Aerial Photography

UNIT – 1

1.1 Introduction

The word 'photography' literally means 'writing with Light.' The term 'Aerial photography' means photographing or taking pictures of the earth from air using the aircraft as the platform.
Aristotle (384-322 B.C.), the great philosopher, was first to learn about the nature of light. He first described the principle of camera obscura, some 2300 years ago. Schulze (1687-1744), a physician of Halle, first demonstrated the sensitivity of certain chemical compounds to light. Niepce and Danguerre, the French inventors, announced their invention of the "Danguerre type" in 1839. Their invention solved the greatest difficulty of 'fixing' the exposed image. Further advances in the field of optics and allied sciences, gradually developed the science of photography of present days.

1.2 Development of Aerial Photography

Photography was born in 1839 by Niepce and Danguerre in France. He used Hypo (Sodium thiosulphate) chemical to fix photographic film.
In 1840, Argo Director of Paris observatory advocated the use of photography for topographic surveying.
In 1858, a parsian photographer named Gaspard Felix Tournachan, known as 'Nadar' carried out the first attempt of aerial photography from a ballon. He ascended to a height of about 80-meter using balloon to obtain the photographed village Petit Becetre near Paris in France.
In 1860, **Boston was photographed**, from a captive balloon from a height of approximately 365m (1200ft), **by two Americans Samuel A. King and J. K. Black.** This was **the first aerial photography taken in the United States**.
In 1882, as an outgrowth of their use in obtaining meteorological data. **Kites were used to obtain aerial photography.**
In 1886, A.M. Koran'ko, **was the first Russian to conduct aerial photography experiment over Saint Petersburg.**
In the early 1900s the kite photography of an American, G.R. Lawrence, brought him worldwide attention on **May 6, 1906**. He photographed San Francisco shortly after the great earthquake and fire. He hosted his personally constructed Panoramic Camera some 600 meter above San Francisco Bay using a train of several kites as well as a stabilizing mechanism he designed. The Camera reportedly weighted 22 Kg yielding large negative about 0.4 * 1.2 K meter in size.
The development of airplane in 1903 by Wright brother solved this problem to some extent. The airplane, which had invented in 1903, was not used as a camera platform until 1909.

In 1909 the first aerial photograph, taken from airplane were made by Wilbur Wright. They were taken in Italy during one Wright's training flights made for Italian naval officers. Since then there have been constant improvements in airborne platforms.
Aerial photography from aircraft received highest attention in the interest of military reconnaissance and plot enemy positions during First World War (1914-1918). During this period good quality film and camera was developed. The period of **First World War proved to a turning point in the development and utility of aerial photography**. The **art of photo interpretation for the military uses developed during these years** one of the major **contributions of Second World War (1945) was that a number of scientists, including foresters, geographers, geologists, soil scientists and engineers etc were trained and gained practical experience initially for military purpose.**
After the world war was over, these scientists made the use of their gained experience in their respective fields in civil life.

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The value of Aerial Photographs in forestry, though under stood since 1887, when a German forester took single photograph of forest region in Germany from kite balloon was realized in practice since 1890. Photographs were made from mountain tops, towards opposite mountain slopes and proved very useful in mapping work in inaccessible country in Austria and parts of Germany in Europe, during this period. HUGERSHOFF, well known as developer of stereoplanigraph, was first to demonstrate value of Aerial Photography in forest mensuration.

Canada was the first country, which applied Aerial Photography in forestry. Canadians first started observation of vegetation patterns from an airplane and noted vegetation boundaries on available maps. It was soon realized that the same work could be done on aerial photos, with more ease, in office, using stereoscopes. It is from this time during 1929-30, photo interpretation in forestry made its appearance and the technique was gradually developed since then. Forest service of Baveria, started using Aerial Photographs as a substitute of forest maps. Sweden was the first European country who adopted this techqnique in mapping of its forest wealth and other natural resources.

In Asia (tropics), **Burma** is the first country to start aerial survey of vegetation of Irrawaddy delta in 1924.
In 1927, Northern Rhodesia used Aerial Photography to produce topographic, soil and vegetation maps.

Japan (1930-40) followed Burma and completed forest survey of Lakhani Island.
American foresters convinced by results in Canada and started use of Aerial Photography from 1933.
Indonesia (during 1930-40) used Aerial Photography for survey of mangrove forests.
In India this technique was used since 1925 for preparing topographical mapping by survey of India. However, in 1963 Canadian expert G.A. Jones took the Aerial Photography of Kullu Valley (Himachal Pradesh) for a quick inventory of forest.

Nepal used Aerial Photography in 1952 for first time. Then in 1993, 1964/65, 1978/79, 1985/86, 1990/91, 1994/96. Aerial Photography was used for the estimation of forest and shrub land cover.
Period after IInd world war saw great revival of this technique in all Photointerpretation branches, all over the world. At present there is no country in the world where outstanding value of aerial photography for general forest inventory is not fully understood.

