AERIAL PHOTOGRAPHY

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Outline

- Definition of aerial photography
- Characteristics of aerial photographs
- Aerial cameras and their types
- Geometric properties of aerial photographs
- Aerial Photo Interpretation Elements
- An Introduction to photogrammetry
- Photo interpretation and photogrammetric equipment
- Taking measurements from aerial photographs
- Mapping with aerial photographs

Defining Aerial Photography

- The term "photography" is derived from two Greek words meaning "light" (phos) and "writing" (graphien). From Greek phōt- , the stem of phōs ‘light’, which is a unit of illumination.
- Photography means the art, hobby, or profession of taking photographs, and developing and printing the film or processing the digitized array image.
- Photography is production of permanent images by means of the action of light on sensitized surfaces (film or array inside a camera), which finally giving rise to a new form of visual art.
- Aerial Photography means photography from the air.
- The word ‘aerial’ originated in early 17th century. [Formed from Latin aerius , from Greek aerios , from aēr ‘air’.]

Aerial Photography: An Overview

- Aerial Photography is one of the most common, versatile and economical forms of remote sensing.
- It is a means of fixing time within the framework of space (de Latil, 1961).
- Aerial photography was the first method of remote sensing and even used today in the era of satellite and electronic scanners. Aerial photographs will still remain the most widely used type of remote sensing data.
- Aerial photographs were taken from balloons and kites as early as the mid-1800s.
- 1858 - Gasper Felix Tournachon "Nadar" took the first aerial photograph from a captive balloon from an altitude of 1,200 feet over Paris.

Characteristics of Aerial Photography

- **Synoptic viewpoint**: Aerial photographs give a bird's eye view of large areas enabling us to see surface features in their spatial context. They enable the detection of small scale features and spatial relationships that would not be found on the ground.
- **Time freezing ability**: They are virtually permanent records of the existing conditions on the Earth's surface at one point in time, and used as an historical document.
- **Capability to stop action**: They provides a stop action view of dynamic conditions and are useful in studying dynamic phenomena such as flooding, moving wildlife, traffic, oil spills, forest fires.
- **Three dimensional perspective**: It provides a stereoscopic view of the Earth's surface and make it possible to take measurements horizontally and vertically - a characteristic that is lacking for the majority of remotely sensed data.

Characteristics of Aerial Photography (2)

- **Spectral and spatial resolution**: Aerial photographs are sensitive to radiation in wavelengths that are outside of the spectral sensitivity of the human eye (0.3 μm to 0.9 μm versus 0.4 μm to 0.7 μm).
- They are sensitive to objects outside the spatial resolving power of human eye.
- **Availability**: Aerial photographs are readily available at a range of scales for much of the world.
- **Economy**: They are much cheaper than field surveys and are often cheaper and more accurate than maps.

Aerial Cameras

- Aerial photographs can be made with any type of camera (e.g. 35 mm small amateur or 70 mm or special cameras that are purpose built meant for mapping).
- Many successful applications have employed aerial photography made from light aircraft with handheld 35 mm cameras.
- For the aerial study of large areas, high geometric and radiometric accuracy are required and these can only be obtained from by using cameras that are purpose built.
- Aerial camera are precision built and specifically designed to expose a large number of films/photographs in rapid succession with the ultimate in geometric fidelity and quality.
- These cameras usually have a medium to large format, a high quality lens, a large film magazine, a mount to hold the camera in a vertical position and a motor drive.

Aerial Cameras

One of the smaller models of aerial camera, dated 1907, kept in Duetsches Museum, Germany.

Source: Curran, (1988).

Types of Aerial Cameras

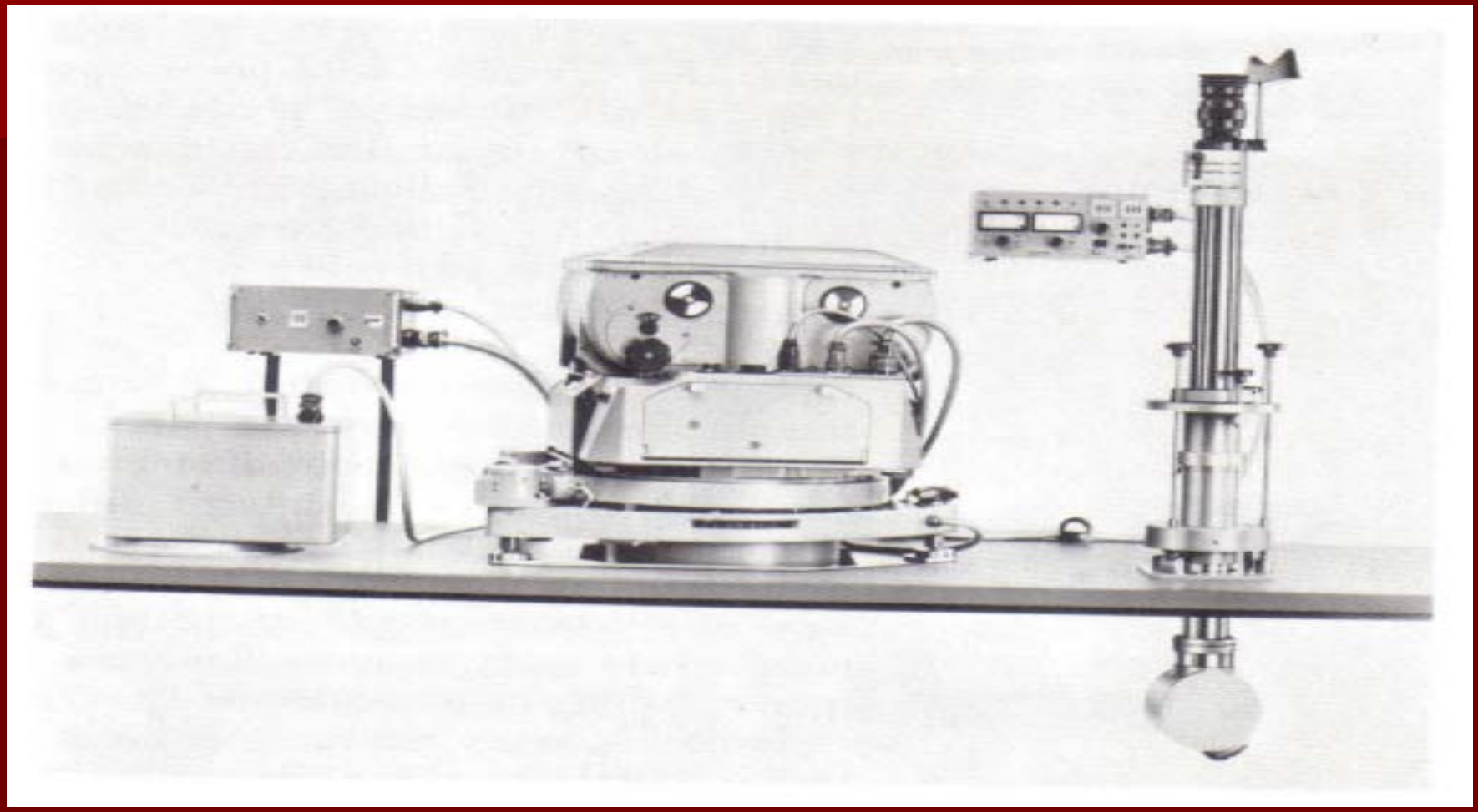
There are many types of aerial cameras:

- Aerial mapping camera (single lens),
- Reconnaissance camera,
- Strip camera,
- Panoramic camera,
- Multilens camera, the multi camera array (multiband aerial camera) and
- Digital camera.

Aerial Mapping (Single Lens) Camera

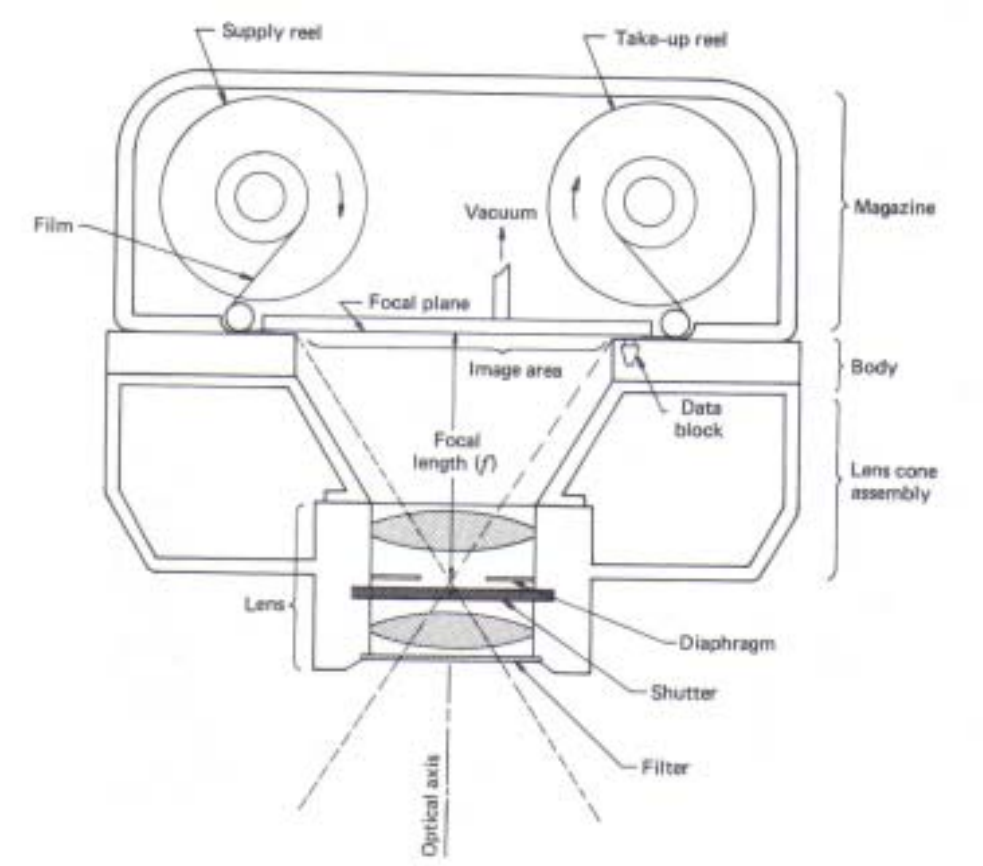
- Aerial mapping cameras (also called as metric or cartographic cameras) are single lens frame cameras designed to provide extremely high geometric image quality.
- They employ a low distortion lens system held in a fixed position relative to the plane of the film.
- The film format size is commonly a square of 230 mm on a side. The total width of the film used is 240 mm and the film magazine capacity ranges up to film lengths of 120 metres.
- A frame of imagery is acquired with each opening of the camera shutter, which is tripped at a set frequency by an electronic device called an *intervalometer*.
- They are exclusively used in obtaining aerial photos for remote sensing in general and photogrammetric mapping purposes in particular.
- Single lens frame cameras are the most common cameras in use today.

