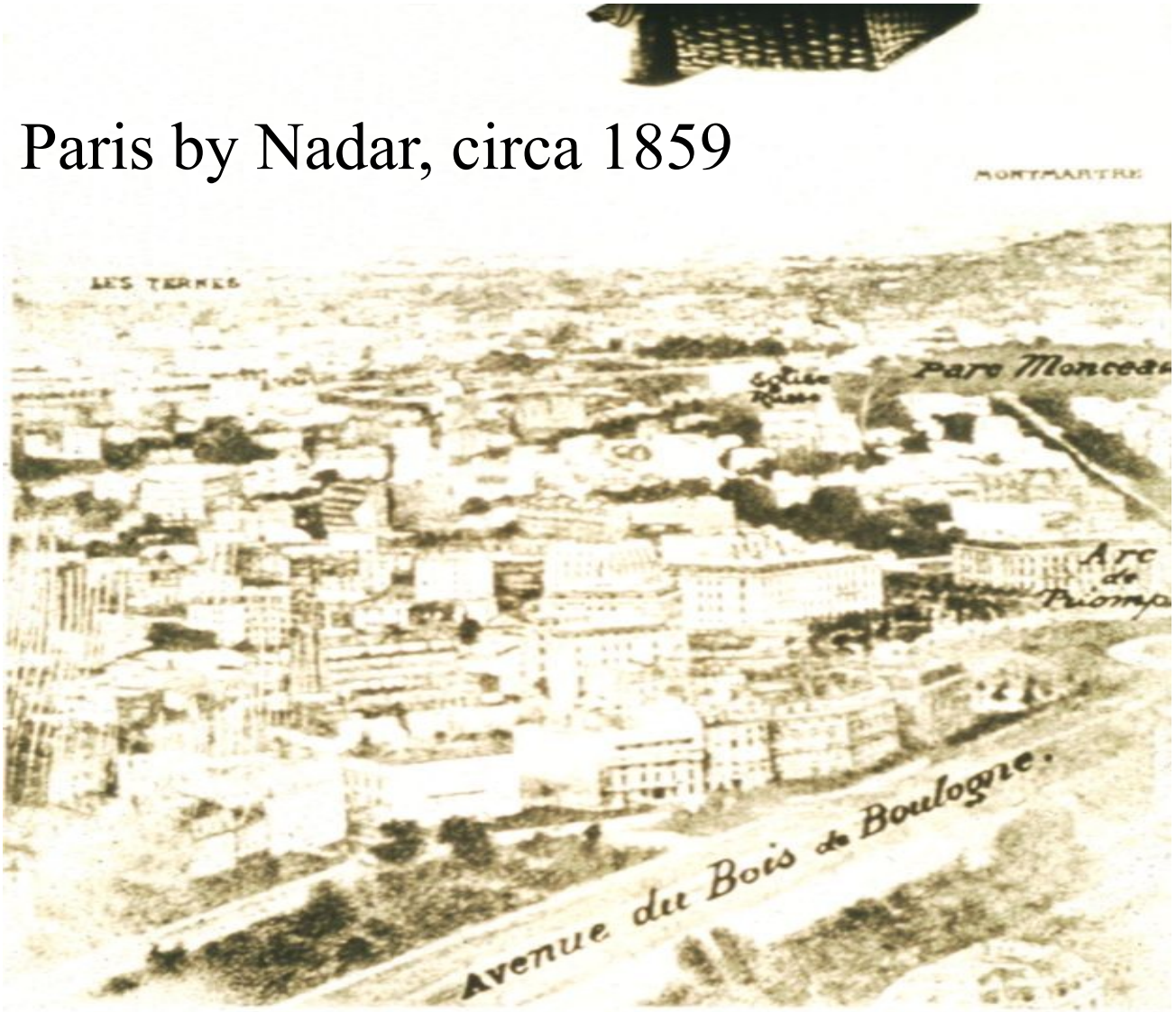


Origins of Photograph and Remote Sensing

1858 Gasper Felix Tournachon "Nadar" takes photograph of village of Petit Bicetre in France from a balloon

Origins of Photograph and Remote Sensing

Paris by Nadar, circa 1859



Origins of Photograph and Remote Sensing

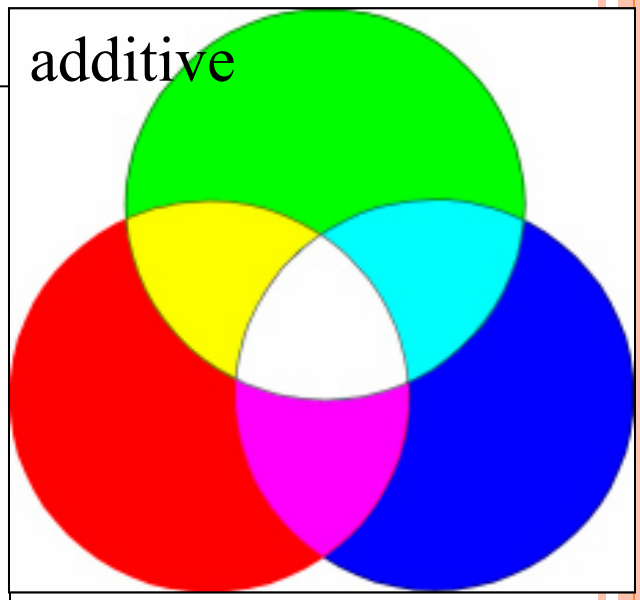
Boston by Black and King (1860)

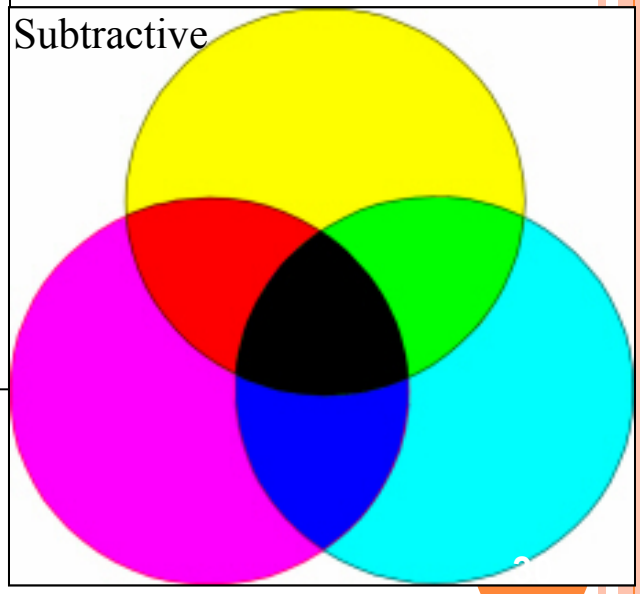
World War One was a major impetus to development of aerial photography

After the war the technology was in place to begin large scale aerial surveys

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 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 of 0.5-1.0 μm, or green, red, IR)
  - 4 bands (blue, green, red, and IR)

Color Science

Normal color (TCC)

False-color infrared (FCC)

Color Science

Normal color

False-color infrared

Satellite photographs

- Extensive collections of photographs have been acquired from manned and unmanned Earth or satellites.
  - Beginning in 1962, USA acquired photographs of moon for Apollo mission
  - 1995, USA declassified intelligence satellites photographs of Sino-Soviet acquired 1960-1972 at 2-8 m resolution.
  - 2000, Russia launched satellites acquired photographs of 2 meter resolution
  - 1999, Mars Global Surveyor of NASA acquires Mars photographs with 1.2 – 12 m resolution
  - 2003, Mars Express of ESA (European Space Agency) acquires Mars photographs with 2 and 10 m resolution.

Basic Information on PHOTOGRAMMETRY

- Mapping from aerial photos is the best mapping procedure yet developed for most large projects.
  - Used successfully for maps varying in scale from 1:1,000,000 to 1:120 with contour intervals as small as 1 foot.
  - Topographic mapping is the most common form. – USGS (United States Geological Survey) updated and done this way.
  - Used to reconstruct a scaled 3-dimensional optical model of the lands surface using a *stereoplotter*.
- Uses: Aerial photos
  - Aid: geological investigations, soil surveys, land surveys, tax mapping, reconnaissance and military intelligence, urban and regional planning and development, transportation system investigations, quantity estimates, shore erosion, etc.
  - Mathematical methods have been developed to make precise 3-dimensional measurements from photos.
    - Phototriangulation: 3-dimensional positioning of survey stations.

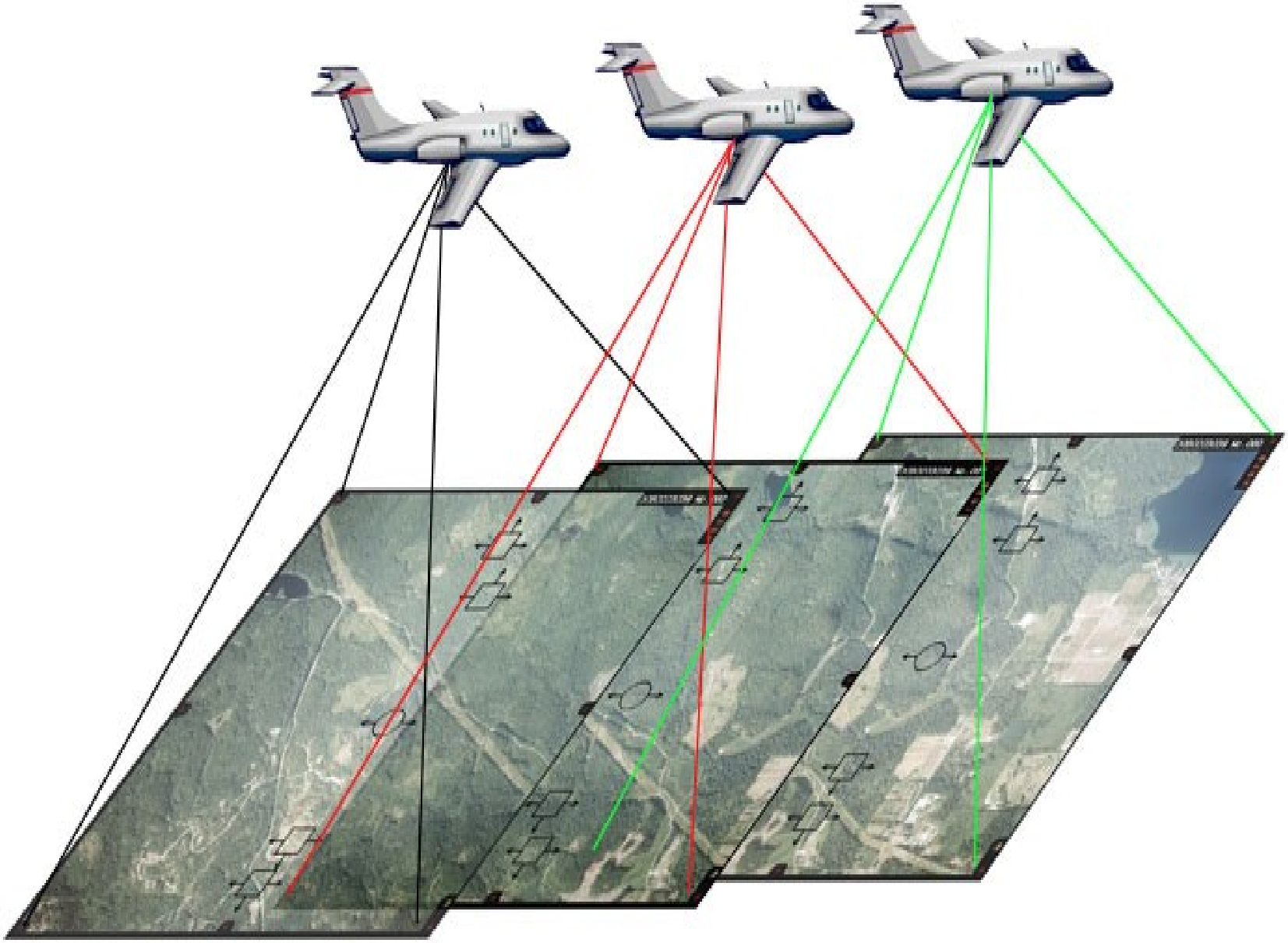
Basic Information on PHOTOGRAMMETRY

- Photo has been used to take geometric measurements of human bodies, artificial human hearts, large radio telescopes, ships, dams, buildings and very accurate reproductions.

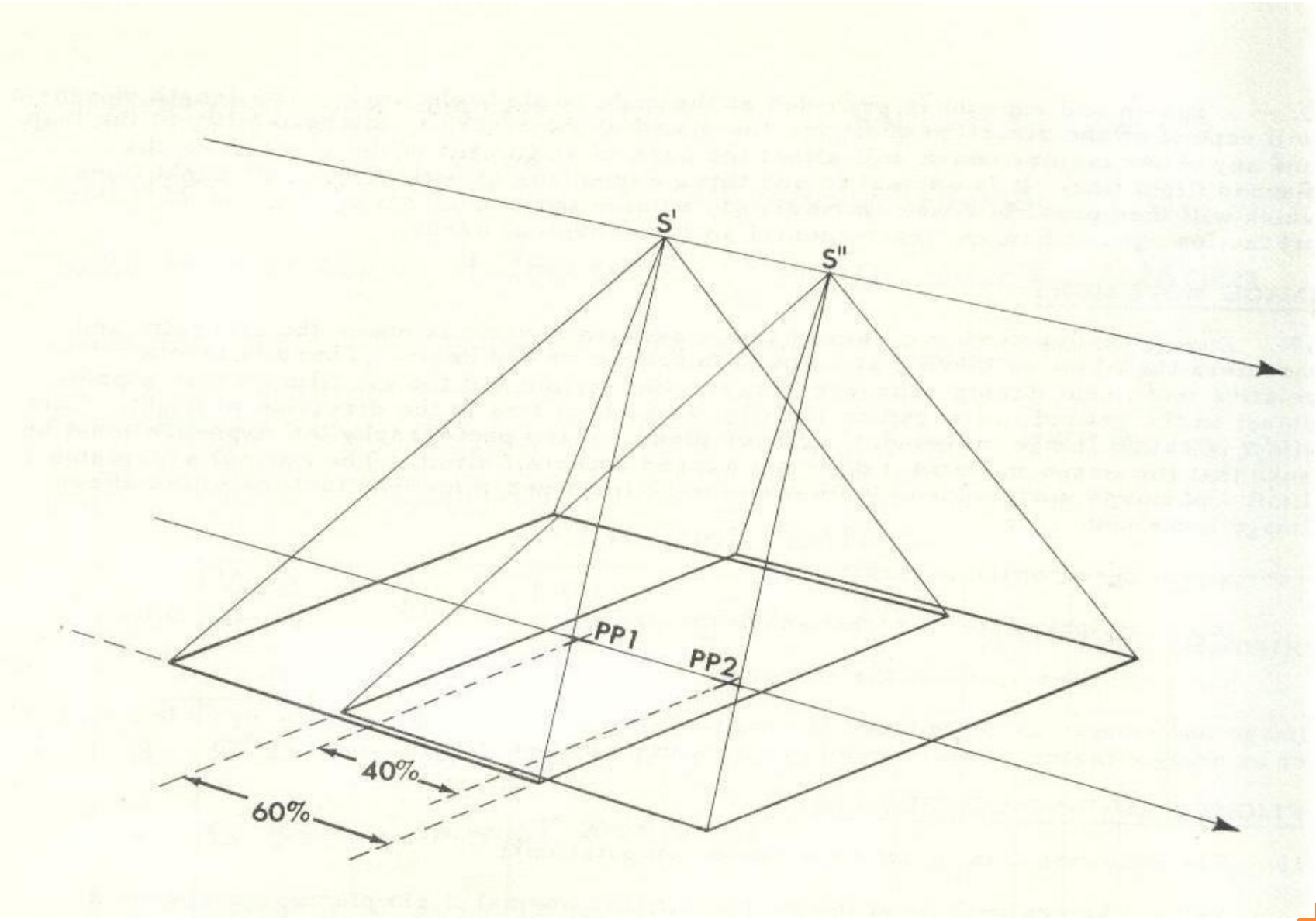
- In general it is not economical for small projects – the cost break even point is somewhere between 30 – 100 acres depending on the situation.
- Photogrammetry can not be used successfully over the following types of terrain.
  - Desert or plains areas, sandy beaches, and snow – the photograph as uniform shades with little texture.
  - Deep canyons or high buildings that conceal ground surface.
  - Areas covered by dense forest.