TYPES OF AERIAL PHOTOGRAPHS

Aerial Photography may be classified into various types depending on the different criteria.
1) On the basis of Scale of photography
1) Large scale between(1:5000 to 1:20000)
2) Medium scale between (1:20000 to 1:50000)
3) Small scale (<1:50000)

2) On the basis of angle of view or angular coverage
1) Narrow angle (<50° & focal length 12")

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2) Normal angle (60° & focal length 8.25")
3) Wide angle (90° & focal length 6")
4) Super wide angle (120° & focal length 3.5")

3) Tilt orOn the basis of direction of exposure

1) Vertical
2) Oblique
   i)Lowl oblique
   ii) High oblique

4) Number & types of camera & lenses used

1) Tricamera. OR Trimetrogon 2) Convergent 3) Multiple lens
4) Continuous strips 5) Small camera

5) Types of film & sensor

1) Panchromatic black & white 2) Infrared black & white
3) Color film – a three layered film sensitive to full visible range
4) False color – a film whose blue sensitivity is replaced by infrared sensitivity.

6) Season of photography & time

1) Autumn & winter 2) Spring & summer 3) Rainy season

7) Type of photographic paper

1) Single weight & double weight 2) Glossy print & mattee print

8) Security

- Top secret & secret
- Restricted & derestricted

DESCRIPTION

1. Scales:

Large scale – Large Scale Aerial Photography are used for detailed study such as inventory, management planning, logging planning, road alignment, disease and damage survey, forest type mapping.
Medium Scale: for regional inventory and stratification
Small Scale: for broad land use survey, mapping of forest condition classes, for nationwide survey and reconnaissance mapping.

2. Angle of view:

Narrow angle: - angle is $<50^0$, focal length 12" or 21cm; format size 18*18cm or 9"*9"
Normal angle: - angle is 60° and format size similar to narrow angle.
Wide angle: - angle is 90°; negative size is 14*14cm, focal length is 10cm or nearby so or less, highest precision of height measurement.
Super wide angle: $<120^0$, focal length is 9cm or less, highest precision of height measurement.

The angle of view decreases with increase in focal length.

3. Direction of exposure or Tilt:

Direction refers to the deviation of the optical axis from the vertical. Based on the deviation, the Aerial Photography may have a vertical exposure or an oblique exposure.

Vertical exposure: - Optical axis of camera is kept perpendicular or nearly perpendicular to the horizontal plane. The degree of tilt is less than 4°. It is considered to be best because ground features like, buildings, crossings, roads, streams, forest boundaries appear same as the map of similar scale covers small area but scale is quite uniform over the whole picture.

Advantages of the vertical Aerial Photograph

- More accurate, can be used as map substitute.
- Can be located on maps quickly and by simple means.
- Height and depth of object can be perceived and measured.
- Overlapping pair gives a 3D picture if viewed under a mirror stereoscope.

Low oblique: -

Optical axis of camera is tilted by 30° or less from the vertical and horizon does not show in the picture.

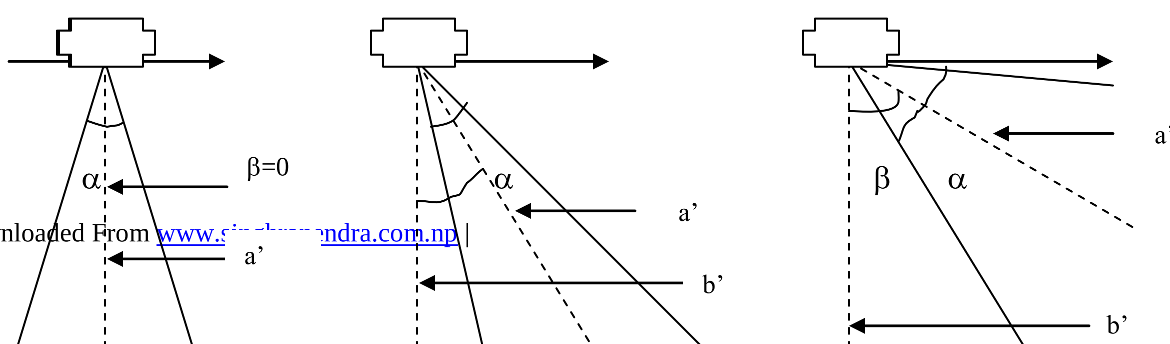
High oblique: - optical axis of camera is tilted by 60° and horizon is apparent.

Unlike vertical photograph the scale of an oblique photograph is variable, and that is why there is distortion. The degree of distortion increases towards the horizon. Amount of distortions is more in high oblique photograph.

- It covers larger area than vertical photograph.
- Terrain features have more normal appearance.
- Don’t give stereoscopic viewing. Therefore seldom used in forestry.

Other advantages of oblique photograph

- Coverage is more, with an appreciable reduction in the number of photographs.
- Appear more normal to the average users i.e. relief (terrain feature) is more apparent.
- Supplement information for the interpretation of vertical photographs.
- More economic and informative.



β

Figures: a, b, c, vertical, low oblique, high oblique direction of exposure.

α = Angle of view β = Deviation of optical axis from vertical line
a'= optical axis of camera b'= vertical line perpendicular to the horizon

4. Number & type of and lenses used

Trimetrogon or Tricamera

Three cameras are used simultaneously out of them one is vertical and other two-placed left and right are oblique. Three camera fields view overlap each other in such a way that photographic strip is made horizon to horizon across the flight line.