Aerial Mapping Camera



An aerial mapping camera (Carl Zeris RMK/A15/23) with automatic levelling and exposure control. It is mounted on a suspension mount, between the remote control unit (left) and its navigation telescope (right). Source: Curran, 1988).

Single Lens Frame Camera



The principal components of a single lens frame mapping camera.

A typical aerial mapping camera and its associated gyro-stabilised suspension mount.

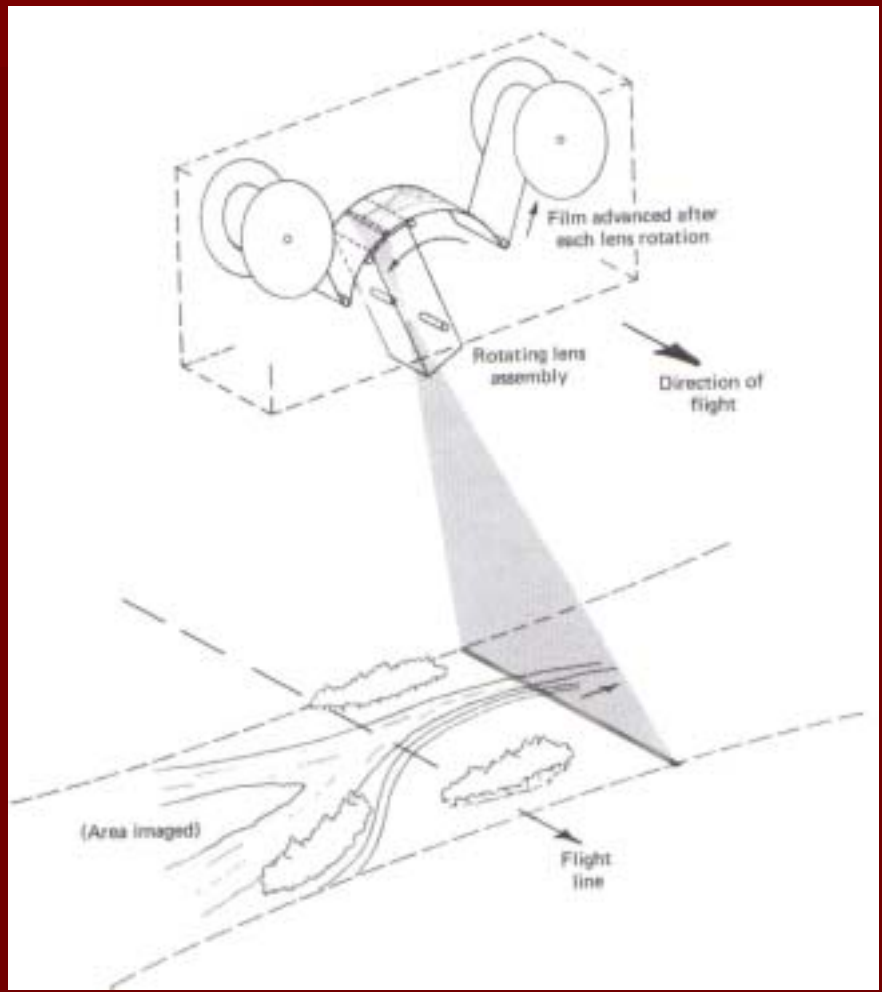
Source: Lillesand et al, 2005.

Panoramic Aerial Camera

In panoramic cameras the ground areas are covered by either rotating the camera lens or rotating a prism in front of the lens.

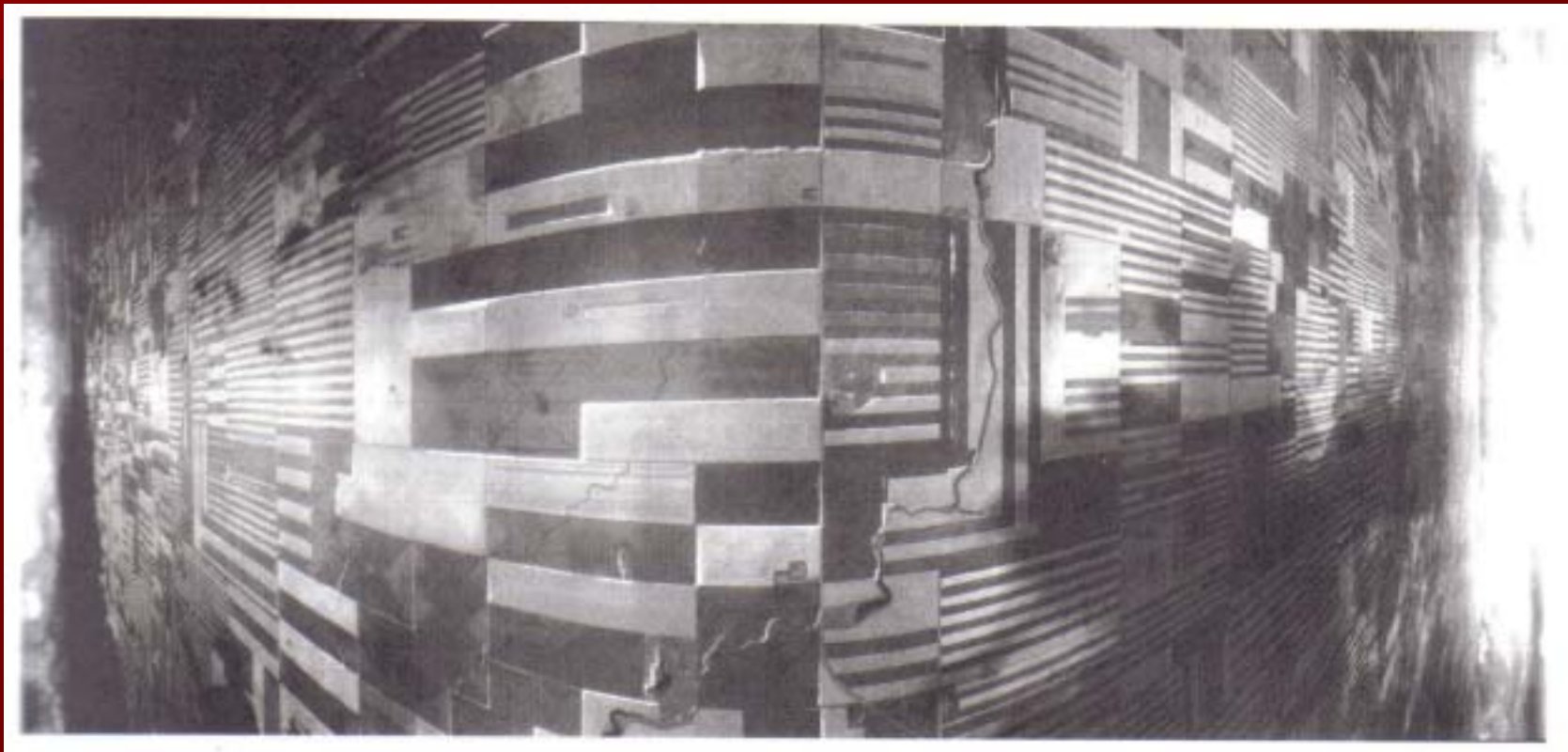
The terrain is scanned from side to side, transverse to the flight direction. The film is exposed along a curved surface located at the focal distance from the rotating lens assembly, and the angular coverage can extend from horizon to horizon.

Camera with a rotating prism design contain a fixed lens and a flat film plane. Scanning is accomplished by rotating the prism in front of the lens.



The operating principle of a panoramic camera

Panoramic Photograph



Panoramic photograph with 180 degree scan angle. Note image detail, large area of coverage and geometric distortion. Area near the two ends of the photograph are compressed. Source: Lillesand et al, 2005.

Multiband Aerial Cameras

Multilens camera system

Multicamera array comprising four 70 mm camera

Imaging digital camera comprising eight synchronously operating CCD-based digital cameras

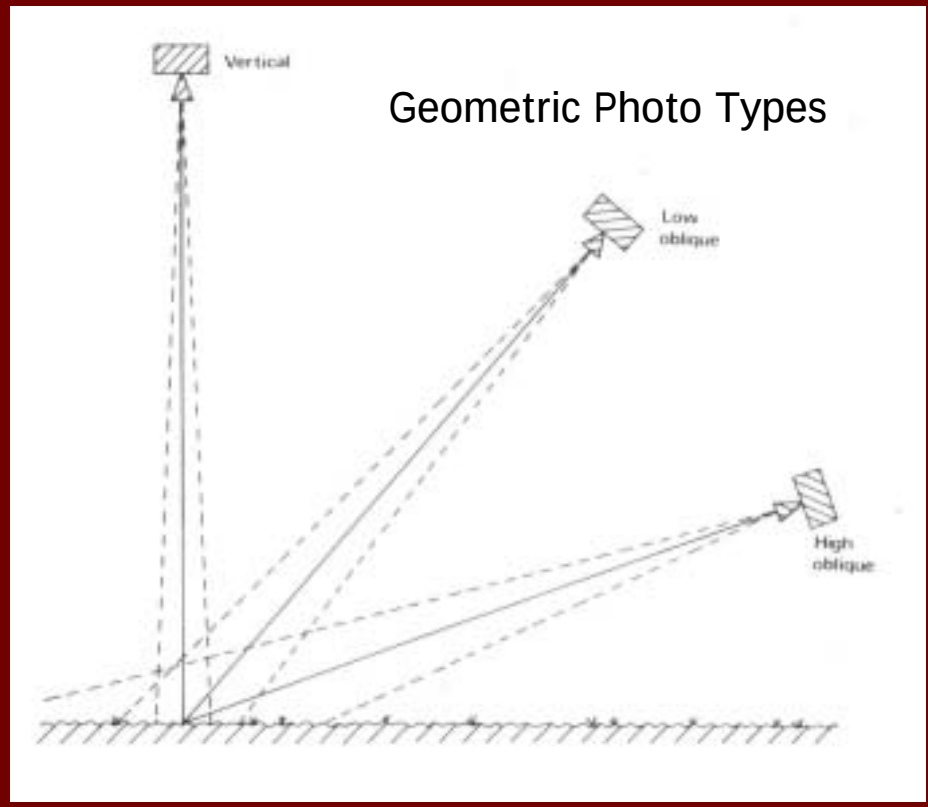
Multiband Aerial Photo of Waterfront Area, Cape Town

Geometric Properties of AP

The most important geometric properties of an aerial photograph are those of an **angle** and **scale**.