Photogrammetry

Photogrammetry



A Stereo pair of Aerial Photographs



THE BASIC CONCEPT OF STEREO PLOTTER

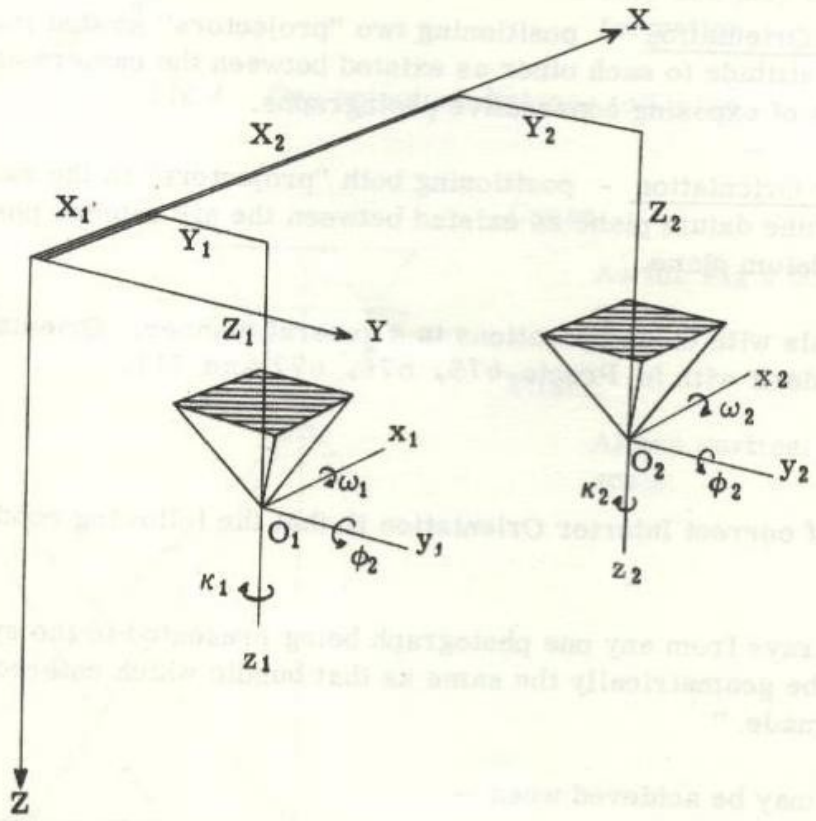
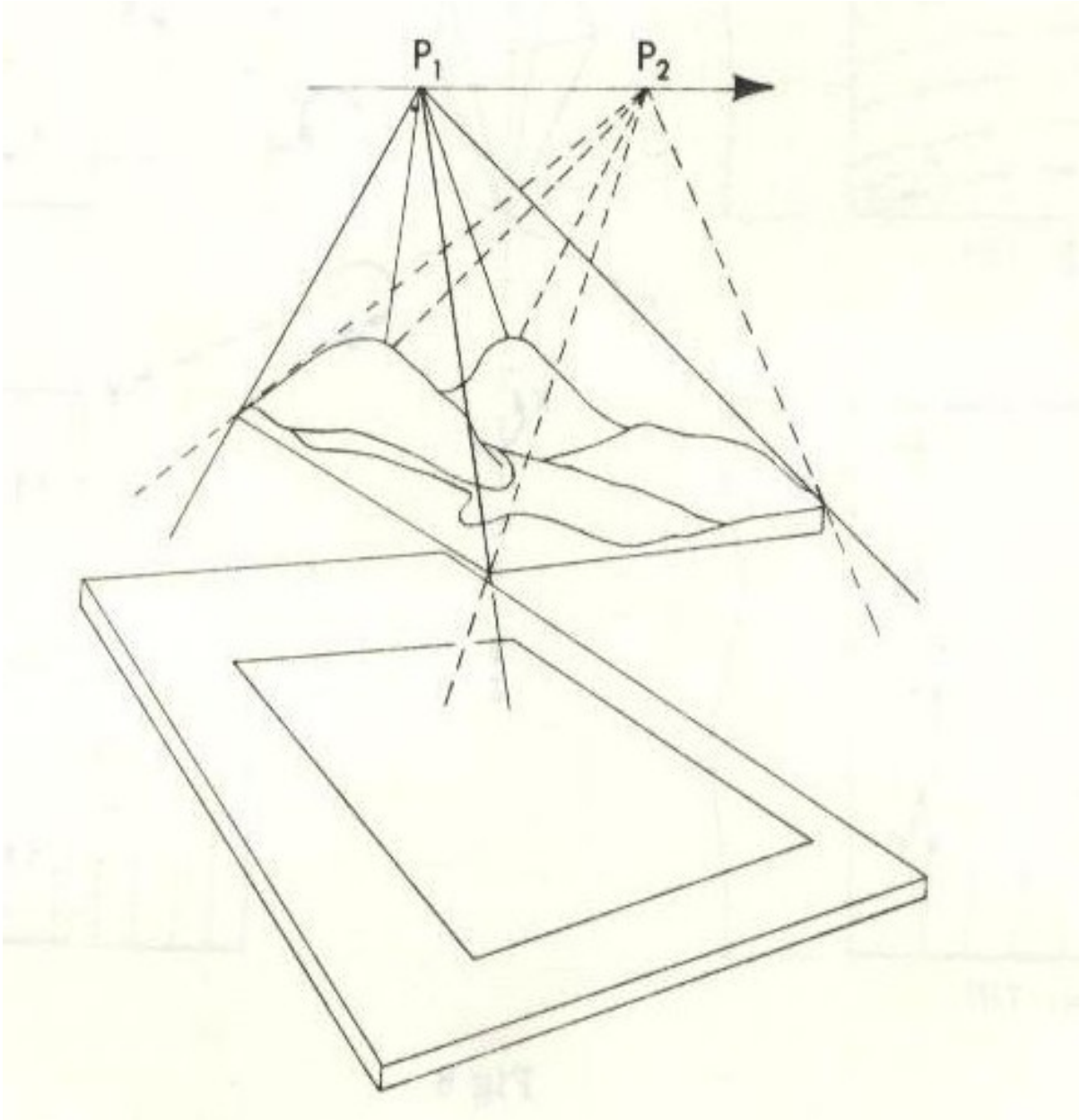


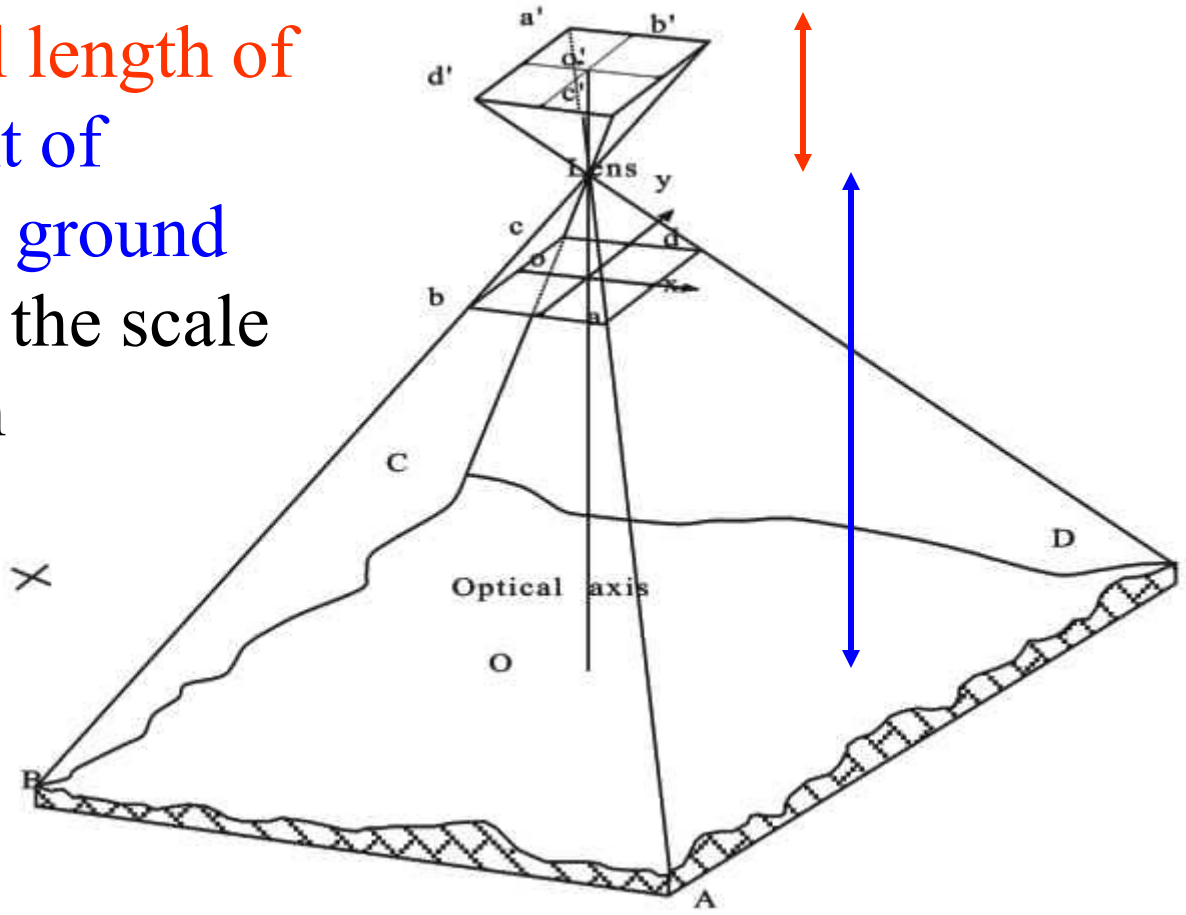
Fig 1 : Photogrammetric co-ordinate system

The Basic Concept of Stereo Plotter



PHOTOGRAMMETRY

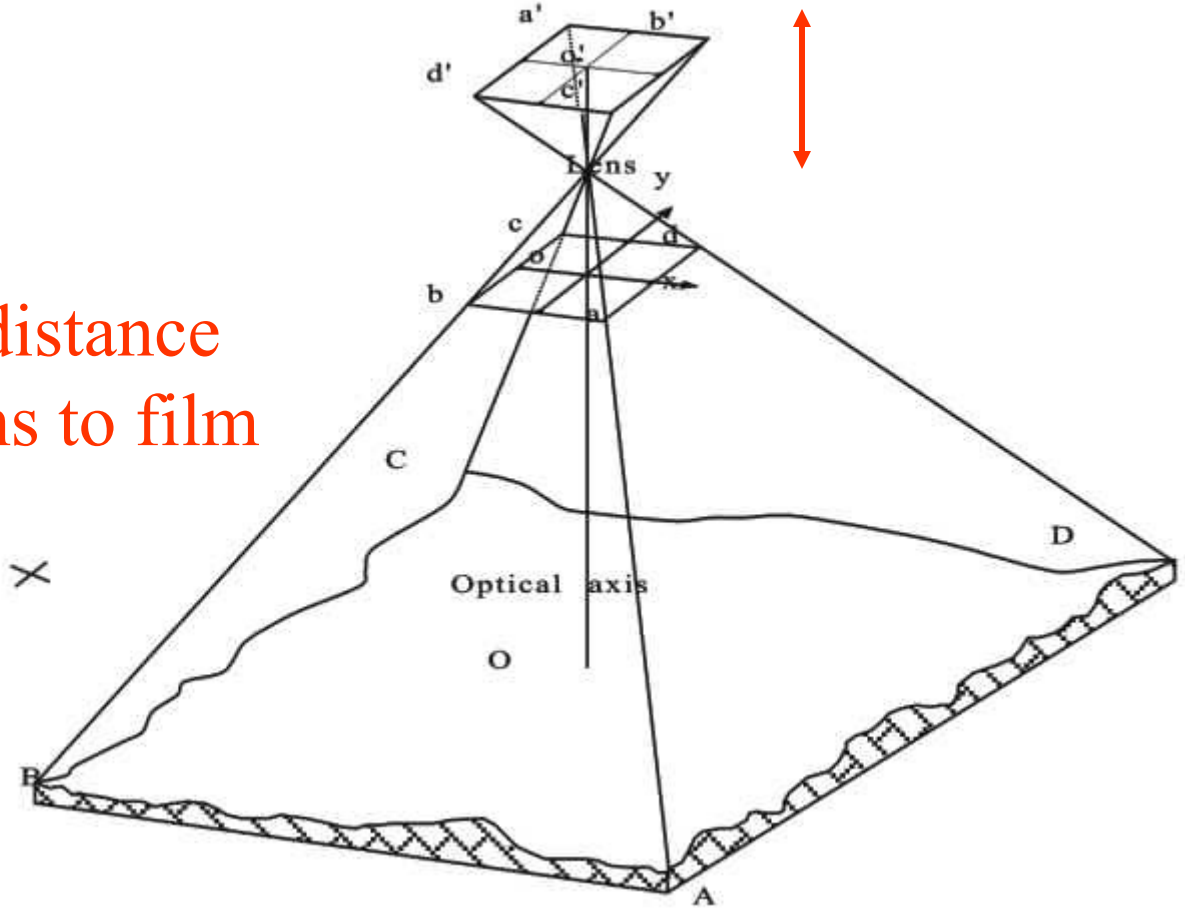
If you know focal length of camera and height of aircraft above the ground you can calculate the scale of the photograph