Advantages: -

- Relatively cheap
- Provides small scale with high coverage
- Not suitable for vegetation mapping

Convergent photography:

There are two cameras; one facing forward and other facing backward are tilted at a certain angle from vertical line in the direction of flight lines. These are synchronized in such a way that the forward exposure of first locality forms a stereospair with the back locality. Thus by the use of convergent camera stereopairs with the varying degree of overlap can be produced.

Multiple lenses photography:

Only one camera equipped with many lenses (4-9). The camera is loaded with 1,2 or 3 films, which can be exposed together.

Continuous strip photography:

Photography taken from this camera has no shutter. The altitude and speed of the plane are taken into account while determining the speed of the camera film. The camera is used for large-scale photography.

Small camera photography:

Photography taken from small camera such as 70mm or 35mm is generally known as small camera photography.

5. Types of film & Sensor

Panchromatic black and white:

These are useful in visible light range 3.5 to 7.5 milli μm of electromagnetic spectrum. Therefore, covers a little bit more than human eye (4-7milliμm). Panchromatic film has relatively low sensitivity in the green color. Thus film produces a picture, which appears "normal"i.e. dark objects appears dark and light appears light. This film is usually used in combination with minus blue filter, which absorbs light wavelengths shorter than 0.5μm.

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Infrared (IR) photography (B & W):
The IR films are sensitive to visible light and near infra red (NIR) radiation (3.5-9.0 milli μm). Good registration of vegetation because of radiation penetrates the haze, dust particles better.
IR film has some advantages over panchromatic film in high altitude photography.
The IR film is used in combination with dark red filter, which cuts out all visible light below 6.8milliμm. the resulting prints show a high tonal contrast between high IR reflecting objects (conifers) or IR absorbing objects/water surface and objects in shadow.

Color photography:
The color film also called true color film registers visible colors by human eye (0.4-0.7μm). It is 3-layered film with emulsion sensitive to B, G; R. the yellow filter layer of film screens out the UV radiation and some of the blue. The color photography is much more useful in separation and identification of different species and diseases, color quality is adversely affected by haze and increasing height. It is costlier than PAN photography.

False color photography:
False rendition of colors so called false color photography. False color also called IR color film. It differs from ordinary color film. In that 3 layers are sensitive to G, R and NIR radiation of the visible spectrum. When false color film is processed, the color B, G & R appear in the final transparency but with false rendition, yellow orange filter gives most normal result.

Color Photography	false color Photography	In false color photography
R	IR	IR replaces R
G	R	R replaces G
B	G	G replaces B

A false color film enhances color differences between natural and manmade objects, healthy and diseased trees, deciduous and evergreen trees. Thus making it most effective in identification. The chlorophyll in plants reflects IR so strongly (40-50%) that healthy vegetation has reddish cast, expected from green. In contrast reflectance of B, G, R is nearly 15-20% only.

6. Season of photography:
Autumn and winter photography: The autumn (Oct-Nov.) and winter (Dec-Feb) months are best for forest photography to make distinction between broad leaved and coniferous trees.
Spring and summer photography: Photography of the months March-June is called spring and summer photography. Good for distinguishing tropical moist evergreen forests from dry deciduous forest in summer and coniferous from broad leaved even in broad-leaved e.g. some species, which shows typical leaf and flowering characteristics in spring.
Rainy season photography:
Photographs taken in the months of June-September are known as rainy season photographs. Not convenient as the days are normally cloudy. However, it is good for flood studies and hydrological investigation.

7. Type of photographic paper:
Single weight and double weight:

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1. Single weight: less expensive, suitable for mosaic construction, easier to handle but less durable. (Mosaic: assemblage of overlapping Aerial Photographs' edges is matched to form a continuous photographic representation of a terrain.)
2. Double weight paper: more expensive and more durable & suitable for field use as it is less liable to creasing.

Glossy print and matte print:

1. Glossy print: contrast range is much larger compared to matte paper. It offers sharpest print with finer details but frequently cracks and reflects glare (smooth and shining surface).
2. Matte print: these papers are more flexible, do not glare (dull finish) and are easy to write on. It has low contrast.

8. Security:

1. Top secret: operational photographs of Air force and installation of Army and Navy.
2. Secret: photographs of border area and civil vital points.
3. Restricted: All aerial photographs other than those covered by higher categories are placed in restricted types.
4. Derestricted: some aerial photographs are derestricted for educational purposes, planning of roads, study of forest inventory etc.

Time of Aerial photography: Best time is 9-11AM and 1.30-3.30PM.

USES OF AERIAL PHOTOGRAPHS IN MATURAL RESOURCE MANAGEMENT

Aerial photographs has been found to be

- Fast, accurate, cost effective (reduce the field work and thereby cost effective)
- Suitable for inaccessible areas
- Information is reliable and accepted.
- Works as a map substitute)

Presently there are wide uses of Aerial photographs in different fields.