Angle of Arial Photographs

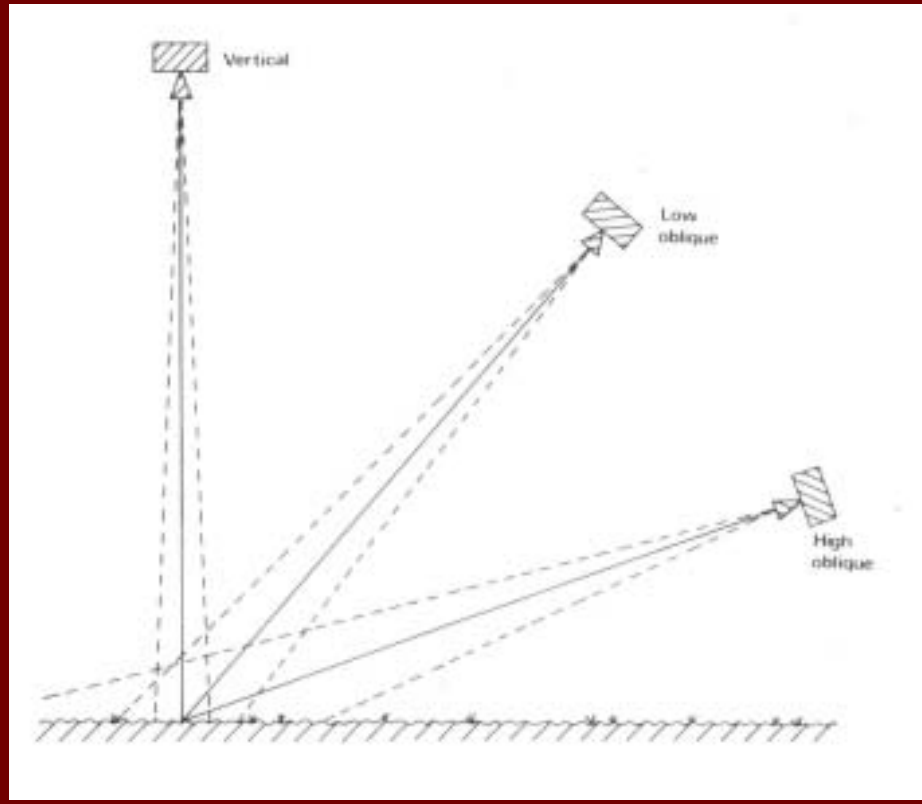
- The angle at which aerial photograph is taken is used to classify the photograph into one of three types viz. vertical, high oblique and low oblique.
- Vertical photograph taken with a single lens is the most common type of aerial photography used in remote sensing applications.
- The vertical photography is taken with the camera axis pointing vertically downwards.
- Oblique photography is taken with the camera axis pointing obliquely downwards (intentional inclination of the camera axis).



High oblique photography incorporates an image of the horizon into the photographs while low oblique photographs do not.

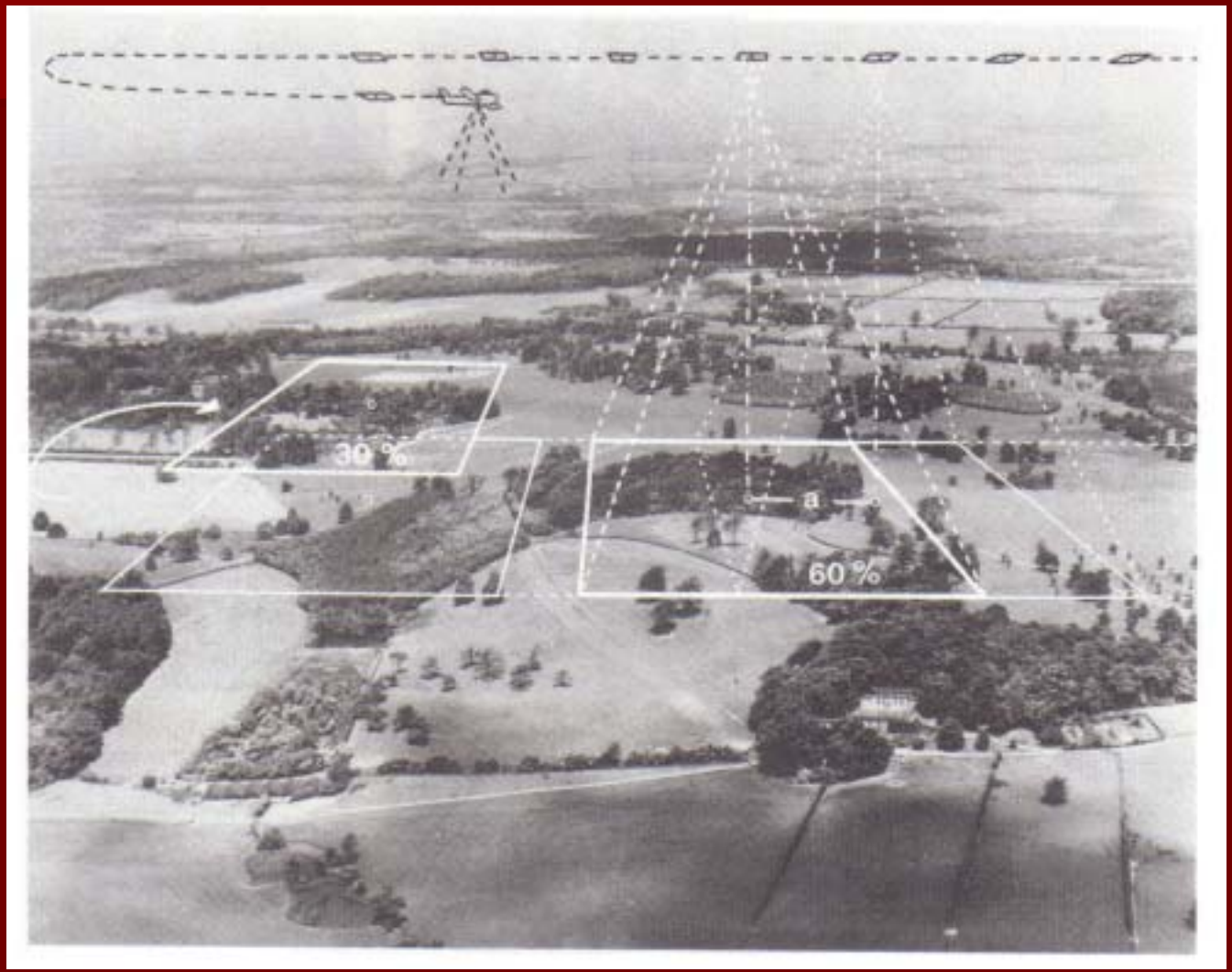
Geometric Properties: Camera Angle

- A ‘truly’ vertical aerial photograph is rarely obtainable because of unavoidable angular rotations or tilts, caused by the angular attitude of the aircraft at the instant of exposure.
- These unavoidable tilts cause slight (1 to 3 degrees) unintentional inclination of the camera optical axis, resulting in the acquisition of *tilted photographs*.
- Vertical photographs have properties similar to those of a map with a approximately constant scale over the whole photograph, and therefore can be used for mapping and measurements.