PHOTOGRAMMETRY

Scale = f/H-h

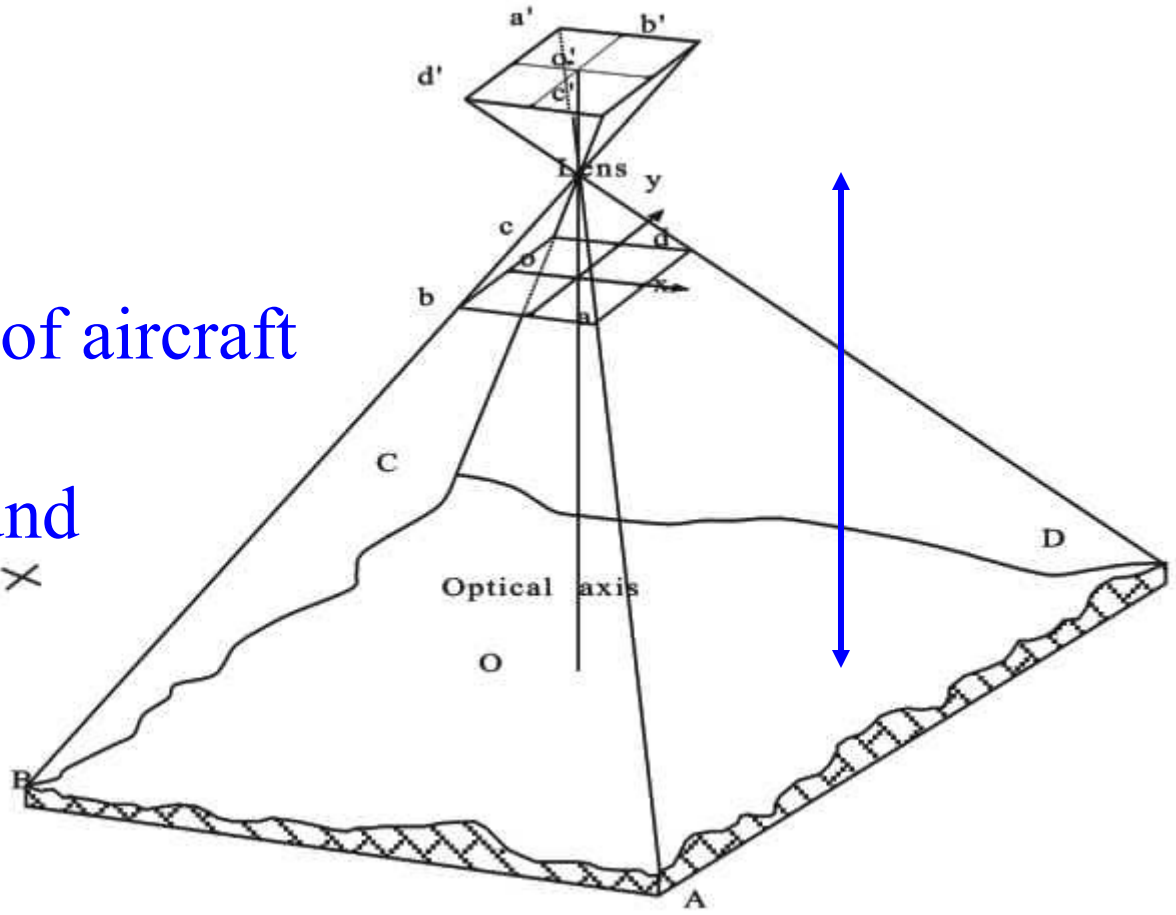
f = focal length (distance from centre of lens to film surface)



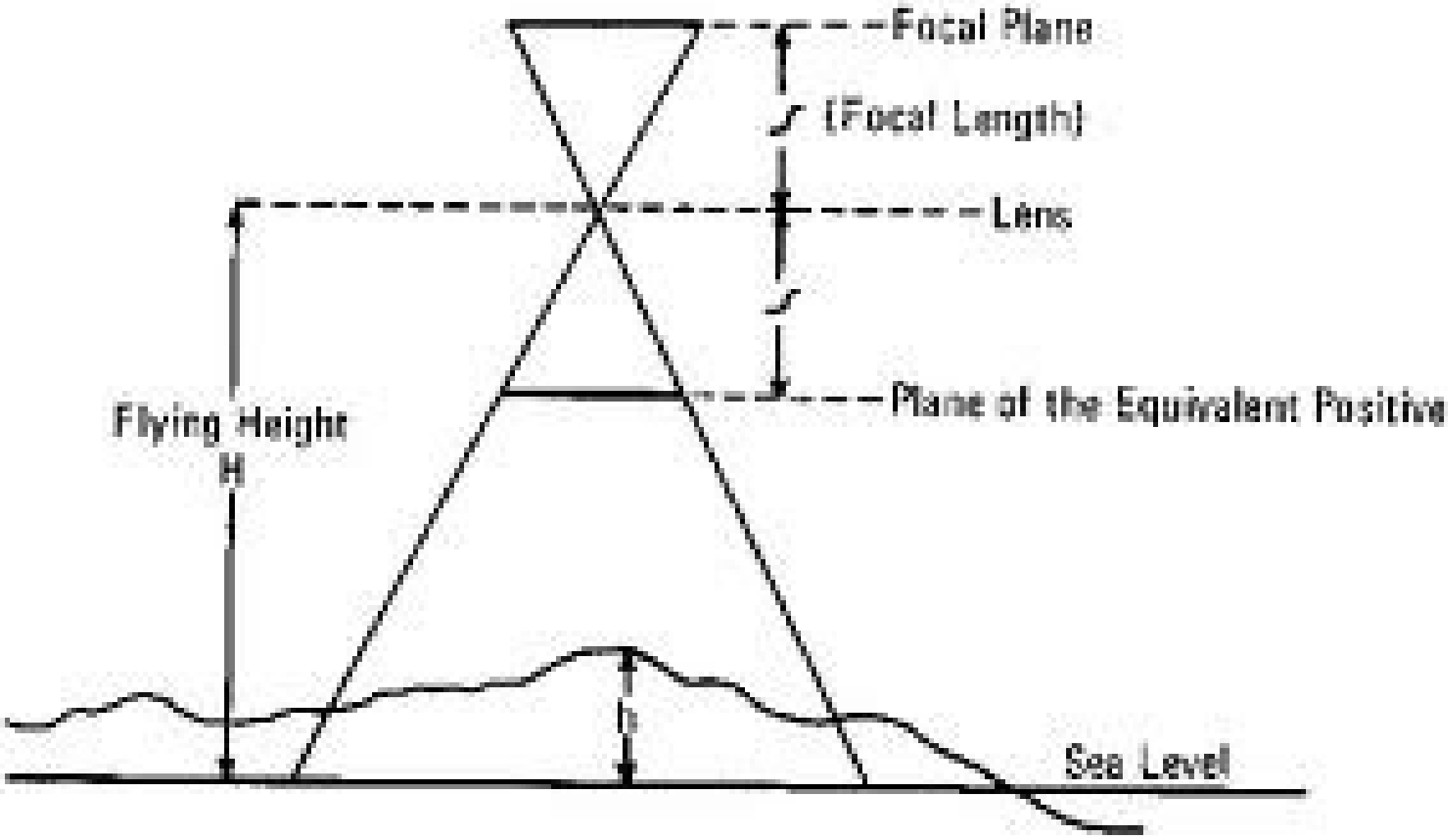
Scale = f/H-h

H = flying height of aircraft above sea level

h = height of ground above sea level



Scale of Photograph



Scale of a Vertical Photographs

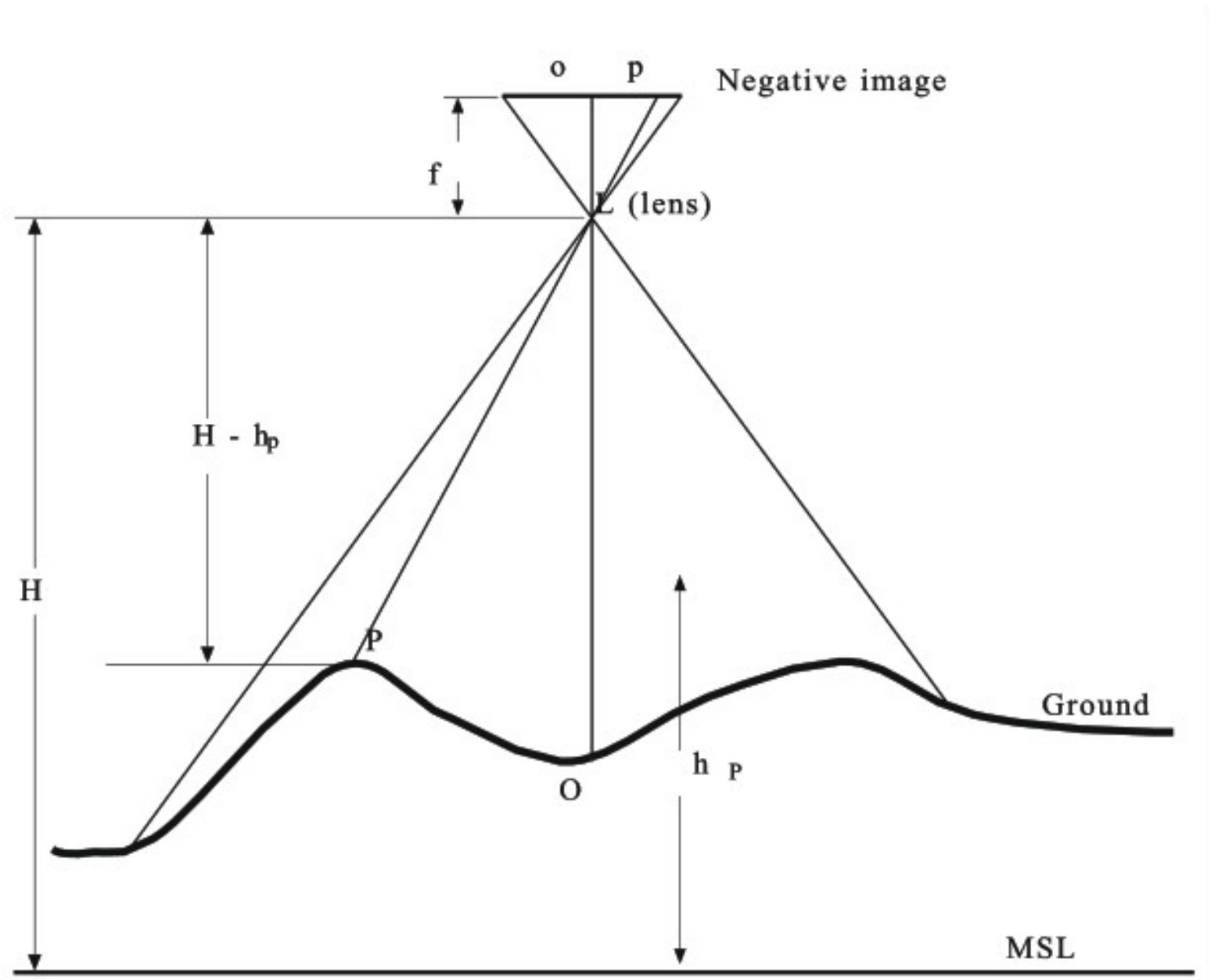
- To perform computations, one must know:
  - H = height above datum from which photos taken.
  - f = focal length of camera lens – in cm or mm

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

  = 1”/ 120”

  - f = focal length 6” or 152.4 mm is common
  - H’ = height of plane above ground
  - h = height (elevation) of ground
  - H = height of place above datum

Scale of a Vertical Photographs



Scale Varies from Point to Point

- Scale of photograph at point P on ground having elevation h_p $= \frac{f}{H - hp}$
- Scale for any point = s
- Representative fraction (R.F.) $= \frac{1}{\frac{f}{H - h}}$

Scale of a Vertical Photo

- **Datum Scale** = All the points of photograph are asumed to be projected on M.S.L. (R.L.± 0.00)

$$S_D = \frac{f}{H}$$

- **Average Scale** = All the points of photograph are asumed to be having average elevation above m.s.l.

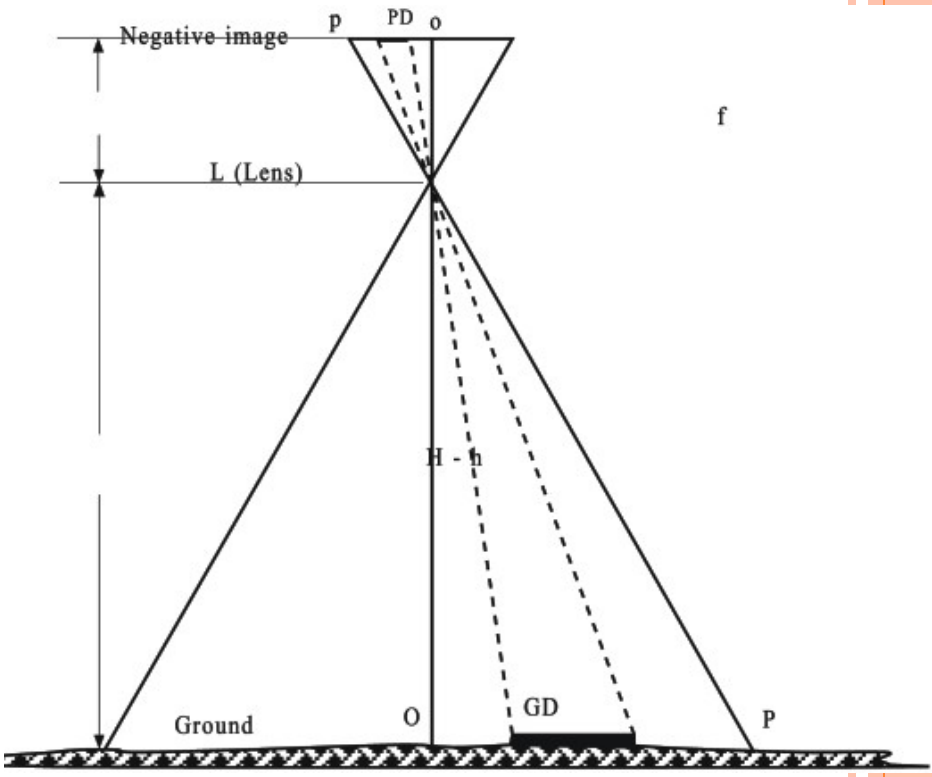
$$S_{AV.} = \frac{f}{H - h_{av.}}$$

Other methods of finding scale of vertical photograph

$$PS = \frac{PD}{GD}$$

$$MS = \frac{MD}{GD}$$

PS is the photo scale,
MS is the map scale,
PD is the photo distance measured between two well identified points on the photograph,
MD is the map distance measured between two points on the map, and
GD is the ground distance between the same two points on the photograph (or on the map), expressed in the same units.