a. Forestry:

i. Forest resources mapping and inventory (tree volume estimation)
ii. Vegetation growth distribution investigation
iii. Forest resources investigation
iv. Forest fire monitoring
v. Forest disease and pest monitoring
vi. Shifting cultivation
vii. Forest tree species identification

b. Agriculture:

i. Crop inventory forecast, crop acreage
ii. Crop area investigation
iii. Soil classification
iv. Pasture supervision

c. Land use

i Land use investigation

ii Application to various map making

d. Disaster:

i. Volcanic activity monitoring
ii. Earthquake prediction

e. Geology and mineral resources investigation:

i. Land surface geology investigation
ii. Surface structure investigation
iii. Sub terrain heat investigation

f. Water resources:

i. Snow distribution investigation
ii. Surface water distribution investigation

g. Environment:

i. Environmental map making.
ii. River pollution investigation
iii. Environmental destruction monitoring

h. Fishery:

i Ocean temperature distribution, current, sea water mass investigation
ii Tide investigation
iii Waves, sea wind
iv Ocean circulation

i. Atmosphere:

i. Air pollution investigation and monitoring
ii. Weather investigation and forecasting
iii. Thermal circulation investigation

j. Planning purposes:

i. Urban planning
ii. Road planning

k. Wildlife management:

i. Habitat analysis
ii. Sites for cover or nesting
iii. Distance and water
iv. Food availability

UNIT-2: principal of Photography

The word "photography "literally means writing or drawing with light. 'Aerial photography' means taking pictures of the earth from the air.

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Pinhole Camera: It has (i) no lens (ii) a light tight box (iii) pinhole at one end and the light sensitive material to be exposed positioned against the opposite end; (iv) requires very long time to expose the film.

Simple Lens Camera: (i)Similar geometry as pinhole camera (ii) pinhole is replaced by lens (iii) The size of the opening(aperture) is much greater in lens camera. So, picture can be taken in a fraction of second (iv) It has an adjustable shutter and adjustable diaphragm (v) The amount of light entering the camera can be adjusted by changing the lens diameter by changing the diaphragm and shutter speed.

Thus simple lens camera is the basic piece of equipment needed in photography. It has a light proof box or chamber in which an image of an exterior object is projected upon a sensitized film through an opening usually equipped with a lens, a shutter, and an adjustable aperture known as diaphragm. The shutter is the mechanism which controls the length of time that the film is exposed to light. The aperture is that part of the lens which limits the amount of light passing through the lens. The lens gathers the light rays reflected from objects and focuses them onto a light sensitive area.

An aerial camera is one which is specifically designed for use in aircraft of which there are many types in use today. A good aerial camera is capable of producing photographs of high pictorial (image or picture) quality as well as maintains geometric fidelity (accuracy). In order to fulfill these requirements, the camera should have following characteristics (i) The camera should be capable of performing under wide range of temperature conditions (ii) The lens aperture should be large (iii) The film should be exposed within a fraction of second (high speed film) (iv) the camera lens should be free from aberration (distortion of image) and (v) The camera should produce high image quality. The diagram of main parts of a typical frame aerial camera is shown in fig. 2a

Some of the more commonly used aerial cameras (types of aerial cameras) are

(1) **A frame camera**: Most aerial cameras can be classified as frame camera in which an entire frame or photograph is exposed through a lens that is fixed relative to the focal plane of the camera. Frame camera may be a single lens or multiple lenses. The number of lenses in a multiple lens camera may vary from four to nine lenses. The photographs taken by multi lens camera normally yields enhanced contrast between different terrains features. They are used for reconnaissance, mapping, and interpretation purposes.

(2) **Panoramic camera:** Unlike the frame camera the panoramic camera takes a partial or complete (horizon to horizon) panorama of terrain. In some panoramic cameras, the film is stationery, but the lens revolves about the longitudinal axis of the aircraft to produce highly detailed photography.

(3) **A continuous strip camera:** In this type of camera a continuous strip exposure is made by rolling a film continuously onto a narrow slit opening, under which the film moves at a speed which is proportional to the ground speed of aircraft. This type of camera is developed to eliminate blurred photography caused by movement of camera at the time of exposure.

Camera lens: A camera lens can be defined as a piece or a combination of pieces of glass or other transparent material which is shaped to form an image by means of refraction of light. Aerial camera lenses can be classified according to focal length or angle of coverage. One of the most important features of an aerial camera, besides the quality of the lens, is the focal length, which can be defined as the distance from the film to approximately the center of the lens when focused at infinity. The parallel rays of light coming from an object from infinity enters the camera through lens are focused to a point on the focal plane and its image is formed on the film which is real, inverted and diminished in size. The angle of coverage is the angle of cone of light rays which pass from the ground through the lens and expose the film. The angle of coverage increases as the focal length of the lens decreases. The distance between the lens and the film is adjustable until a sharp image of the object is formed on the film. The focal lengths commonly used are 3”, 6”, 8.25” and 12”. Out of which most commonly used are 6” and 8.25”. A lens for aerial cameras are very precise with distortion of images on photograph is usually less than 10 microns of an inch.

Camera calibration: The objective of camera calibration is to determine the numerical value of the camera focal length (principal distance) and distortion characteristics of camera lens. It is essential to carryout calibration before flight, by proper authority and its report should be made available. Interval between calibration and flying should not exceed two years. Camera or image magazine should also be calibrated. Each film magazine should also be tested before use. In general, camera calibration methods may be classified into three basic methods.

(1) Laboratory method (2) Field method and (3) Steller method.