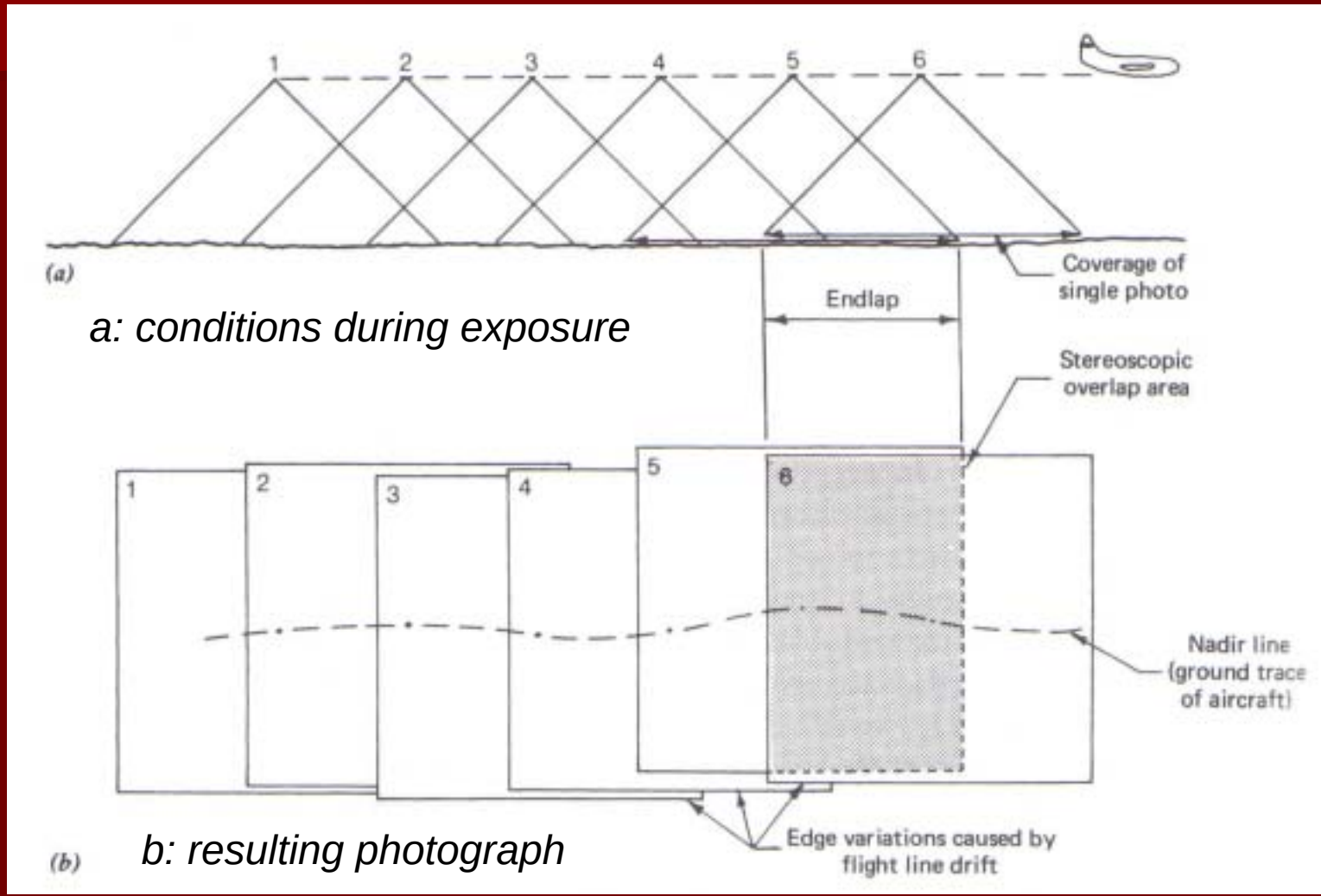


Geometric Photo Types

Taking Vertical AP: Flying Pattern



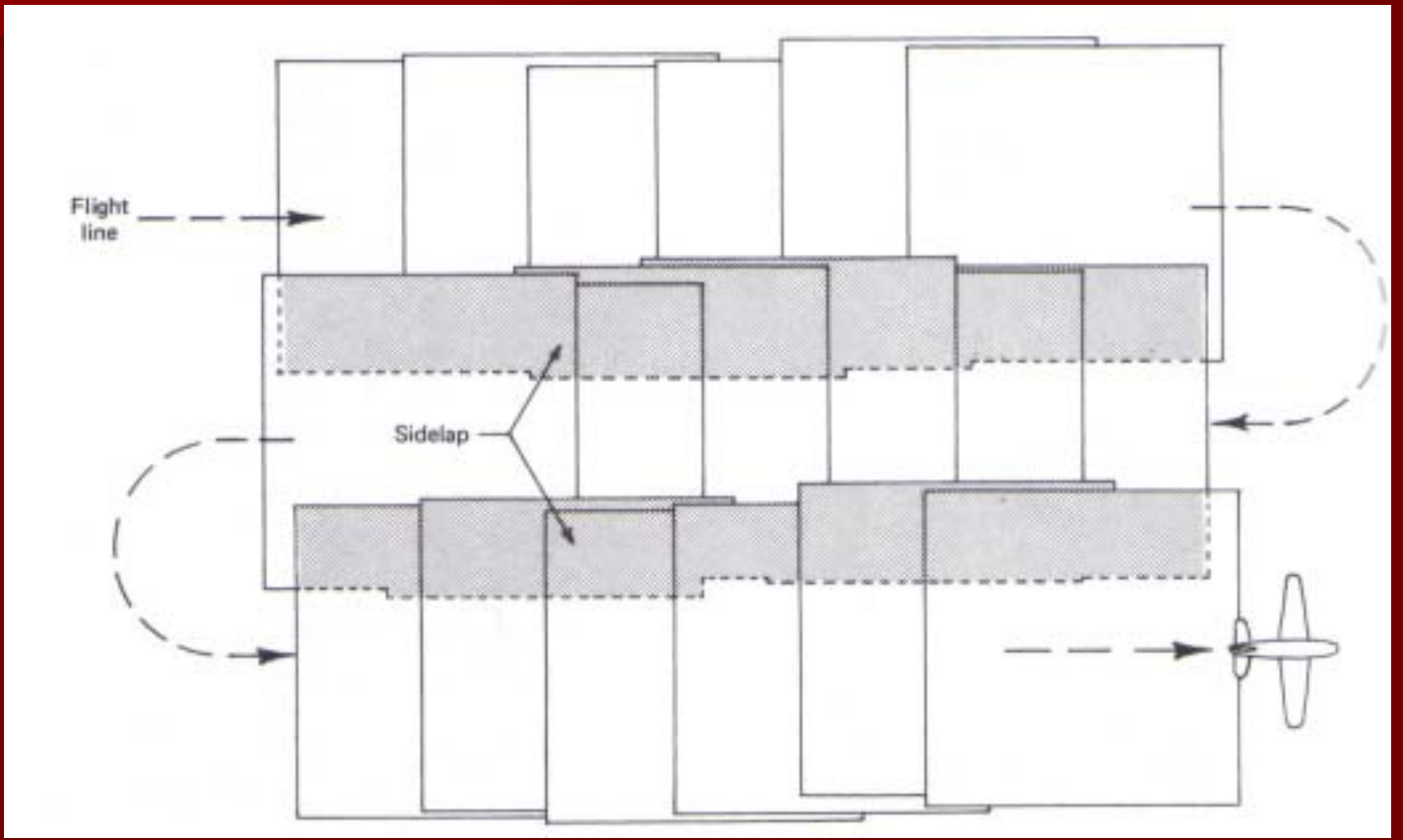
Photographic Coverage Along A Flight Strip



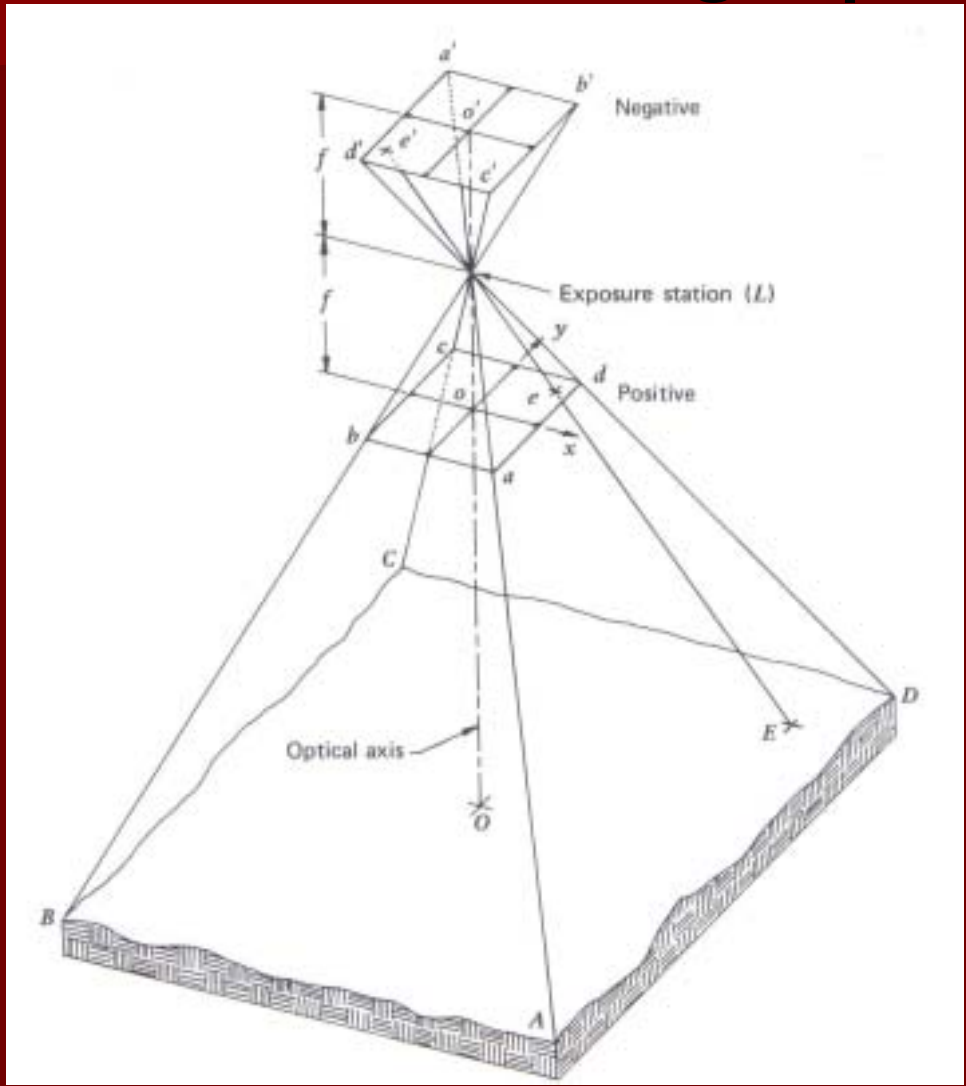
a: conditions during exposure

b: resulting photograph

Flying Pattern



Basic Geometric Elements of Vertical Photograph



Vertical Aerial Photograph

Image ID

Clock

Level bubble

Altimeter

Frame No.