- **By measuring Ground distance**

$$\text{Scale of photograph} = \frac{Photo\ Distance}{Ground\ Distance} = \frac{L_p}{L_g}$$

- **By determining the distance from existing map**
  - L_p = Photo distance
  - L_g = distance on existing map

$$\frac{\text{Scale of photograph } S_p}{\text{Scale of existing map } S_m} = \frac{Photo\ Distance\ L_p}{Ground\ Distance\ L_g}$$

$$\text{Scale of photograph } (S_p) = S_m \times \frac{L_p}{L_g}$$

EXAMPLE

Assume that the distance between two points was measured to be 83.33 mm on a vertical photograph and 125.00 mm on a map. If the surveying ground distance between the same two points is 3000 m, what are the scales and the scale reciprocals of the photograph and the map?

Solution

From equations

$$PS = \frac{83.33mm}{3000x1000mm} = 1:36000$$

$$MS = \frac{125mm}{3000x1000mm} = 1:24000$$

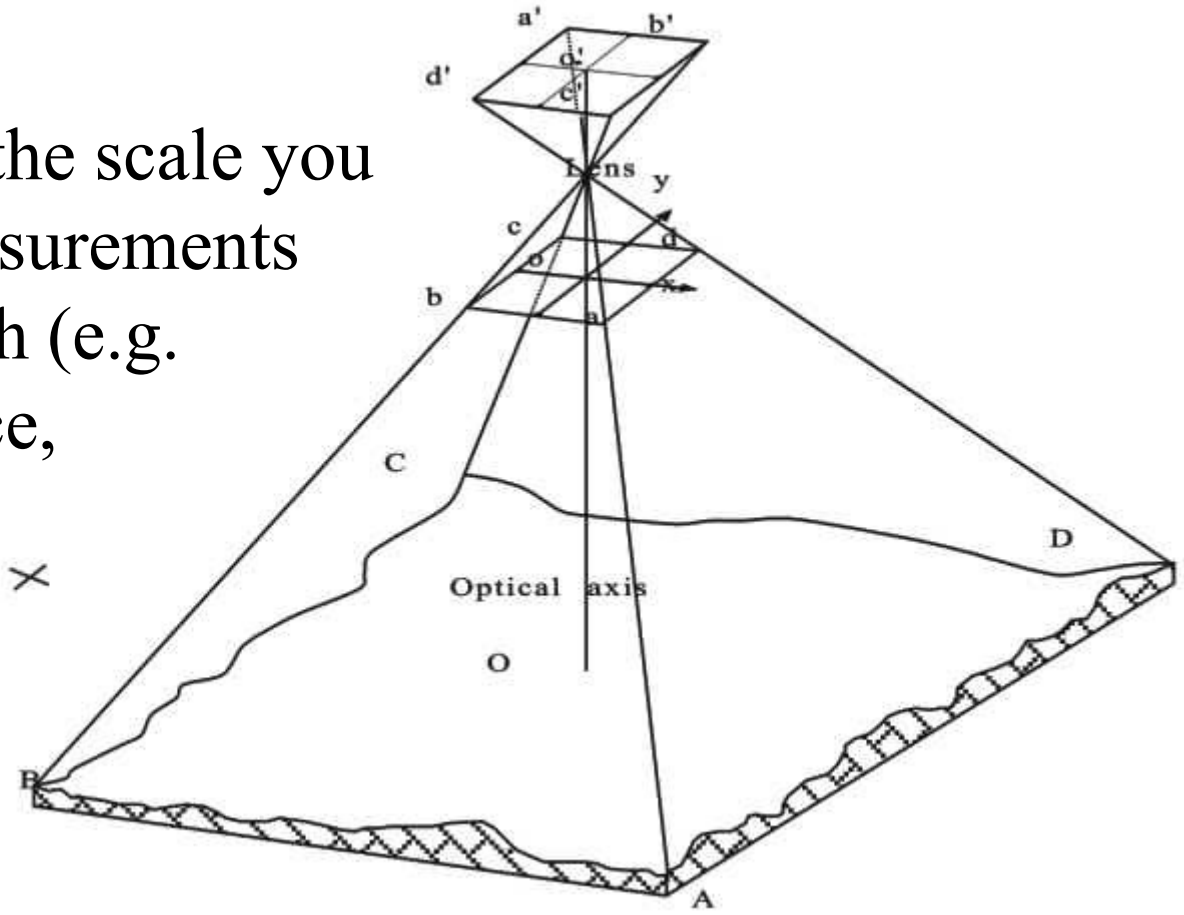
and

$$PSR = \frac{1}{PS} = \frac{1}{1/36000} = 36000$$

$$MSR = \frac{1}{MS} = \frac{1}{1/24000} = 24000$$

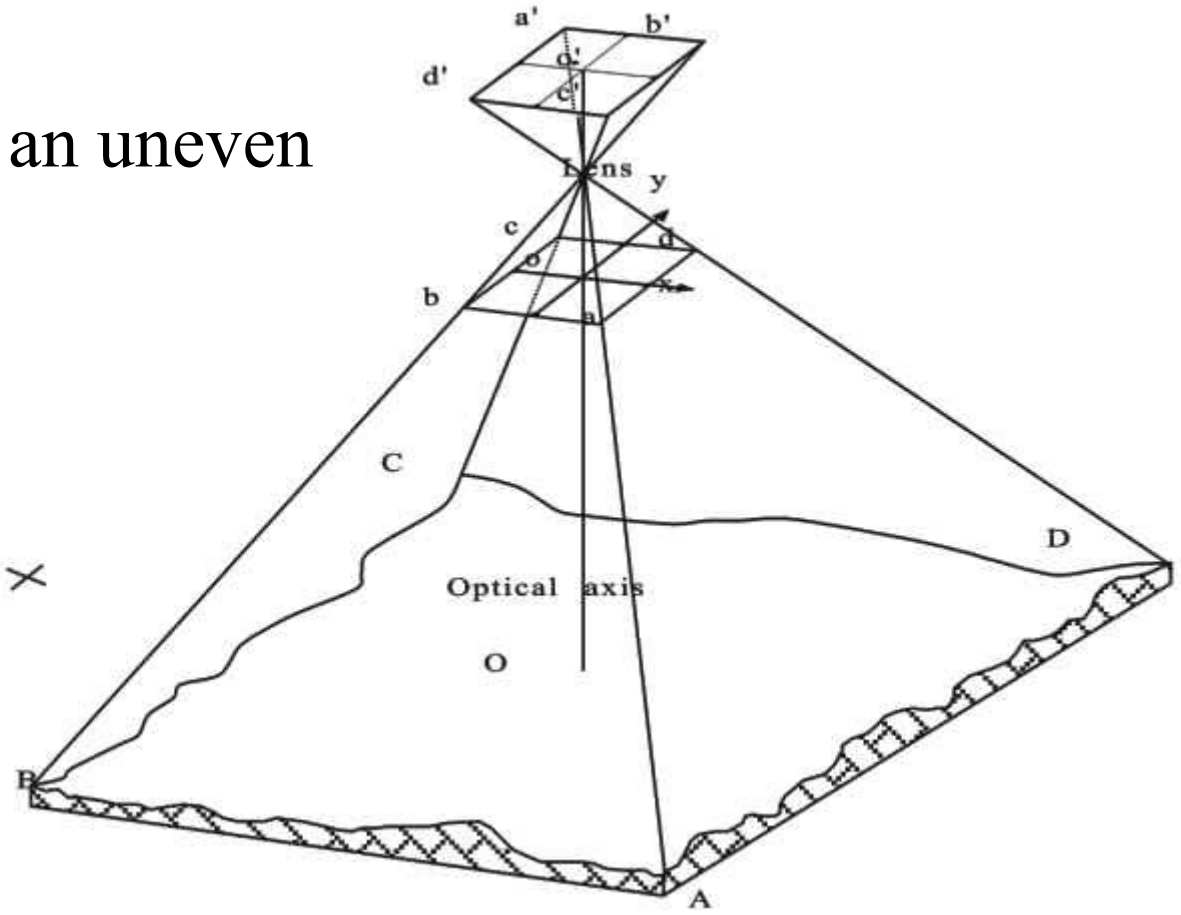
PHOTOGRAMMETRY

When you know the scale you can take 2-D measurements from a photograph (e.g. horizontal distance, horizontal area, etc.)



PHOTOGRAMMETRY

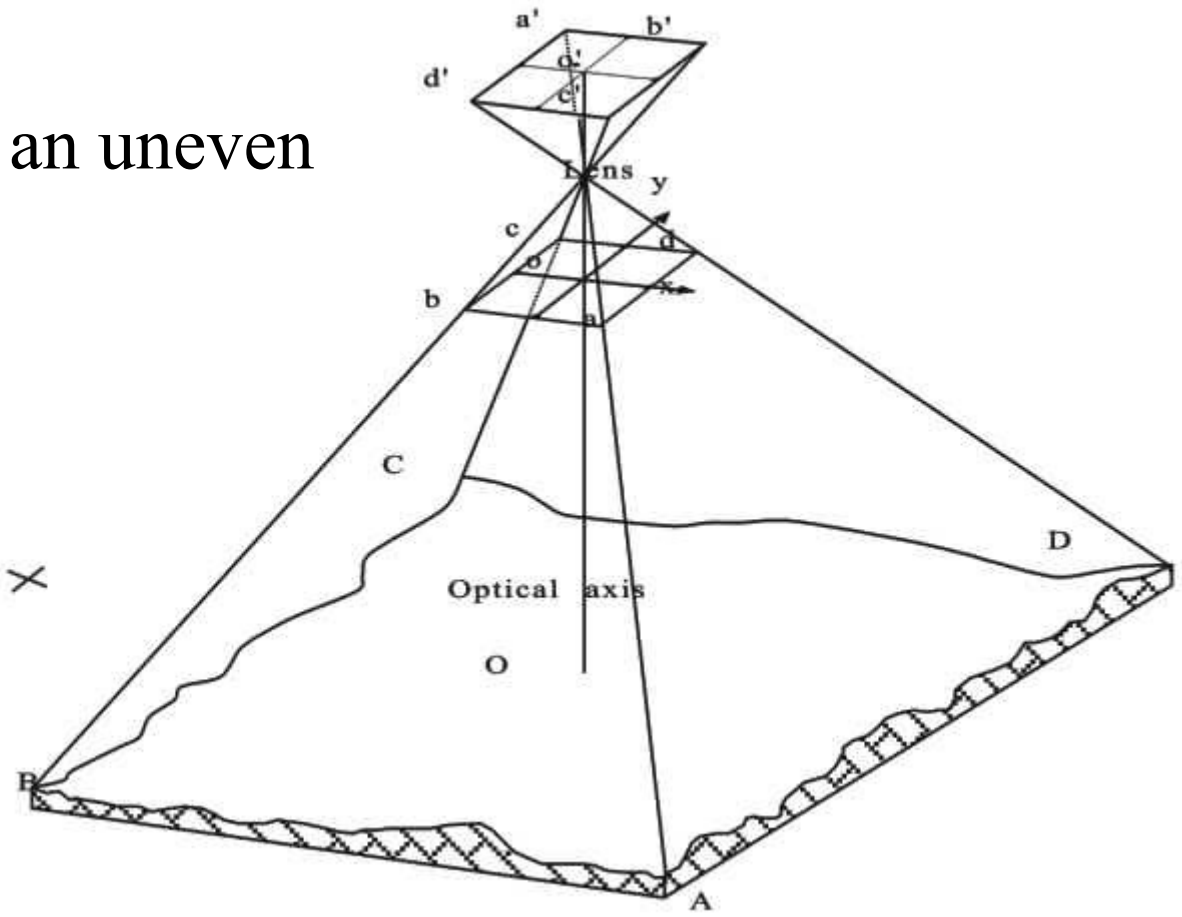
But to take "true" measurements on an uneven surface you need to work in 3-D



PHOTOGRAMMETRY

But to take "true" measurements on an uneven surface you need to work in 3-D

You can do this thanks to parallax



Two Basic Categories

- Photogrammetry -→ Known as Aerial survey
- Classification of Photogrammety

Terrestrail Photogrammetry

Photographs are taken from fixed position on or near the ground

Aerial Photogrammetry

Photographs are taken by a camera mounted in an aircraft flying over the area

Types of Aerial Photographs

Vertical Photographs-

- Axis of camera vertical < 3°

Oblique photographs:

- Axis of camera inclined to vertical line > 3°

Convergent photographs

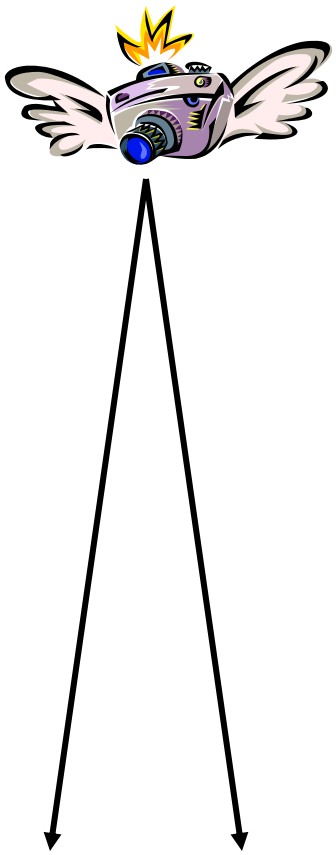
- Photographs taken with pair of camera with axis inclined

Trimetrogen photographs

- Photographs taken simultaneously from pair of camera with axis vertical and other slightly tilted.