- Of these Laboratory method is most frequently used

Camera calibration report usually contains follows:

- Manufacture’s name and type of camera
- Serial number of camera optical lens and units
- Angle of intersection of fiducial axes
- Distance between fiducial marks
- Focal length(principal distance) of camera and its distortion value
- Comment on flatness of focal plane

Photographic film type: The commonly used aerial films are

(a) Panchromatic B/W

(b) Infrared(IR)

(c) Standard or normal color

(d) Color infrared

Panchromatic film is the most commonly used type for general aerial photography; since it is sensitive to approximately the same range of wavelengths from blue over green and to red light as is the human eye (0.4 to 0.7 micrometer). Thus it produces a more natural picture. Infrared photography (black and white) may be either” true” or “modified”. Modified IR film is sensitive to extensive range in NIR portion of the wavelength (0.7 to 0.9 micrometer- which is called photographic IR region) in addition to those wavelengths as seen by the human eye. True IR photography makes use of the same film but utilizes a filter which blocks the visible light waves below 0.7 micrometers, thus allowing only the photographic IR wavelengths to expose the film.

Some of the advantages of IR and non-IR film types are:

Advantages of non-IR film (color and panchromatic):

a) The various shades of grey are more natural to human eye and therefore, easier to interpret.

b) Much more detail can be seen within areas covered by the shadow.

Advantages of IR film (black and white and color IR):

a) Much better penetration of haze.

b) Emphasize water or moist areas.

c) Good differentiation between hardwood and conifers.

d) Diseased, dying or vegetation under stress is more easily detected specially on color IR film.

Film specifications: Regardless of film type used we must consider its resolution, speed and granulity. Film speed refers to the sensitivity of film to light. A higher film speed indicates a higher sensitivity to light, but it also usually means increased granulity. The grain of a film is the relative size of the light-sensitive particles and has a course texture. An increase in granulity results in a low photographic resolution.

Resolution may be defined as the ability of the system to distinguish between two or more closely spaced objects usually expressed as the number of distinct lines per millimeter for a specified target, background contrast, target illumination, etc, since resolution, film speed and granulity are all interrelated, a change in one will result in the other two also. It means, if you want a film with a high speed you will have to sacrifice resolution and vise versa.

Filters: Photographic filters are transparent colored plates of glass or dried gelatin between glasses which are placed in the optical path of a camera lens in front of the lens. The filter either absorbs or reflects the undesired radiations. Hence, filter cut out some of the incident light and their main purpose is to perform all ground details clearly by penetrating the atmospheric haze and to modify reproduction of colors. A yellow filter (haze filter) absorbs blue light and transmits green and red light energy. So the photograph made by green red (yellow) filter is also called ‘minus blue’ filters. Aerial cameras are usually exposed through yellow filters. Filters are essential because small dust and moisture particles in the atmospheric air prevent the distant image from registration. Filters enhance the contrast of the image. Filters commonly used are yellow (minus blue), Magenta, cyan, white, gray, black, etc,.

Film Exposure: The quantity of energy which is allowed to reach the film is called film exposure. The exposure at any point on a photographic film depends on several factors, including the scene brightness, the diameter of the camera lens opening, the exposure time and the camera lens focal length. The energy is largely controlled by the relative aperture and stutter speed of the camera as well as the intensity of the energy source. Shutter speed, which is variable, and is defined as the duration of exposure and its length of time the shutter is open allowing light to expose the film in a fraction of second. In aerial cameras the speed of shutter ranges between 1/100 to 1/500 of a second.

The exposure at any point in the film in focal plane of a camera is determined by the irradiance at that point multiplied by the exposure time, expressed by

$$E = sd^2t/4f^2 \text{ ....1}$$

Where, E= film exposure, J mm $^{-2}$

S = scene brightness, J mm $^{-2}$ sec^{-1}

d=diameter of lens opening, mm

t = exposure of time, sec

f = lens focal length, mm

It can be seen from Equation 1 that for a given camera and scene, the exposure reaching a film can be varied by changing the camera shutter speed t and/ or the diameter of lens opening d.Various combinations of d and t will yield equivalent exposures.

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Example 1: A film in a camera with a 40-mm-focal-length lens is properly exposed with a lens opening diameter of 5 mm and an exposure time of 1/125 sec (condition 1). If the lens opening is increased to 10 mm and the scene brightness does not change, what exposure time should be used to maintain proper exposure (condition 2)?

Solution

We wish to maintain the same exposure for conditions 1 and 2, Hence

$E1= s_1 (d_1)^2 t_1/4(f_1)^2 = s_2 (d_2)^2 t_2/4(f_2)^2 = E_2$

Canceling constants we obtain

$(d_1)^2 t_1 = (d_2)^2 t_2$

Or $t_2 = d_1 t1/(d2)^2 = 5^2/10^2 .1/125 = 1/500$ sec

The relative aperture, or the diameter of lens opening of a camera, which is also variable is determined by adjusting the diaphragm to a particular aperture setting which is called f-stop. This can be defined as the focal length divided by the effective lens opening diameter.

F= f- stop = lens focal length/effective lens opening diameter = f/d……….2

As can be seen in Equation 2, as the f- stop number increases, the diameter of the lens opening decreases and accordingly, the film exposure decreases. Because the area of the lens opening varies as the square of the diameter, the change in exposure with f- stop is proportional to the square root of the f-stop. Shutter speed is normally established in sequential multiples of 2(1/125sec, 1/250 sec, 1/500 sec, 1/ 1000 sec,..). Some of the more common f/stop from larger to smaller lens opening are: f/2, f/2.8, f/4, f/ 5.6, f/8, f/ 11, f/16, f/22, and f/32. When the value of f- stop is 2, it is written as f/2.