Fiducial mark defining the frame of reference for spatial measurements

Vertical photo taken from with a 230 x 230-mm precision mapping film camera showing Langenburg, Germany

Geometric Characteristics: Photo Scale

Scale of Arial Photographs (Photographic Scale)

- The scale of a photograph expresses the mathematical relationship between a distance measured on the photo and the corresponding distance measured on the ground.
- A photograph scale is an expression that states one unit of distance on a photograph represents a specific number of units of actual ground distance.
- Scales may be expressed as unit equivalents (1 mm = 25 m), representative fractions (1/25,000) or ratios (1: 25,000).
- Unlike maps, which have a constant scale throughout, the aerial photographs have a range of scales that vary in proportion to the elevation of the terrain involved.
- The most straight forward method for determining photo scale is to measure the corresponding photo and ground distances between any two points. The scale ***S*** is then computed as the ratio of the photo distance ***d*** to the ground distance ***D***.
- ***S*** = photo scale = photo distance/ground distance = ***d/D***

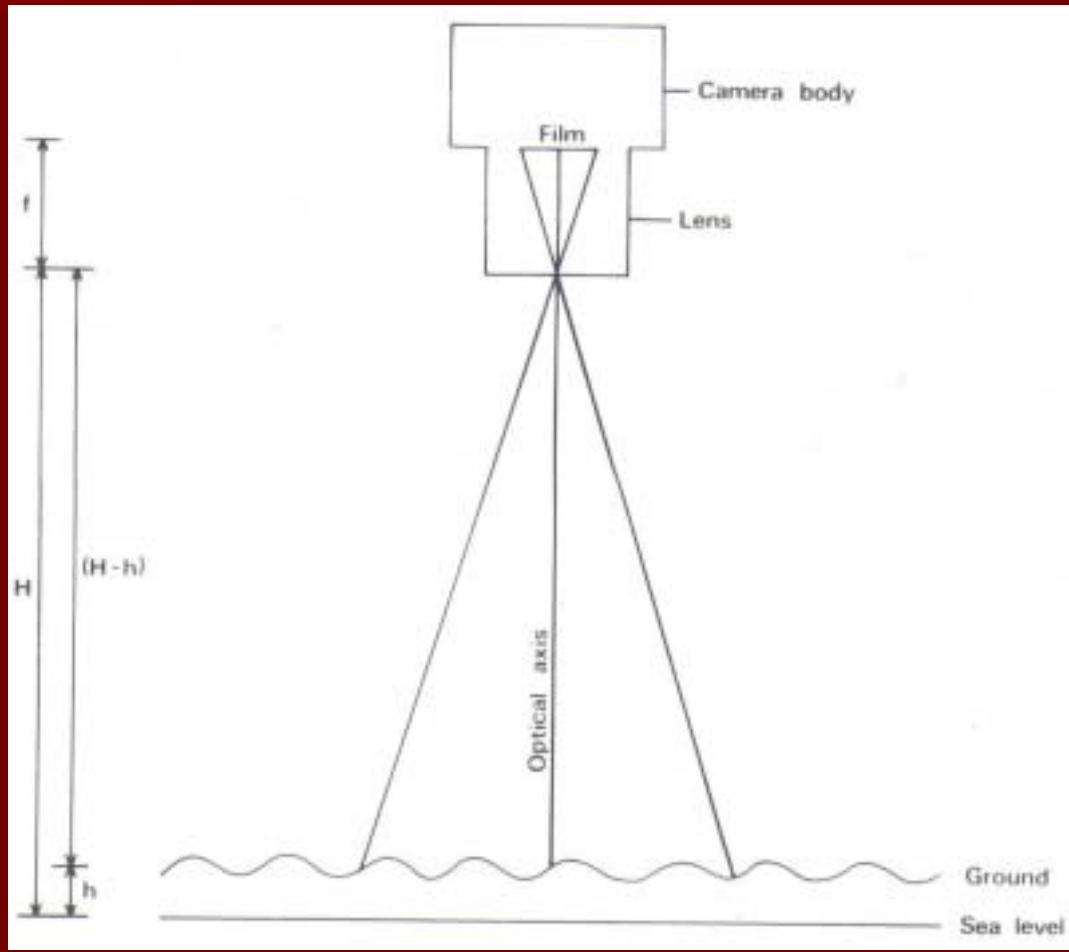
Aerial Photo Scale

The scale of a photograph is determined by the focal length of the camera and the vertical height of the lens above the ground.

The focal length (f) of the camera is the distance measured from the centre of the camera lens to the film.

The vertical height of the lens above the ground (H-h) is the height of the lens above sea level (H), minus the height of the ground above see level (h), when the optical axis is vertical and the ground is flat.

These parameters are related by formula
$S = f / (H – h)$



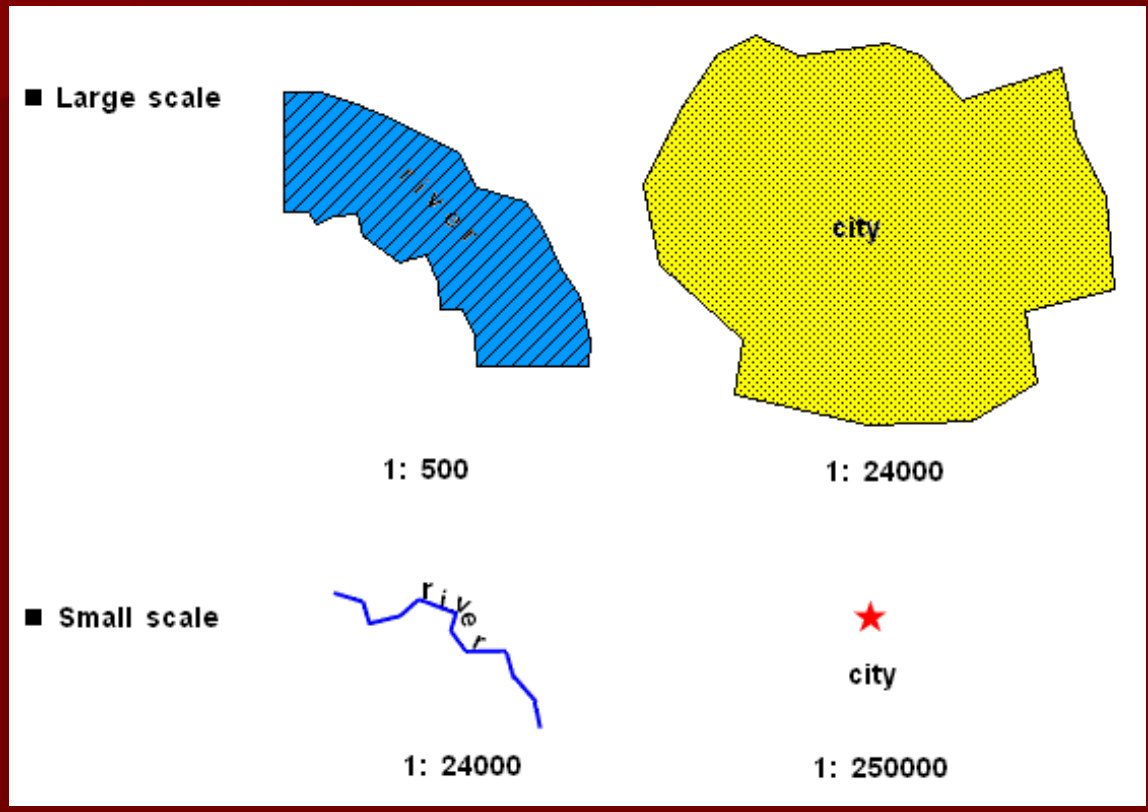
Geometric Characteristics: Scale

Photographic Scale Contd.

- For instance, if the photo scale were 1:63,360,, then 1 inch on the photo would represent 63,360 inches. The first number (map distance) is always 1. The second number (ground distance) is different for each scale; the larger the second number is, the smaller the scale of the map. i.e. Large is Small.
- Quite often the terms large scale and small scale are confusing to those whose who are not working with scale expression on a routine basis.
- A convenient way to make scale comparisons is to remember that the same objects are smaller on a smaller scale photograph than on a larger scale photo.
- A large scale photograph will provide a detailed and high resolution view of a small area.

Large Scale Vs. Small Scale

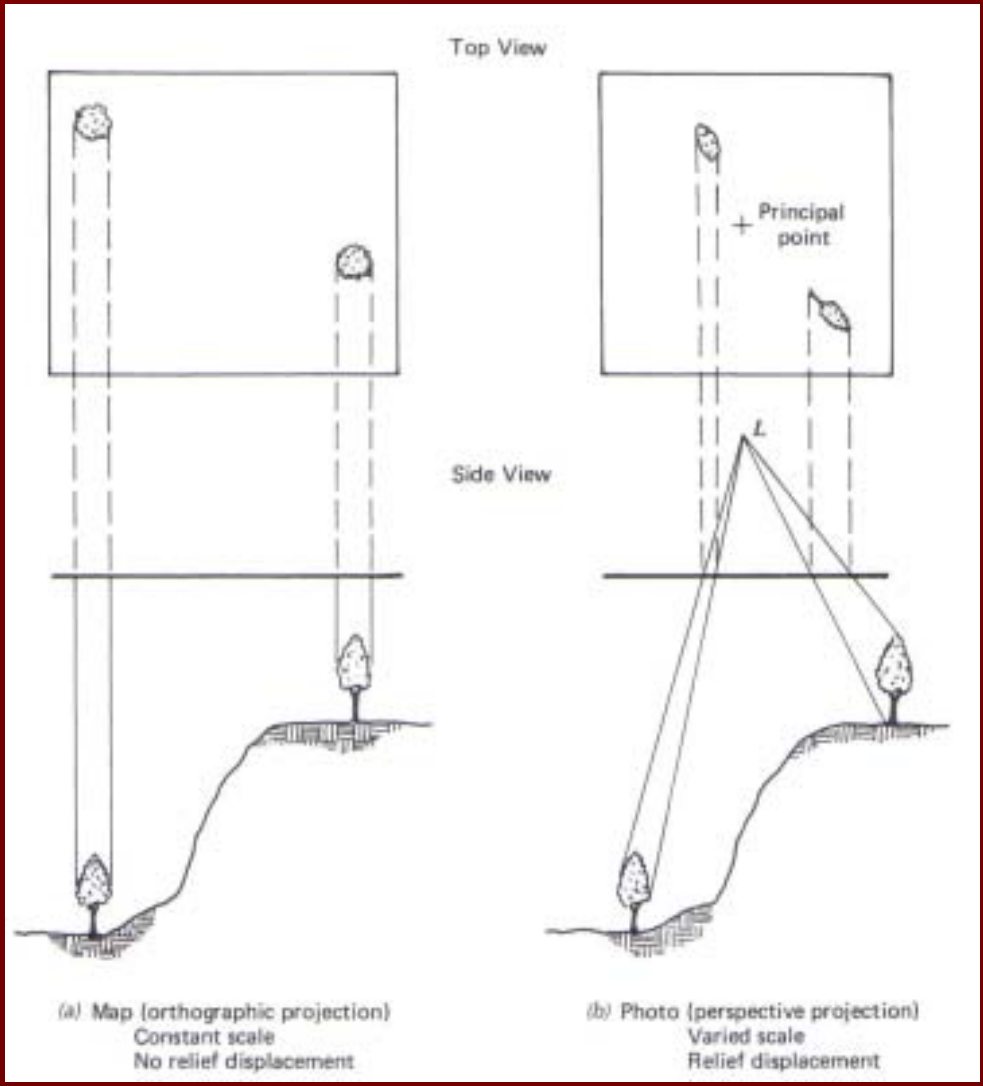
Scale can be used as a measure of viewable detail; small scale implies less detail is visible, large scale implies more detail is visible. Thus, in GIS scale can be used to control display; as scale increases (becomes larger and more "zoomed in") more detail can be displayed without overcrowding the screen display.