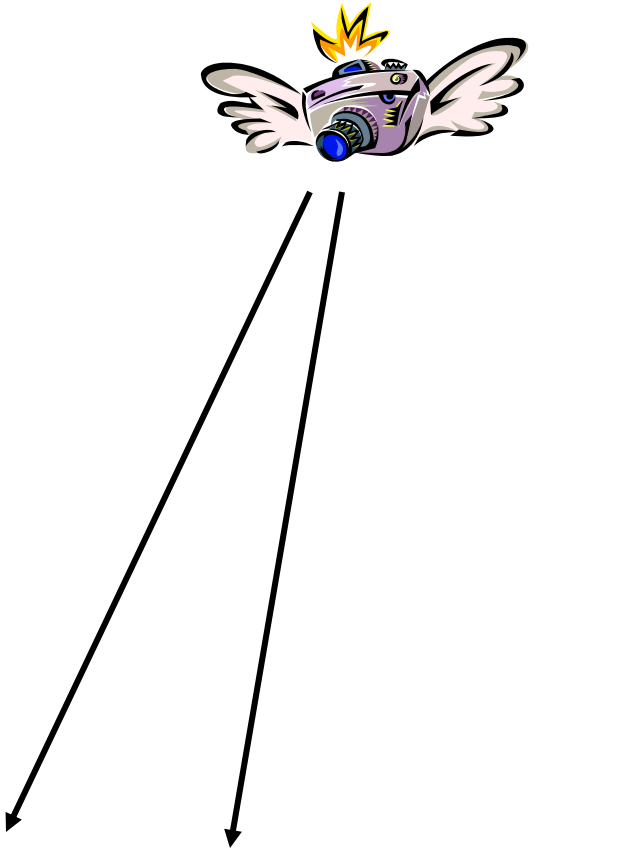
Types of aerial photograph

- Vertical
- Low oblique
- High oblique



Types of aerial photograph

- Vertical
- Low oblique (no horizon)
- High oblique



Types of aerial photograph

- Vertical
- Low oblique
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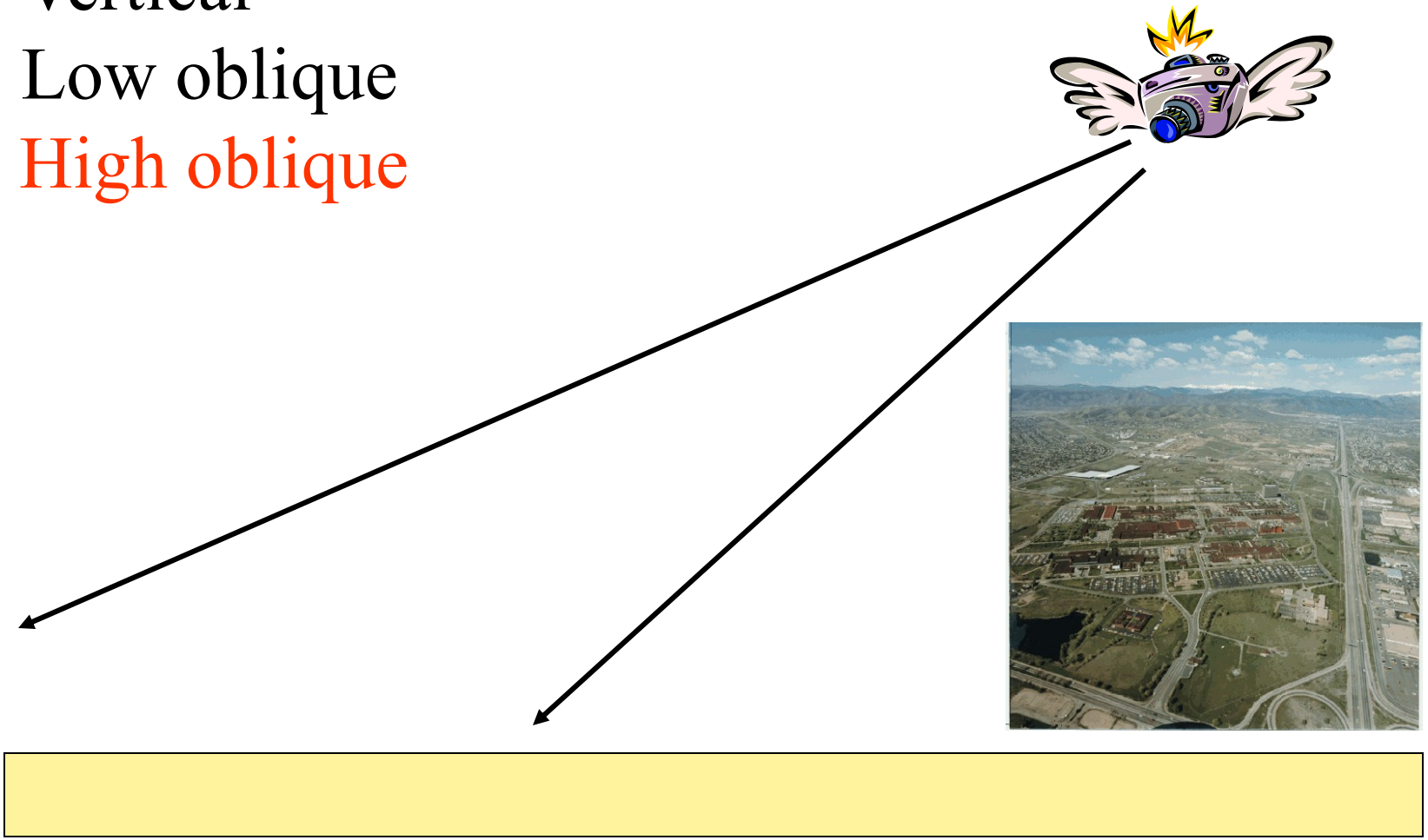
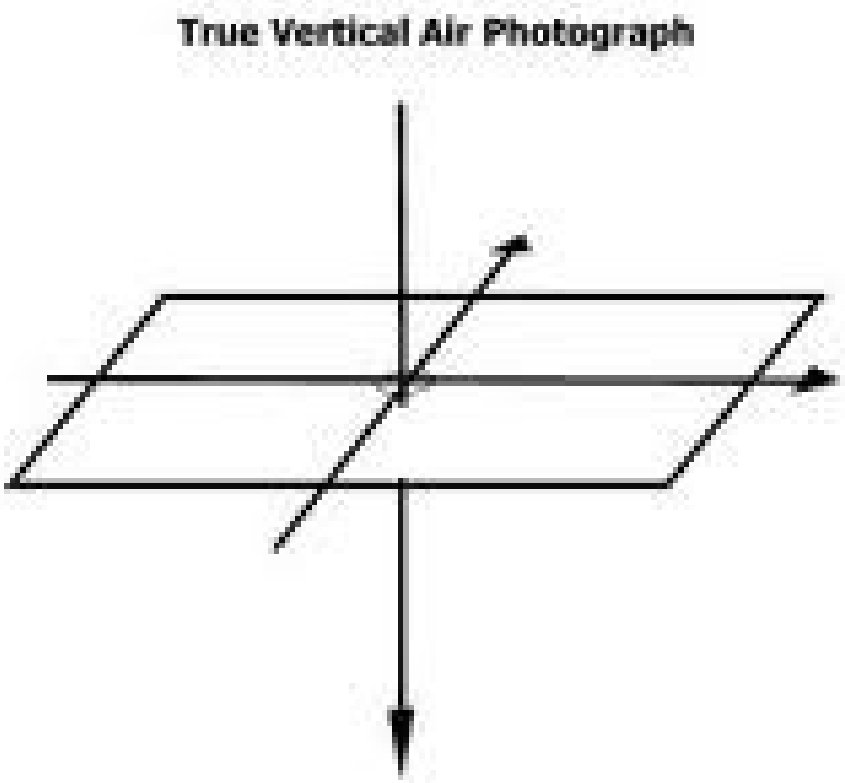
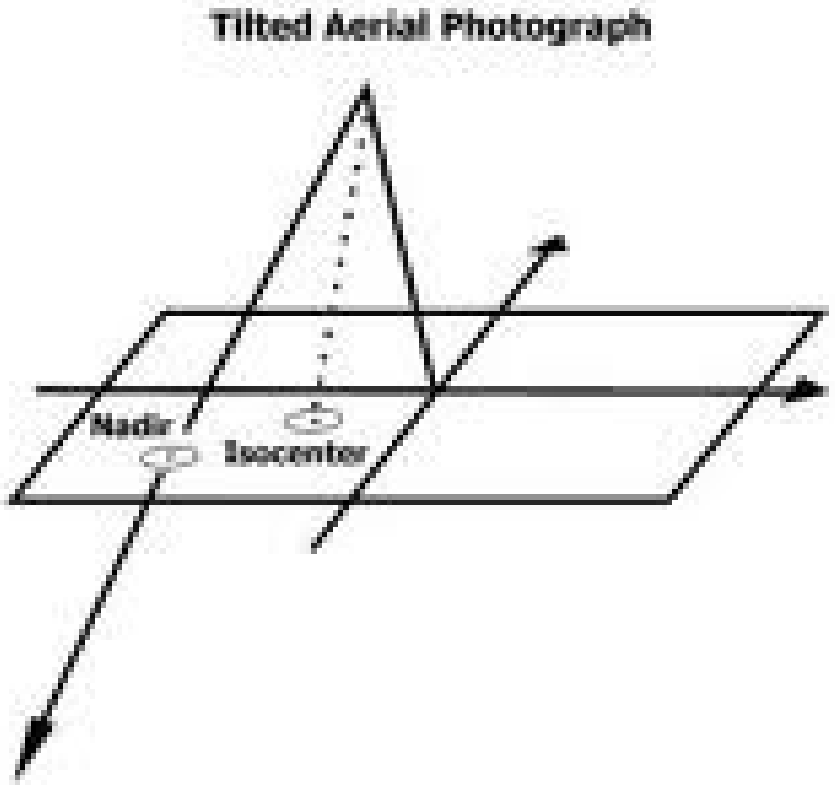
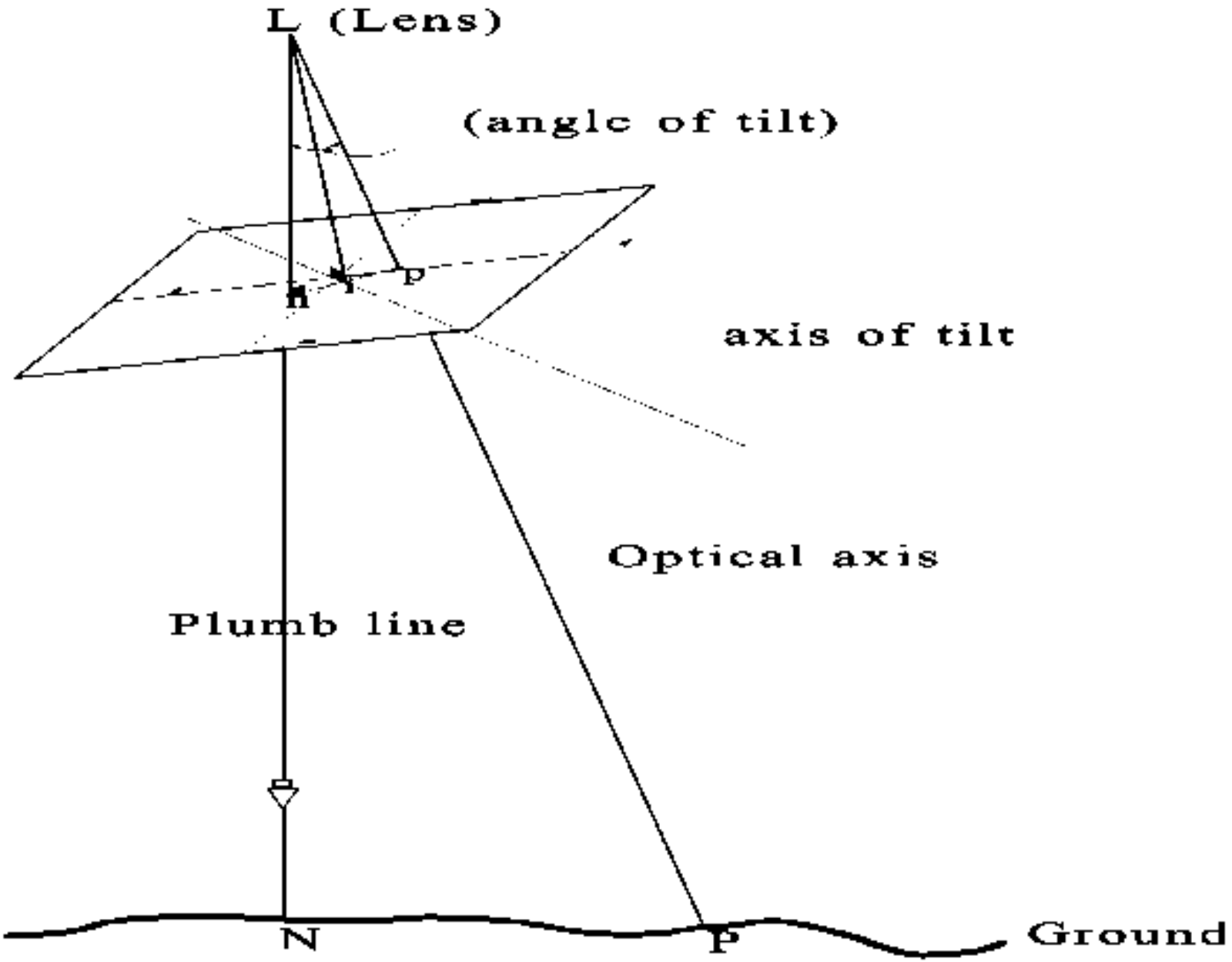