For constant exposure, an incremental change in shutter speed setting must be accompanied by an incremental change in f-stop setting. That means if the time the shutter remains open is doubled, the lens opening must be decreased by one f/ stop to maintain the same exposure. For example, the exposure obtained at 1/500 sec and f/1.4 could also be obtained at 1/250 sec and f/2. Similarly, if a photo is taken with a shutter speed of $1/100^{th}$ of a second and a relative aperture of f/11. If the shutter speed is changed to $1/50^{th}$ of a second, the relative aperture must be decreased one f/ stop to f/16 in order to maintain same exposure of the film. Short exposure time allow one to “stop action” and prevent blurring when photographing moving objects (or when the camera is moving, as in the case of aerial photography).Large lens opening diameter (small-stop numbers) allow more light to reach the film and are useful under low light conditions. Small lens opening diameters (large f-stop numbers) yield greater depth of field. The f-stop corresponding to the largest lens opening diameter is called the “lens speed”. The larger the lens-opening diameter (smaller f-stop number), the “faster” the lens is.

Using f-stops Equation 1 can be simplified to

$E= st/4F^2$, where F=F-stop=f/d.

Focus: The lens of a camera is used to focus the image and **t**hree parameters are involved in focusing a camera lens, the focal length of the camera lens (f), the distance between the lens and the object to be photographed (o), and the distance between the lens and the image plane (i). The focal length of a camera lens is the distance from the lens at which parallel beam of light rays are focused to a point. When a camera is properly focused, the relationship among the f, o and i is given as

$1/f = 1/o+ 1/i$

Since, f is a constant for any given lens, as object distance o for scene changes, image distance i must change. This is done by moving the camera lens with respect to the film plane.

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In aerial photography the object distances involved are normally infinite. Hence the term 1/o in the above equation becomes zero and I must be f. Thus most aerial cameras are manufactured with their film plane precisely located at a fixed distance f from their lens. Now if o< and equal to focal length (very close) the image is formed but can not be focused.

When an object is focused at a discrete distance, a camera can image over a range just beyond and in front of this distance with acceptable focus. This range is commonly referred as the *Depth of field*. So, *Depth of field* is the distance between the points nearest to and farthest from the camera and the objects that are in focus within acceptable distances.

In other words, *Depth of field* of a lens is the range in object distance that can be accommodated by a lens without introducing significant image distortion. For a given lens *Depth of field* can be increased by reducing the size of the lens opening (aperture). This limits the usable area of the lens to the central portion. For aerial photography, the *Depth of field* is seldom of consequence because variation in the object distance is generally a very small percentage of the total object distance. For close range photography, however, *Depth of field* is often extremely critical. The shorter the focal length of a lens, the greater it's *Depth of field*, and vice versa. Thus, if *Depth of field* is critical it can be somewhat accommodated through the selection of an appropriate lens.

Photographic Processing

1: Black and white Photos

2: Color Photos

A photographic film is ordinarily composed of a thin layer of polyester base that has been coated on one side with light sensitive (Photo sensitive) silver halide crystals (or grains) layer with a solidified gelatin called emulsion. On the other side of the film base is the anti-halation backing, a light absorbing dye that prevent the formation of halos (prevents reflection from other side) around the bright images.

Emulsion for photographic films posses varying degrees of sensitivity to light waves and knowledge of a particular film's speed is essential to obtain a correct exposure." slow" films require bright light for exposure while "faster" films may work in less light condition. Aerial films are available in various lengths such as 200, 500, and 1000feet.

Paper or plastic is the base material for paper print and negative print, forming an invisible latent image.

PANCHROMATIC BLACK AND WHITE FILM: B & W film that is sensitive to a broad wavelength of visible light is called panchromatic film. The two types of panchromatic B & W film are mapping film which has equal sensitivity to all visible wavelengths, and reconnaissance film which has reduced sensitivity to blue wavelengths to minimize the effect of atmospheric scatter. The majority of panchromatic B & W aerial photographs are taken using mapping film.

The film emulsion which gives uniform exposure in the visible part of spectrum namely 0.4 micrometer – 0.7 micrometer is known as panchromatic (normal black and white) film. This part of spectrum is visible to human eye. The infrared film shows maximum sensitivity in the region of 0.7-0.9 micrometer. This part of spectrum is invisible to human eye and can be used to detect the difference between green vegetation and dry vegetation, which radiate different amount of energy. The dry vegetation being at a slightly higher temperature due to lack of moisture emits radiation in the 0.8-0.9 micrometer range and hence can be used to photography by infrared film.

Black and white films are the simplest kinds of photographic films. They contain only one emulsion layer. The emulsion layer works such that if more light strikes the film, more silver halide crystals per unit area react with the light, and the object shows up brighter on the finished photograph.