A map's scale determines how a feature will be represented. On a large-scale map, a river might be represented as a polygon rather than a line or a city's extent is so large that it can only be accurately represented as a polygon rather than a point.

Comparative Geometry of a Map and a Vertical Photograph

- On a map we see a top view of objects in their true relative horizontal positions. On a photograph, areas of terrain at the higher elevations lie closer to the camera and therefore appear larger than the corresponding areas lying at lower elevations.
- The image of the tops of objects appearing in a photograph are displaced from the images of their bases. This distortion is known as ***relief displacement*** and causes any object standing above the terrain to lean away from the principal point of a photo radially.



Aerial Photo Interpretation

- When we look at a photo we see various objects of different sizes and shapes. Some of these objects may be readily identifying while others may not, depending on our individual perceptions and experience.
- When we can identify certain objects or areas and communicates the information identified to others we are then practicing ***image interpretation***.
- Aerial photographic interpretation is defined as the act of examining photographic images for the purpose of identifying objects and judging their significance (Curran, 1988).
- During the process of interpretation, the aerial photo interpreters usually make use of seven tasks, which form a chain of events. They are: 1) detection, 2) recognition and identification, 3) analysis, 4) deduction, 5) classification, 6) idealisation and 7) accuracy determination.

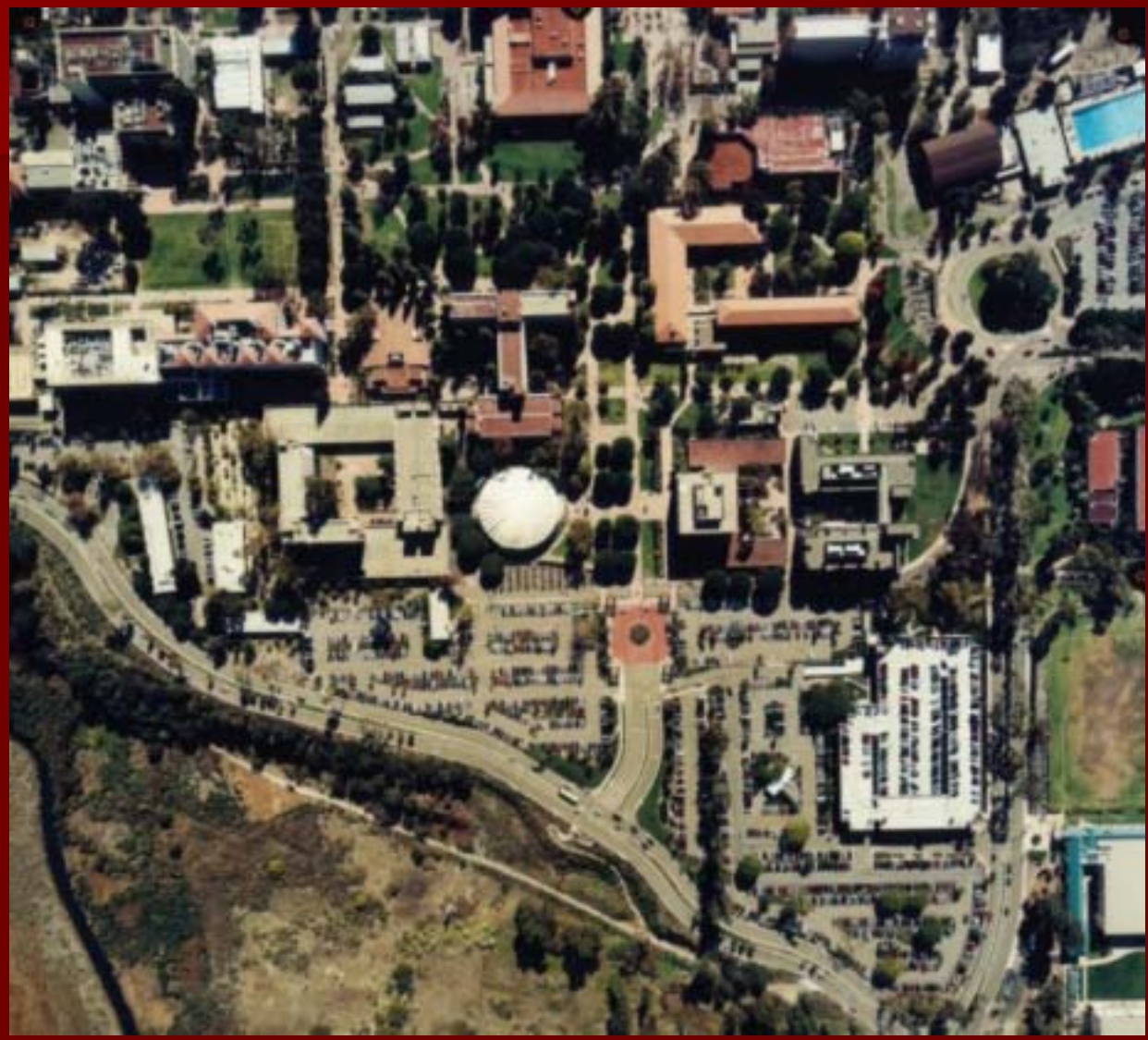
Aerial Photo Interpretation (2)

- **Detection** involves selectively picking out objects that are directly visible (e.g. water bodies, rivers, rock faces etc.) or areas that are indirectly visible (e.g. areas of wet soils or palaeochannels) on the photographs.
- **Recognition and identification** involve naming objects or areas (most important task in this chain of events).
- **Analysis** involves trying to detect the spatial order of the objects or areas.
- **Deduction** is rather complex and involves the principle of convergence of evidence to predict the occurrence of certain relationships on the photo.
- **Classification** helps or comes in to arrange the objects and elements identified into an orderly system before the interpretation is **idealised** using guidelines/directions which are drawn to summarise the spatial distribution of objects (e.g. land use/land cover).
- During **accuracy determination** random points are visited in the field to confirm or refute the interpretation.

Elements of Photo Interpretation

- An interpreter uses following basic characteristics of photograph such as **tone, texture, pattern, place, shape, shadow and size**.
- **Tone** or hue refers to the relative brightness or colour of objects on an image. It is the most important characteristics of the photo. It represents a record of the radiation that has been reflected from the Earth's surface onto the film.
- Light tone represents areas with a high reflectance/radiance and dark tone represents areas with low radiance. The nature of the materials on the Earth's surface affects the amount of light reflected.
- **Texture** is the frequency of tonal changes within an aerial photo that arises when a number of features are viewed together. Texture is produced by an aggregation of unit features that may be too small may be discerned individually on the image such as the tree leaves and leaf shadows. It determines the overall visual "smoothness" or "coarseness" of image features.
- Texture is dependent on the scale of aerial photograph. As the scale is reduced the texture progressively becomes finer and ultimately disappears.

Photo Elements



Elements of Photo Interpretation (2)

- **Pattern** is the spatial arrangement of objects. The repetition of certain general forms or relationships is characteristic of many objects. For examples road patterns or drainage pattern, crop disease pattern and lithological pattern.
- **Place/site** is a statement of an object's position in relation to others in its vicinity and usually aids in its identification (e.g. certain vegetations or tree species are expected to occur on well drained uplands or in certain countries).
- **Shape** is a qualitative statement referring to the general form, configuration or outline of an object (e.g. 'V' shaped valleys indicative of deeply incised river).
- **Shadows** of objects aid in their identification. Shadows are important in two opposing respects: (1) the shape or outline of shadow affords an impression of the profile view of objects (which aids in interpretation) and (2) objects with shadows reflect little light and are difficult to discern on a photo.

Shadows in Photographs

Elements of Photo Interpretation (3)

- **Size** of an object is a function of photo scale. The sizes of objects can be estimated by comparing them with objects whose sizes are known.

- Sizes of objects must be considered while interpreting features and some features may be misinterpreted if sizes were not considered (e.g., a small storage shed might be misinterpreted as a barn if size was not considered).

- **Association** refers to the occurrence of certain features in relation to others. For example, a merry-go-round wheel might be difficult to identify if standing in a field near a barn, but would be easy to identify if stand in an area identified as amusement park.

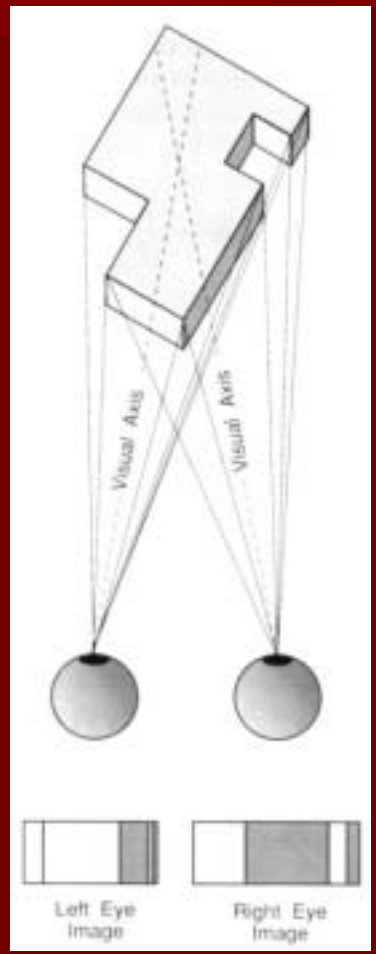
- Success in interpretation varies with the training and experience of the interpreter, the nature of the objects/phenomena being interpreted, and the quality of the image/photo being utilised.