TYPES OF AERIAL PHOTOGRAPH



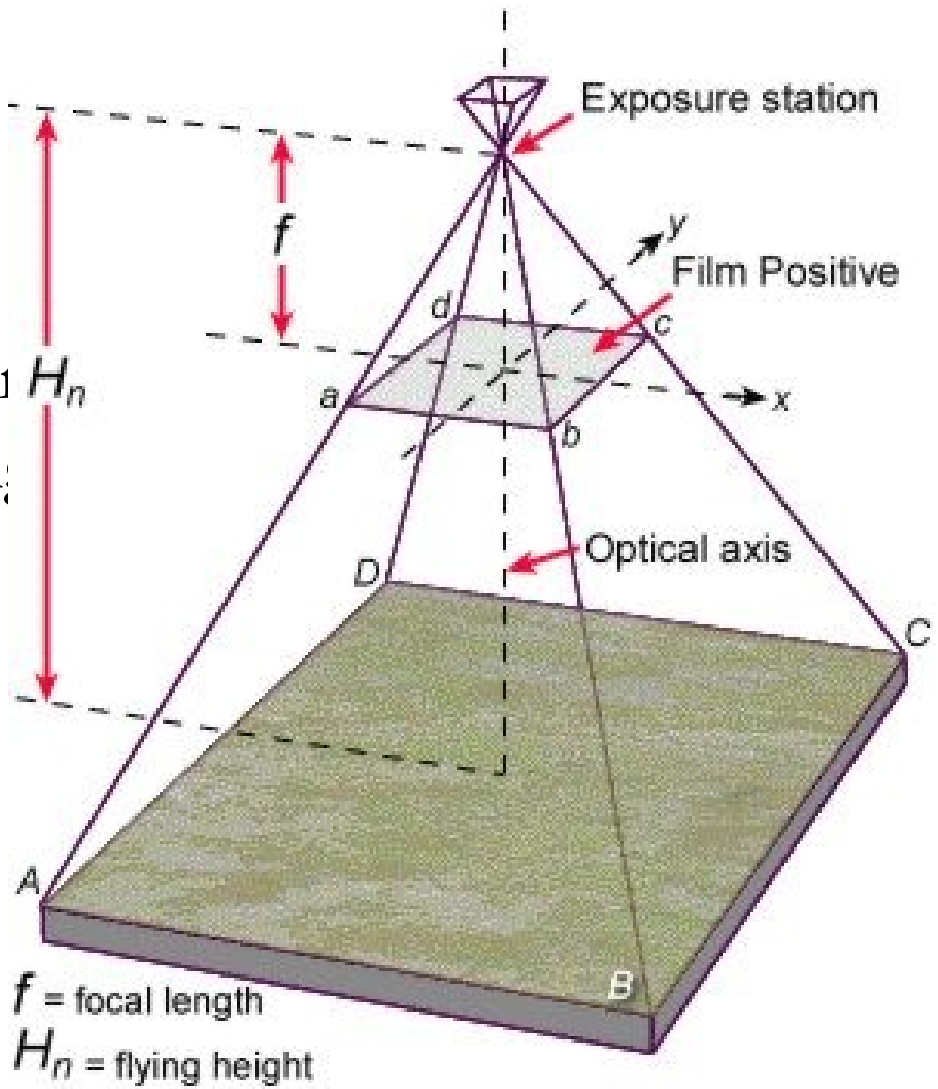


TYPES OF AERIAL PHOTOGRAPH

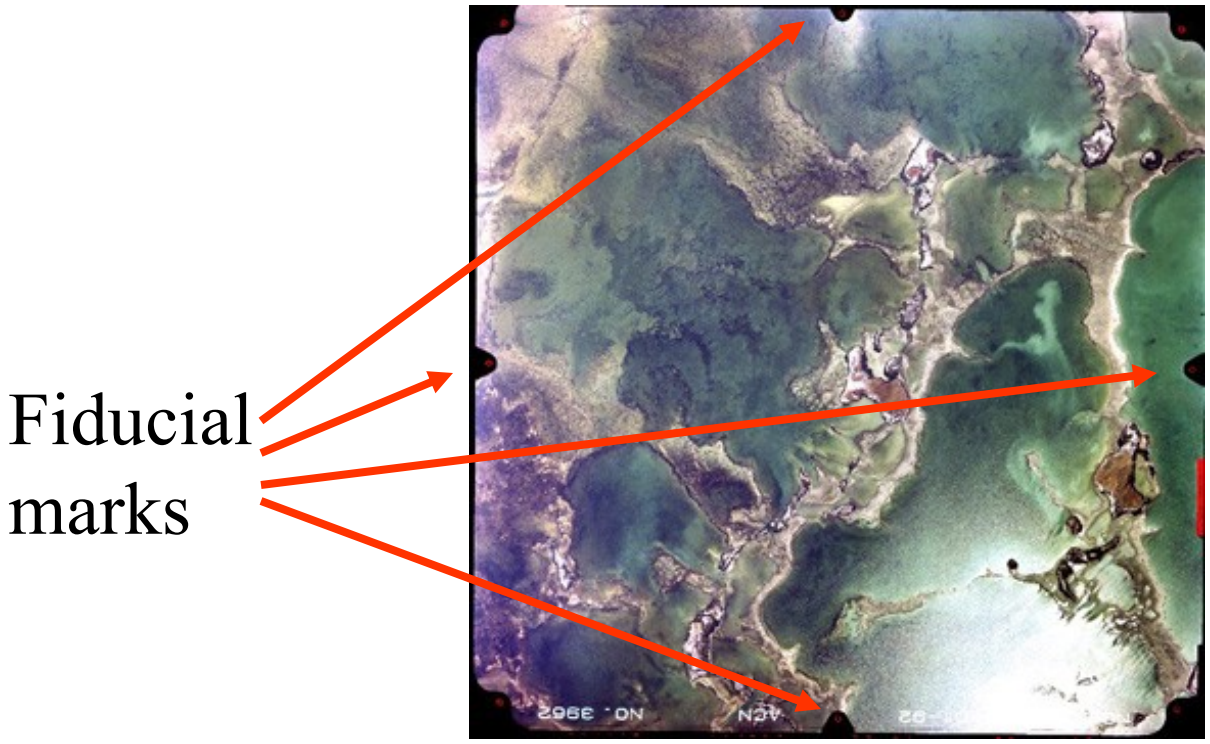


TYPES OF AERIAL PHOTOGRAPH

Vertical is most important as it has minimum distortio and can be used for takin measurements

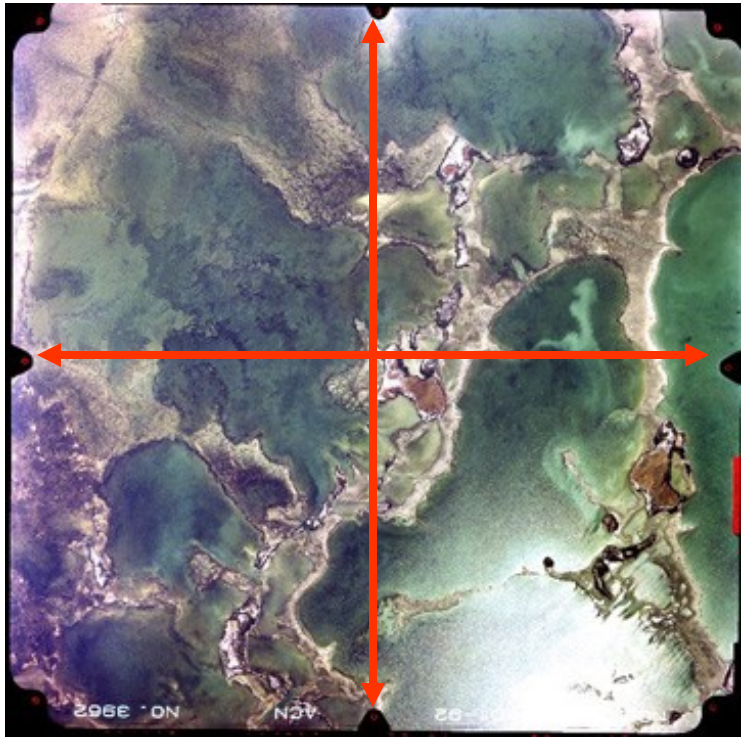


Types of aerial photograph



Types of aerial photograph

Fiducial axes



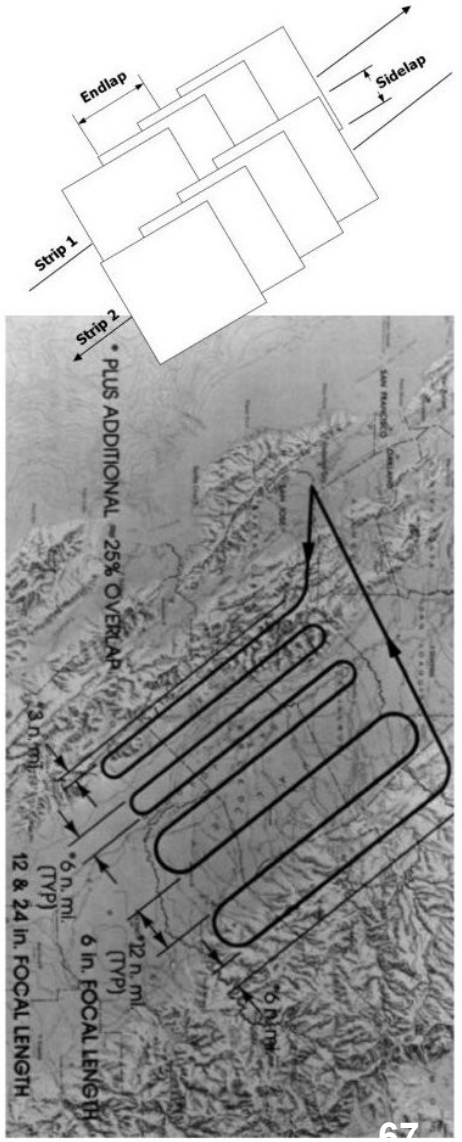
Types of aerial photograph

Principal point

Marginal information

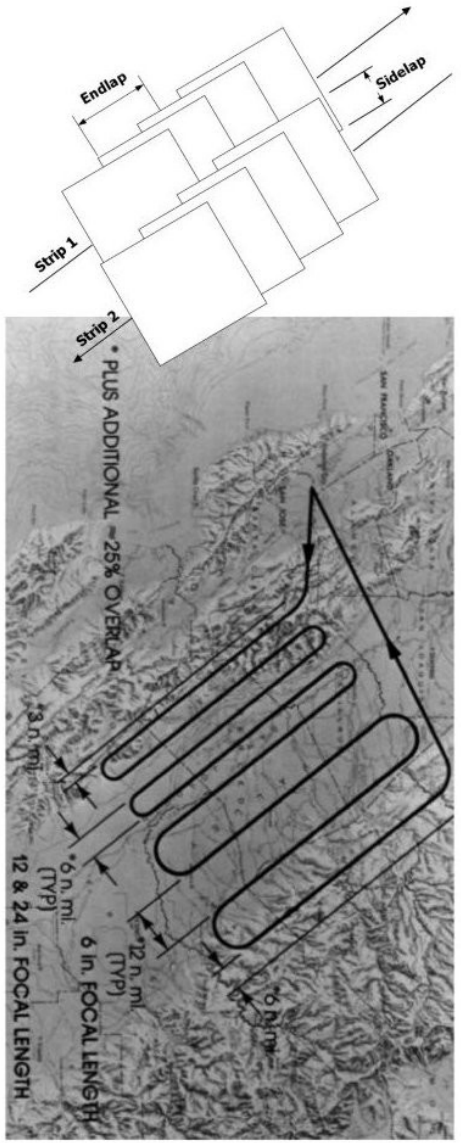
TYPES OF AERIAL PHOTOGRAPH

An aerial photograph mission will be flown in strips, shutter timing set for 60% endlap (needed for parallax) and strips spaced for 30% sidelap (to avoid missing bits)

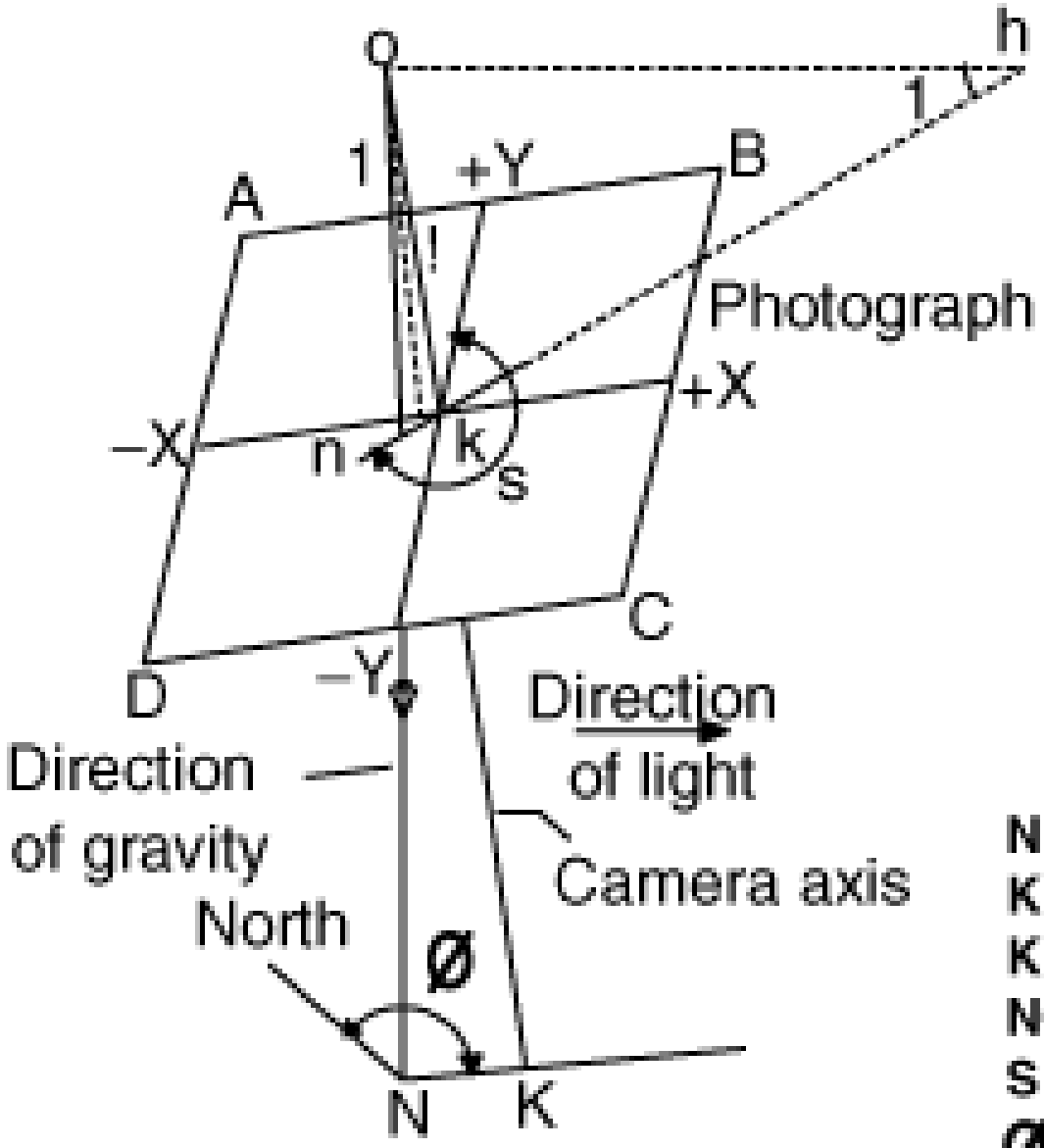


TYPES OF AERIAL PHOTOGRAPH

- Endlap (or forelap) is the important bit
- It ensures every point on the ground appears in at least two photographs
- Distance between principal point of adjacent photographs is known as the "air base"



Principle of Aerial Survey



N = Nadir
K = Principal point
K = Ground principal point
NOK & NOK = Principal plane
S = Swing
Ø = Azimuth of the photograph

Some Basic Definitions

- Exposure station (o) : The point in the atmosphere occupied by center of camera lenses at instance of photography.
- Flying height : Vertical distance between exposure station and mean sea level.
- Flight line: Line traced by exposure station in atmosphere (track of aircraft)
- Photo principal plane (k) It is point on photograph obtained by projecting camera axis to intersect at a point on photograph known as photo principal point(k)
- Camera axis extended up to ground, the point obtained on ground is called Ground Principal point (K)