The 4 resultant film types are i) B & W ii) B & W near Infrared(NIR) iii) color and iv) color Infrared

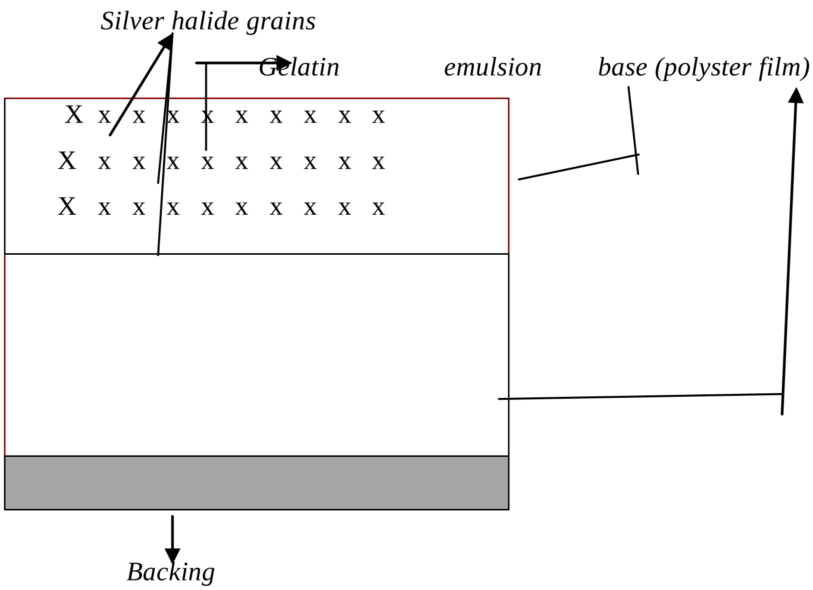


Fig :(a) cross section of Panchromatic black and white film

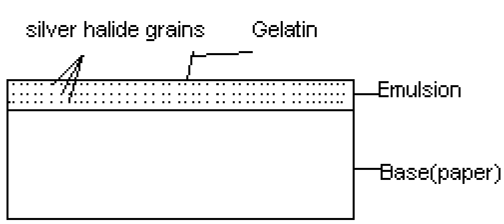


Fig :(b) C.S. of Panchromatic B\W print paper

When a roll of exposed film is removed from a camera, it must be protected from light, extreme temperature and humidity until it is processed.

Developing and finishing: When the light is exposed to the film

1. Silver halide grains within an emulsion layer undergo a photochemical reaction forming an invisible latent image.
2. Upon treatment with suitable agent (developer) in the development process, these exposed silver halides appear black forming a visible image (Fig-1)

PROCESSING PNCHROMATIC BLACK AND WHITE FILMS:

COLOR PHOTOGRAPHY THEORY: Far more information is available in a color photograph than is

The procedure entails the following steps.

1. Developing. The exposed film is first immersed in a ***developer*** solution. Developers are selective, ***alkalin**e* reducing agents. They reduce the silver of the exposed halide grains in an emulsion from a molecular ionic state to a pure atomic state. Since, silver in the atomic state is black; there is proportionate correspondence of image ***darknes**s* on the negative with object ***brightness*** in the scene photographed.

2. Stop bath. After images have been developed to the desired degree, the developing action is stopped by immersing the film in an ***acidi**c* solution called a ***stop bath***. The stop bath neutralizes the alkaline developer solution, thereby stopping the development process.

3. Fixing. In the third step of the process, the film is placed in a ***fixer*** solution. The function of the fixing bath is to remove the unexposed silver halide grains from the emulsion, to harden the emulsion and render it chemically stable. Depending on the film and process involved, steps 2 and 3 are often combined into one operation.

4. Washing. In this step, clean running water is used to wash the film to render it free of any chemical residues that would degrade the image.
Chemical agents are often added to the wash to speed up the washing' process.

*5: **Drying***. The final step in the process is that of drying. Either through air drying in a dust-free environment or through drying in a heated dryer, water is removed from the processed material.

Paper or positive prints: are produced by a series of steps similar to those followed in film development. A sheet of sensitized photographic paper is placed over the negative and exposed by light from underneath. The exposed paper is then subjected to a developing solution, followed by stop bath, fixing, washing and drying.

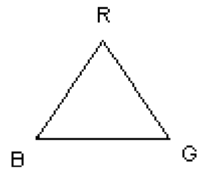
***Safe light**:* Includes red & yellow light. As we know that the film is composed of emulsion layer (silver halide grains & gelatin) and Ag halide is sensitive to blue light.

When & why safe light is used: **When producing positive from negative by using printing paper containing untreated Ag halide in the dark room. Because printing paper can not expose to sun light. So it is proceed in the dark room. Printing paper is sensitive only to blue light. So safe light did not expose printing paper.**

available in a B & W photograph.

Color theory states that there are three primary colors of visible light. These are B, G, and R. White light is the mixture of B, G and R light. These primary colors are called additive colors or additive

Primaries, because they can be added or mix together in various combinations to produce other colors by the following criteria.



Blue + Green = Cyan (Bluish green)

Blue + Red = Magenta (Bluish red)

Green + Red = Yellow

The new colors (cyan, magenta and yellow) produced by mixing together two additive colors in equal proportion are called secondary or complementary or subtractive colors. Thus these dyes (cyan, magenta and yellow) are complementary in color to the primary colors and each absorbs one primary color and transmits two primary colors i.e. yellow dye absorbs the blue light component from white light background and transmits green and red. Magenta dye absorbs the green light component from white light background and transmits blue and red.