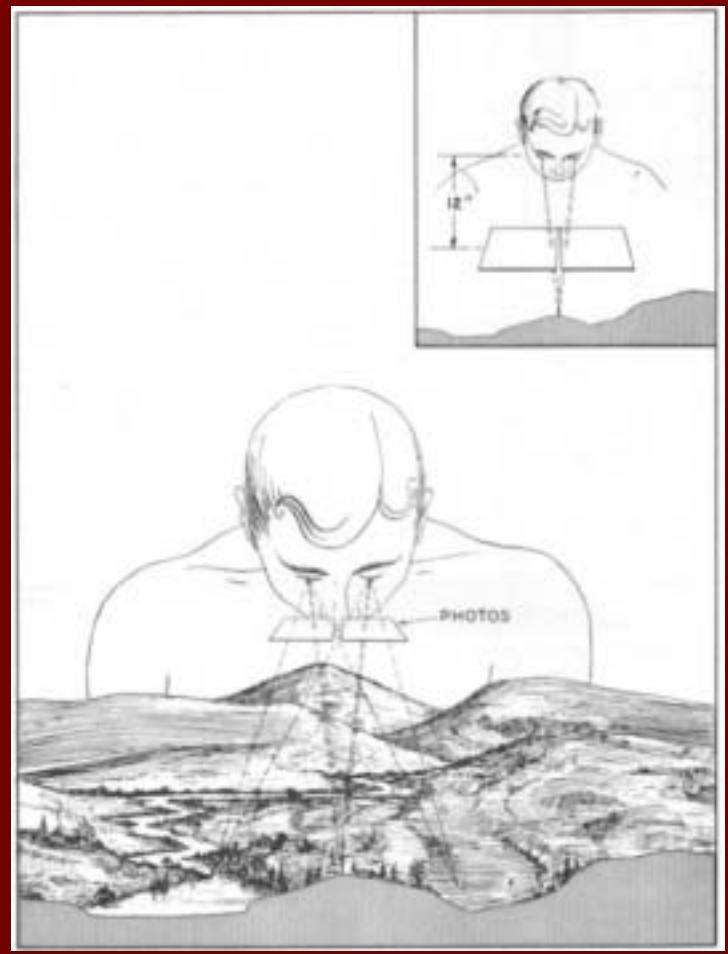
Stereoscopic View

One of the advantage of all aerial photographs is that when taken as overlapping pairs (called stereopairs) they can provide a 3D view of the terrain (also called perspective view).

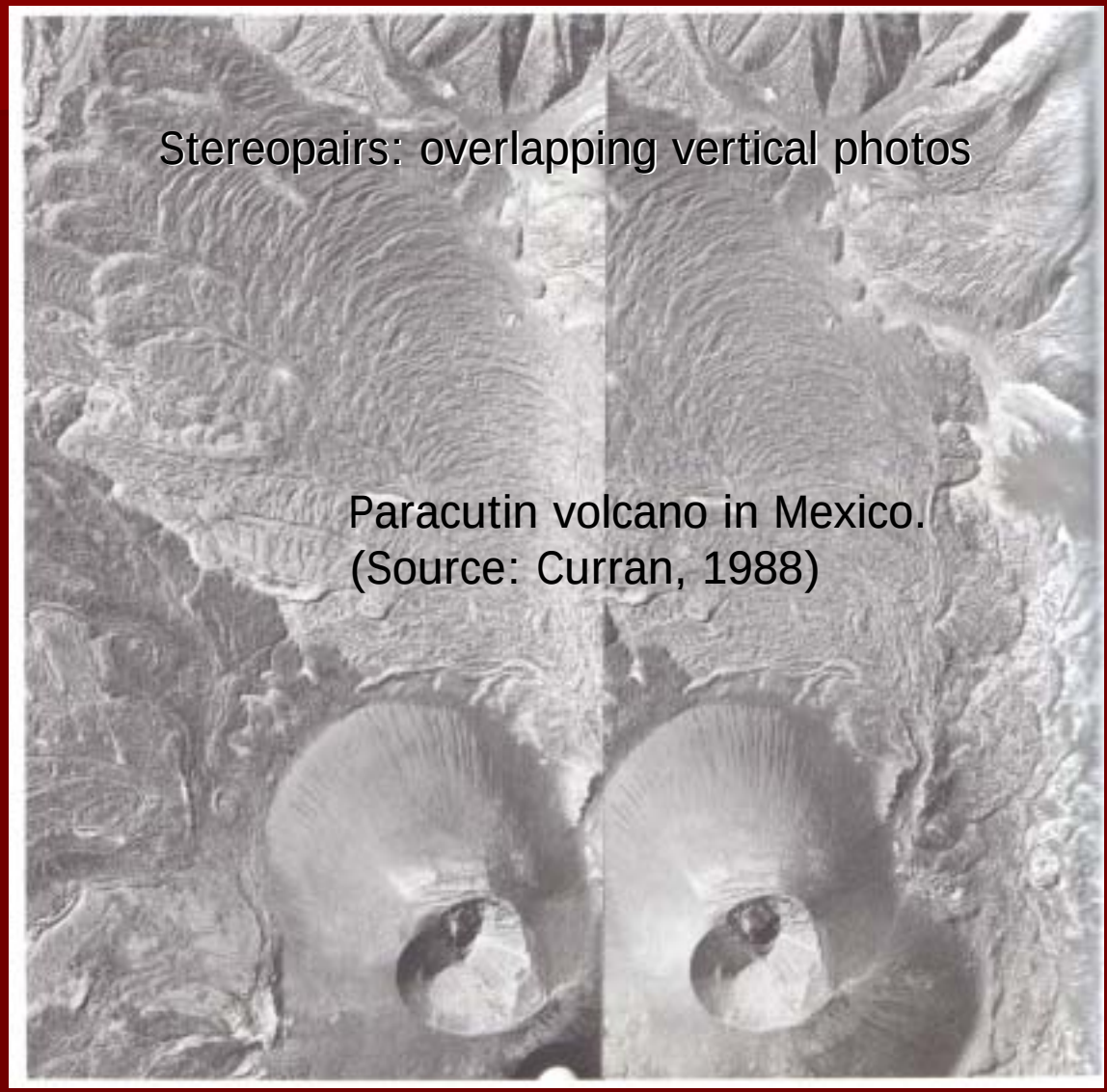
The 3D view is made possible by the effect of **parallax**. **Parallax** refers to the apparent change in relative positions of stationery objects caused by a change in viewing position.

Our left and right eyes are recording information from two slightly differing viewpoints; the brain uses the effect of parallax to give us the perception of depth.

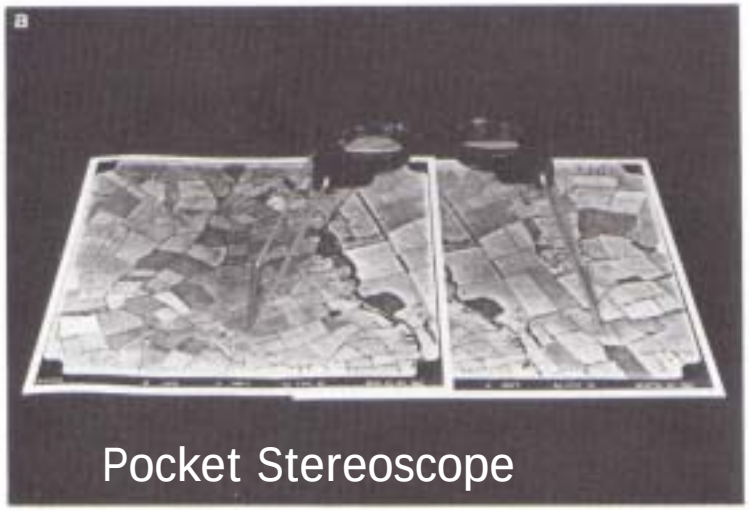




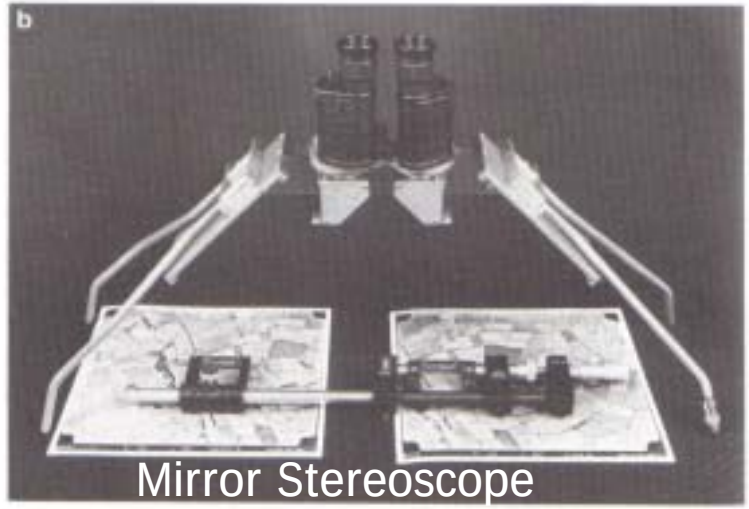
Viewing Photos Stereoscopically



Stereoscopes



Pocket Stereoscope



Mirror Stereoscope

Scanning Stereoscope

'Interpreterscope' (Carl Zeiss)

Photogrammetry: An Introduction

- Photogrammetry is the science and technology of obtaining spatial measurements and other geometrically derived products from aerial photographs (Lillisand et al., 2005).

- Photogrammetric analysis procedures range from obtaining distances, area, elevations using hardcopy (analog) photographic products, equipment and simple geometric concepts to generating precise digital elevation models (DEMs), orthophotos, thematic data and other derived products/information through the use of digital images and analytical techniques.