Some Basic Definitions

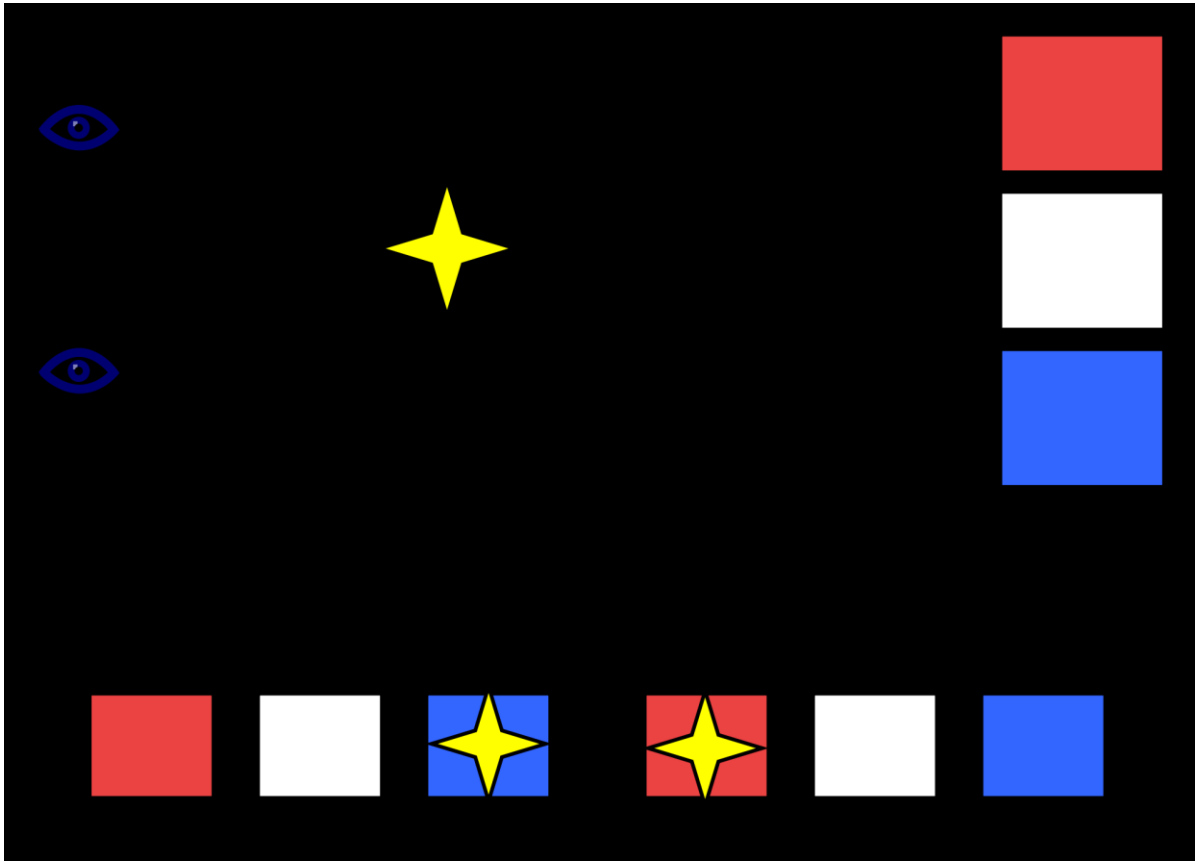
- Photo nadir point (n) : It is a point on photograph obtained by dropping vertical line from camera center. That plumb line extened up to ground gives Ground Nadir Point (N)
- Horizon point (h) : It is point of intersection of horizontal line through center of lenses and principal line (nh) on photograph.
- Principal plane:- Plane defined by exposure station (O), Ground nadir point (N) and ground principal point (P) (i.e. plane NOK)
- Principal line : Line of intersection of principal plane with photograph plane -nk

Some Basic Definitions

- Azimuth : (A) : Clockwise horizontal angle measured about ground nadir point from true north to the principal plane of photograph.(Φ)
- Swing (S) : Angle measured in plane of photograph from +y axis clockwise to photo nadir point.
- Isocenter (i) : Point on photo where bisection of tilt falls on photo. (dotted line ------- in sketch).
- Axis of tilt:- It is line in plane of photograph perpendicular to principal line at the isocenter.

Parallax

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



Parallax

- Apparent change in position caused by change in viewing angle
- Distance between an object on two photographs and the distance between the principal points is a measure of the height of the object.
- A mark can be superimposed on two photographs such that it will "touch" the ground in the fused stereo view at a specific height. This allows the tracing of contour lines on a paper map or the digitization of contour lines into a computer

PARALLAX

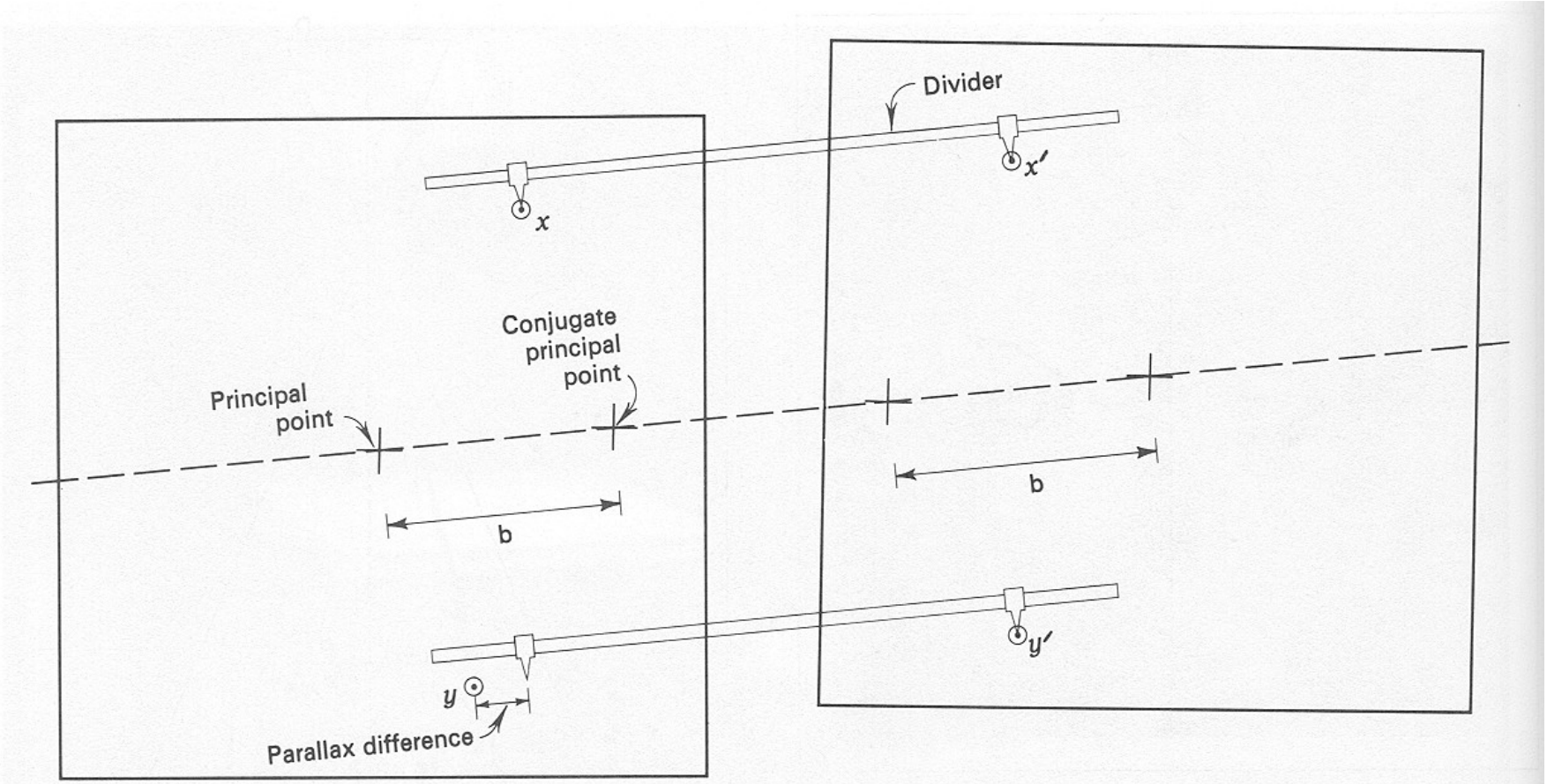
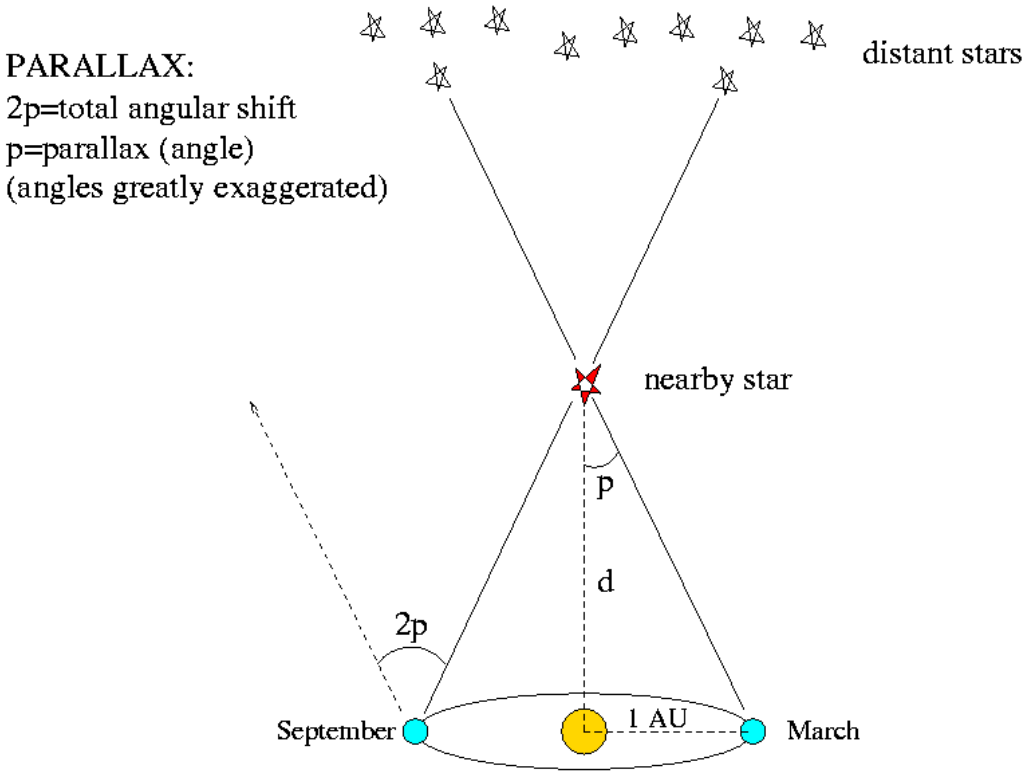


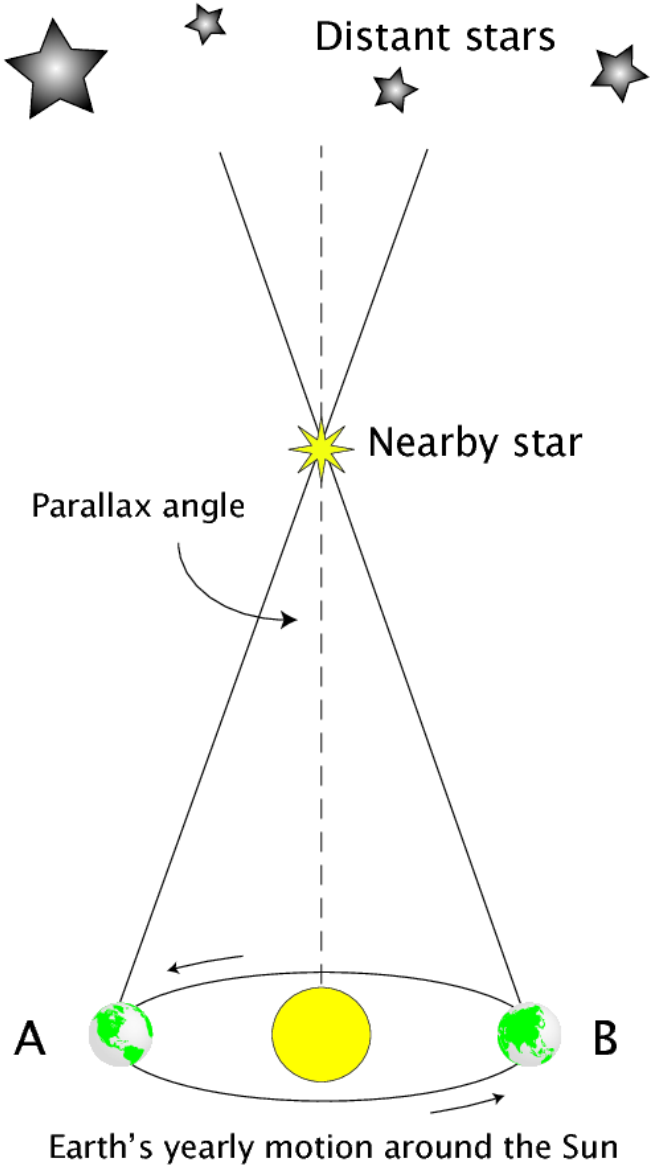
Figure 12.5 Graphically measuring parallax difference. The locations of one of the points on the two photographs is indicated by *x* and *x*', and the second point by *y* and *y*'. If the lines connecting the principal point to the conjugate principal point on each photograph are placed along a straight line, then the difference *xx*'–*yy*' is the parallax difference.

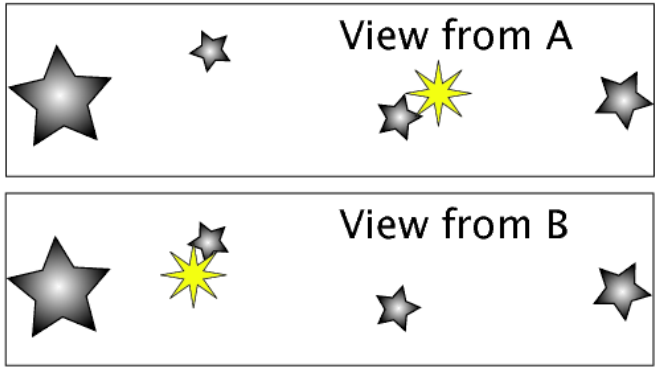
Parallax



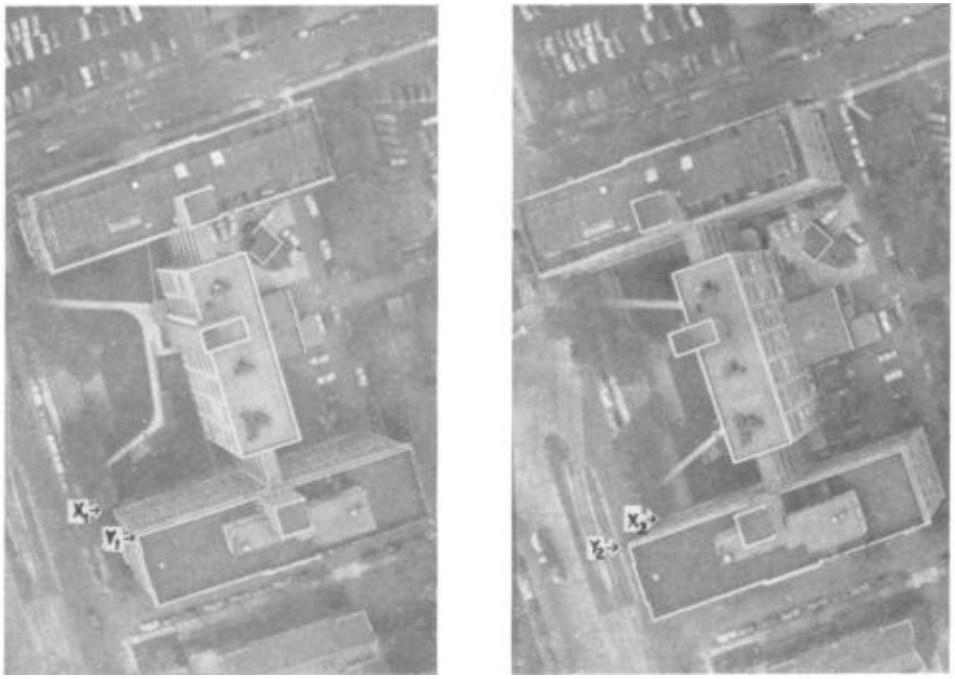
Parallax is used to find distance to stars, using two viewing points on either side of Earth's orbit

Parallax


Distant stars
Nearby star
Parallax angle
A
B
Earth's yearly motion around the Sun


View from A
View from B

PARALLAX



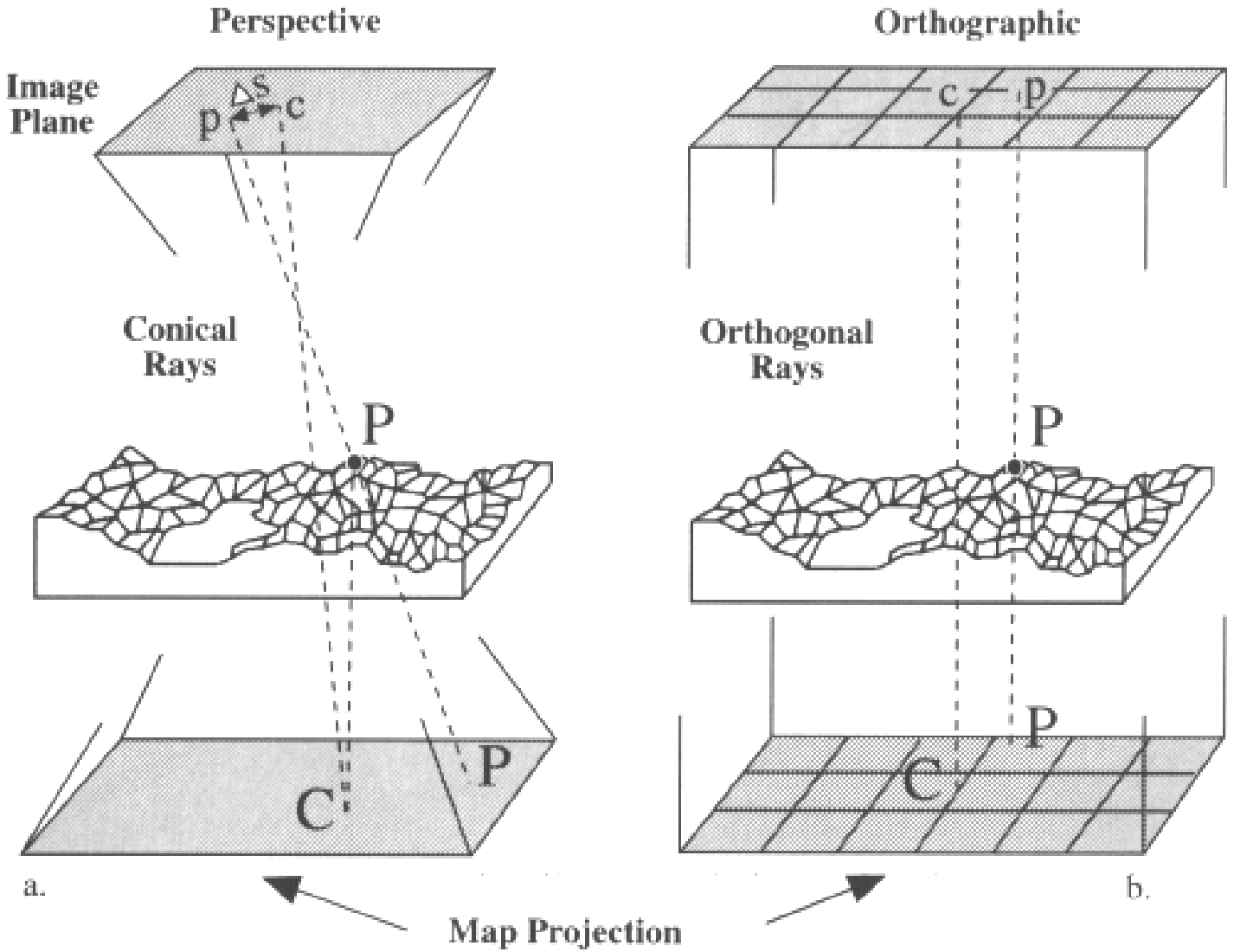
The same principle can be used to find height of objects in stereopairs of vertical aerial photographs

Orthophotographs and digital orthoimagery

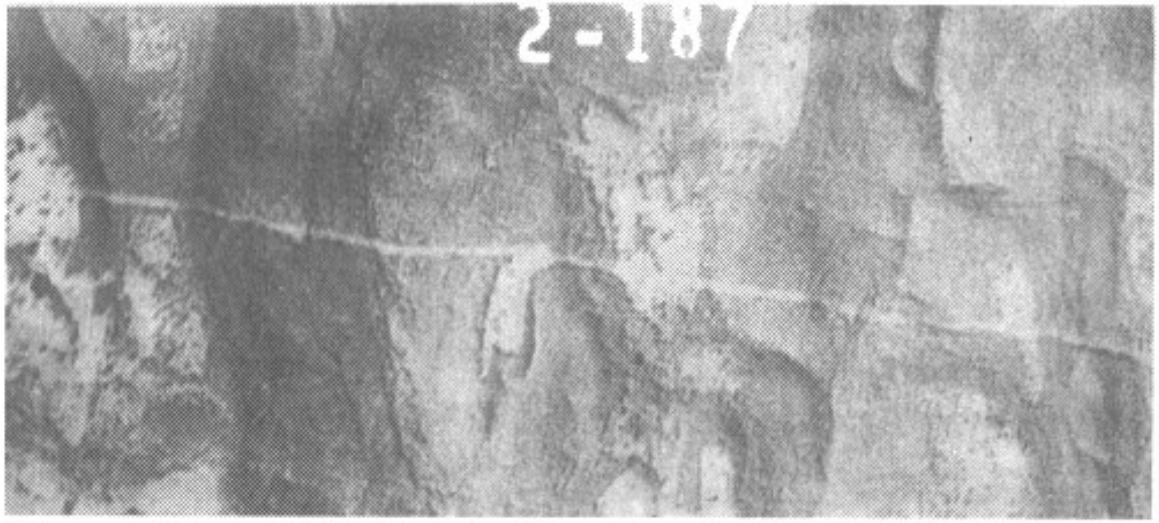
- Photograph after corrected by ground control points (x, y, z) or digital elevation model (DEM) called orthophotograph, orthophoto, or digital orthoimagery.

- Not as photographs, they have different scales in different terrain relief, orthophotos have only one scale, no distortion, and have true distance, angle, and area. Orthophotos can be directly input into GIS as basemap or for interpretation.

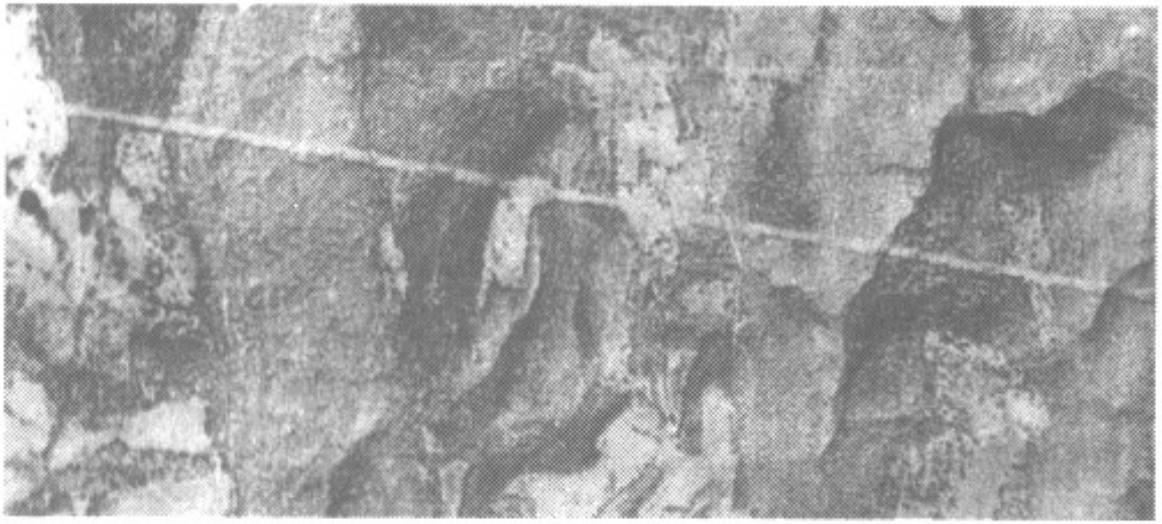
ORTHORECTIFICATION



ORTHORECTIFICATION



a. Uncorrected vertical aerial photograph



b. Orthophotograph

Extraction of Building Infrastructure based on orthophotographs

Orthophotographs and digital orthoimagery

Orthophotograph draped over a DEM

Photographic Interpretation

- Photographic interpretation is concerned with the examination of photographs in order to identify objects, and is an essential part of air survey

Applications of Photogrammetry

a. Topographical Mapping

- The plotting of map detail and contours is normally carried out using aerial photogrammetric methods
- These methods are used for both original survey and revision, and replace classical ground methods except where the task is so small that flying is uneconomical
- The technique needs a certain amount of ground surveyed control, but this requirement is being continually reduced with the improvement of aerial triangulation techniques to provide supplementary control.
- A final Field check is necessary

b. Large Scale Plans

- Large scale surveys can be produced accurately and quickly by air survey methods, but require more field checking in addition to the provision of ground control
- For large tasks, such as road building and major constructions, air survey methods are quicker and cheaper than ground methods
- Profiles for determination of earthwork quantities and other data useful to Civil Engineer may be simply obtained from the same photographs

c. Cadastral Plans

- Similar advantages may be gained by an air survey for cadastral purpose as are provided in the production of large scale plans.
- As the accuracy of the cadastral plan is related to the value of land, the traditional ground method trends to be slower, costly but very accurate
- In most cases, the accuracy of a well planned air survey is sufficient for cadastral purposes, and this method is used in many countries
- Where boundaries are related to described features, or land is very valuable, the additional accuracy of ground survey may be necessary

d. Land use maps

- Air survey techniques may be used not only to define the extent of an area, but also to identify its use and measure the yield of a crop
- Forestry is a typical application where, by plotting the limits of timber and measuring tree heights, an accurate estimate of yield may be given.
- The use of special films, such as color and infra-red will provide additional information about the quality of the crop

e. Hydrographic Maps and Charts

- Air survey techniques are particularly valuable in the accurate plotting of coastlines, sandbanks and small islands where the changing tide is a problem for ground methods
- The use of special film will again add more information, either by clearly delineating water limits or by extra penetration in shallow water

f. Exploration and Reconnaissance

- Information may be gained about areas to which access is restricted by employing air survey techniques
- In the case of military reconnaissance, a high flying or unmanned aircraft can obtain photograph that will provide data for an accurate survey
- For explorers, and area can be mapped before the first entry, either from photographs obtained by aircraft as in the case of Moon or Mars, or by specially equiped satellites

APPLICATIONS OF PHOTOGRAMMETRY

g. **Terrestrial, Industrial and Scientific Uses**

- Photogrammetry has provided rapid, accurate and in some cases unique solutions to many non topographical problems.
- **The following are of particular interest**

h. **Detailed Survey of Historic Buildings**

- Precise plans of building facades and architectural detail may be obtained without direct measurement by terrestrial photogrammetric techniques

i. **Traffic Accidents**

- Terrestrial methods are also used to record details of accidents in some countries
- This allows obstructions to be cleared without delay, the scene being plotted at a later stage

j. **Medical Applications**

- Short range photogrammetry is in use by doctors and dentists to define conditions requiring treatment and also to study the results of treatment

Applications of Photogrammetry

k. **Analysis of movement**

- Tidal and Particle movement may be analyzed by photogrammetric methods by taking photographs of the moving surface with a fixed camera
- The stereo model obtained shows vertical "relief" proportional to the amount of movement "contours" may be plotted

Conclusion

Photogrammetry can also be thought of as the sciences of geometry, mathematics and physics that use the image of a 3D scene on a 2D piece of paper to reconstruct a reliable and accurate model of the original 3D scene. With this in mind it is easier to understand the current expanded definition, which, includes the science of electronics by using video and other synthetic means of reproducing 2D images of 3D scenes. And, these images are also used to reconstruct reliable and accurate models of the captured 3D scenes.

ANY DOUBTS?

What We have Covered….

- What is Photogrammetry
- Single Photograph Approximations
- Multiple Photograph Measurements
- Brief History of Photogrammetry
- Origins of Photograph and Remote Sensing
- Color Science
- Types of photographs
- Satellite photographs
- Basic Information on photogrammetry
- Types of Aerial Photographs
- Some Basic Definitions
- Scale of Photograph
- Parallax
- Orthophotographs and digital orthoimagery
- Orthorectification
- Photographic Interpretation
- Applications of Photogrammetry

What We Learnt

- Understanding of fundamental concept of photogrammetry and its applications especially in urban and regional planning.

Thanking You