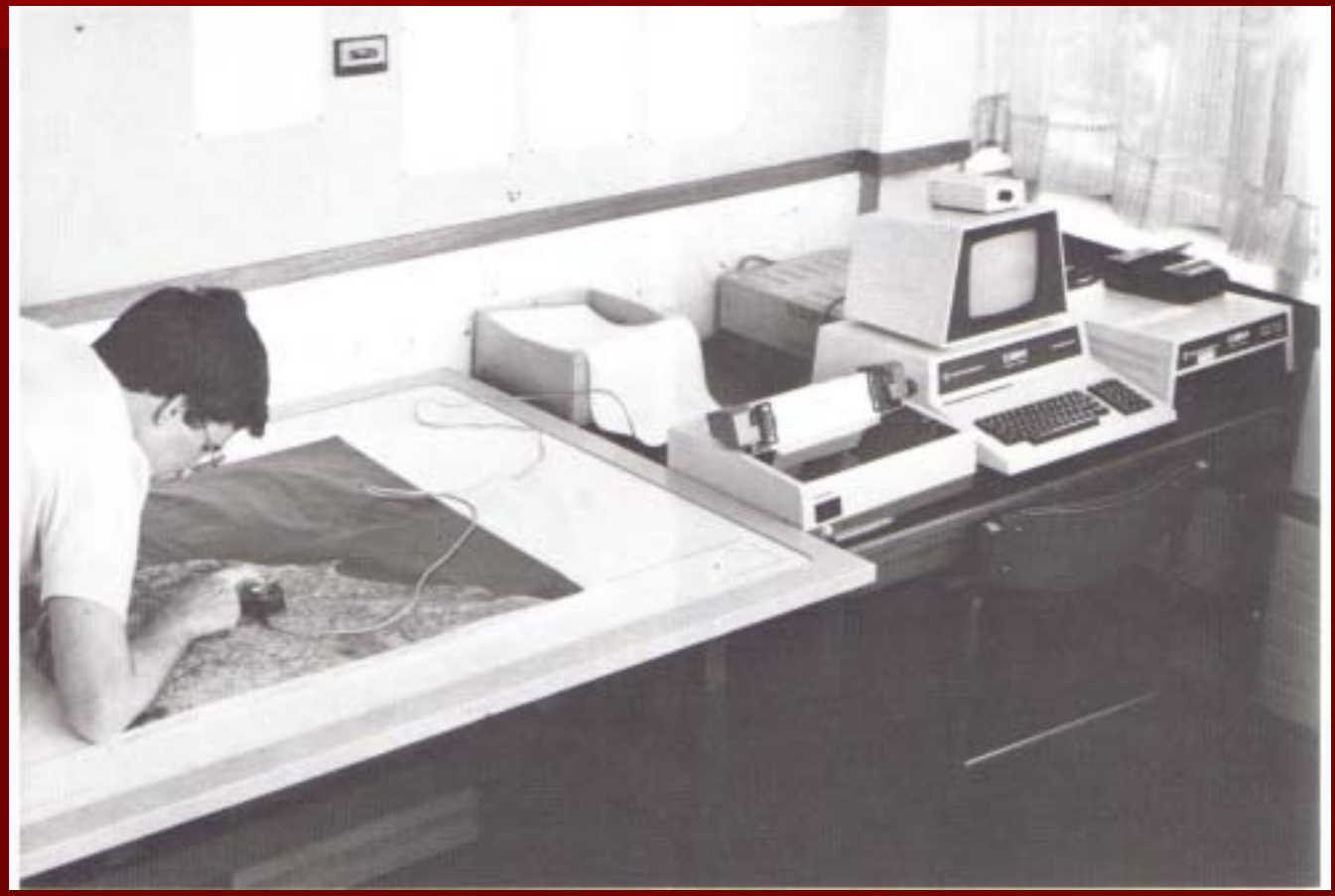
- Digital or soft copy photogrammetry refers to any photogrammetric operation involving the use of digital raster photographic image.

- Historically, one of the most widespread uses of photogrammetry is in preparation of topographic maps. Today, photogrammetric operations are extensively used to produce a range of GIS data products such as thematic data in 2D and 3D, raster image backdrops and DEMs.

Area Measurements on Photographs

Area measurements using transparent dot grid overlay

Area Measurements on Photographs

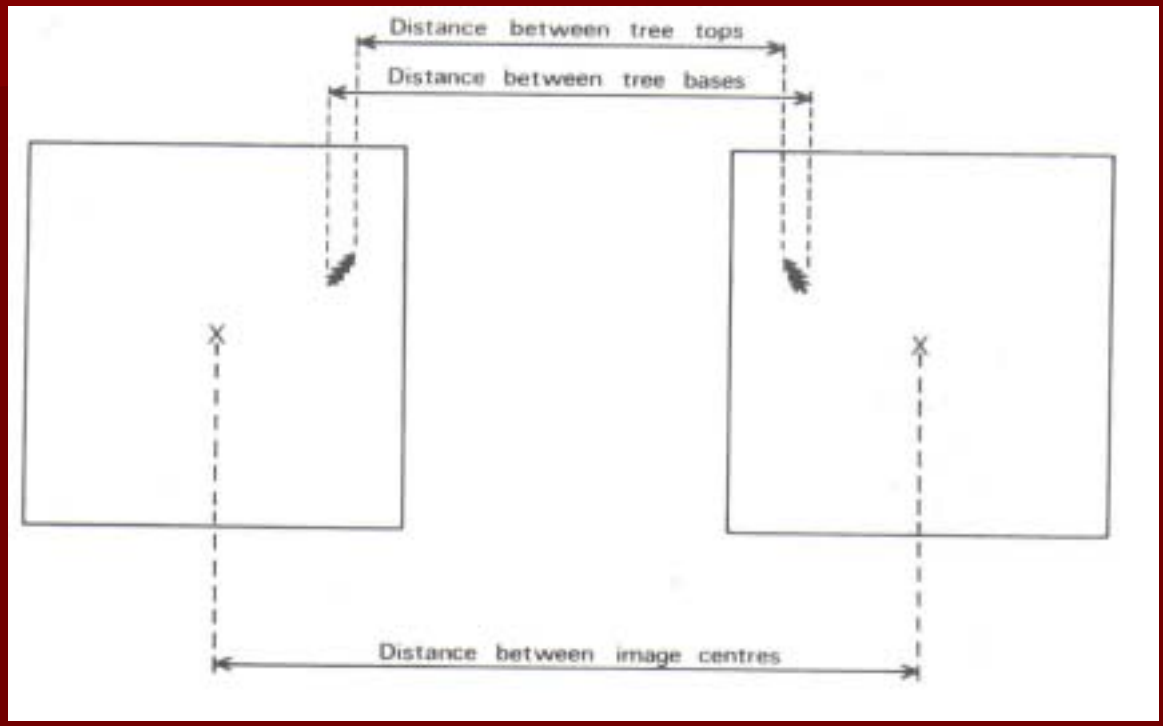


Summergraphics table digitiser being used to measure and record areas.

Measuring Heights from Photographs

$$\Delta h = \frac{\Delta p \times (H - h)}{Pa + \Delta p}$$

where Δh = height of object (tree) in meters



Δp = difference in distance between the top and bottom of the feature on the two photo in mm

Pa = distance between image centres minus the distance between the feature on the two photos in mm

(H – h) = aircraft flying height above the surface of the ground in metres

Mapping With Aerial Photograph

Monoscopic trasnferscope

Monoscopic zoom trasnferscope

Stereosketch

Stereoscopic radial line plotter

Equipment used to transfer planimetric details from photos.

Accurate Plotting of Topography

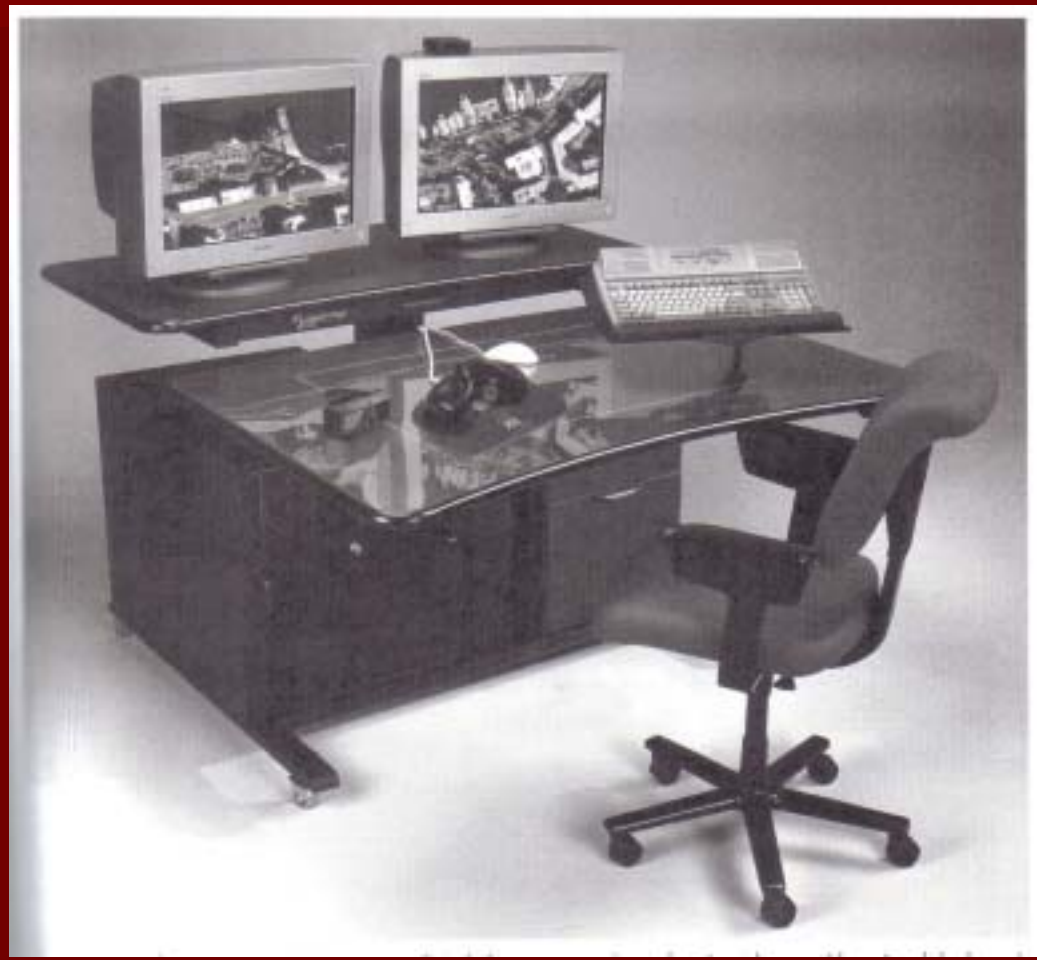
Stereoplotter is the main piece of photogrammetric instrumentation used for the measurement of distance, area, height on aerial photographs and transfer of planimetric details. There are 4 types of stereoplotters: optical-, mechanical, optical-mechanical and analytical stereoplotter.

Optical Stereoplotter

Analytical Stereoplotter

Photogrammetric Workstation

- Photogrammetric workstation involve integrated hardware and software systems for spatial data capture, manipulation, analysis, storage, display, and output of softcopy images.
- These systems incorporate functionality of analytical stereoplotters, automated generation of DEMs, computation of digital orthopohotos, preparation of perspective views and captures 2D and 3D data for use in a GIS.



THANK YOU
VERY MUCH
&
ANY QUESTIONS ?