Cyan dye absorbs the red light component from white light background and transmits blue and green. Thus yellow is called minus blue or complementary to blue because it absorbs blue. Magenta is called minus green or complementary to green because it absorbs green. Cyan is called minus red or complementary to red because it absorbs red. These primary colors can not be obtained by mixing other colors. When these primary colors are mixed in equal proportion, they produce white light. The color of an object tells us a number of thinks about how electromagnetic radiation interacts with the object. It tells us the wavelength of energy reflected by the object, as well as the wavelength of energy absorbed or transmitted by the object. So, color of an object is due to reflected light and transmitted light. When white light falls on opaque object, it absorbs all the colors, except one color which it reflects. This reflected color is the color of the object. For e.g. a blackboard appears black because all the visible energy is absorbed by the blackboard. A white board appears white because it reflects all the colors and absorbs no color. A green leaf of trees appears green because it reflects green light and blue and red light is absorbed by the leaf. Red color is reflected by the rose flower and it absorbs all the rest of the colors. If an object appears cyan in color, this tells us that approximately equal amount of blue and green light are being reflected by the object, and most of the red light is being absorbed. The more bright an object's color appears, the higher is the percentage of incident light being reflected. When white light falls on a transparent object, a particular color is transmitted through it and rest of the color is absorbed. A blue glass appears blue in white light because it transmits blue colors only and absorbs all the other colors. Like the eye, color television operates on the principle of additive colors mixing through the use of B, R and G dots (or vertical lines) on the picture screen. When viewed at a distance, the light from the closely spaced screen elements forms a continuous colored image. Thus color TV simulates different colors through additive mixing of B, R and G lights.

Aerial Photography

The principles of color photography are similar to those of black and white photography except that color films have three photo-sensitive emulsion layers. The top layer is sensitive to blue light, the next green light, and the lowest the red light. Thus there is one emulsion layer for each of the three primary (additive) colors. Hence color photography is based on the principle of substractive color mixture using superimposed yellow, magenta and cyan dyes. These three dye colors are termed the substractive primaries and each results from substracting one of the additive primaries from white light.

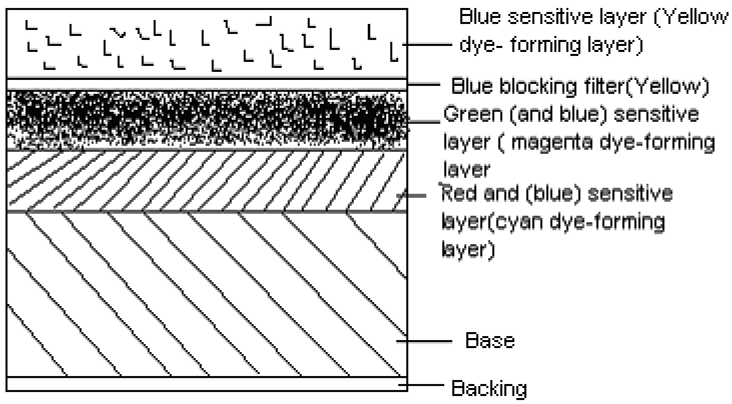


Fig: Generalised cross section of color film.

PROCESSING COLOR FILMS:

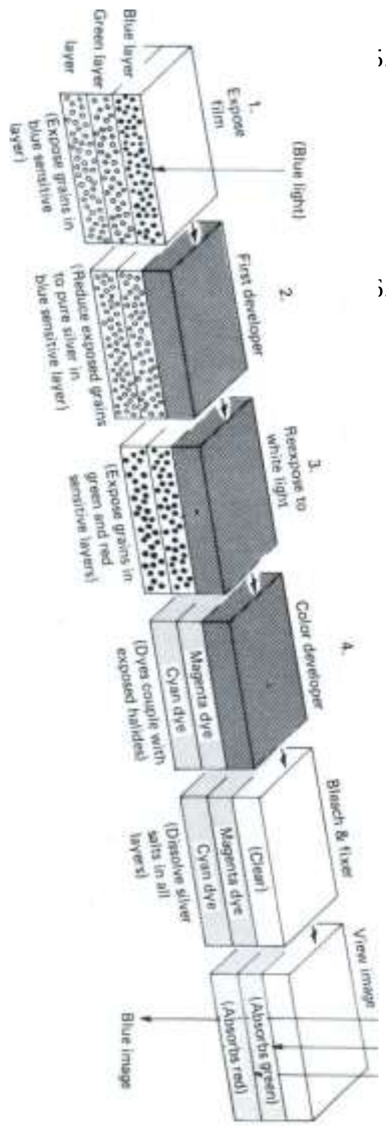
Color negative films produce negative images that are used in a –ve to +ve sequence in much the same manner as black & white –ve films. That is, a film –ve is exposed and processed and subsequently used to produce a +ve (normally in color print paper). Color –ves, like black & white –ves, manifests a reversal of scene geometry and brightness, containing yellow, magenta, and cyan dye. Positives prepared from such negatives correctly reproduce the geometry, brightness and color of the original scene.

Color reversal films: are films that can be processed to produce a +ve image directly on the original film exposed in camera. Color slides are familiar reversal film products. Their counterparts in aerial photography are referred to as color dipositives or color positive transparencies.

The exposure/processing sequence for the color film is given as follows.

1. The blue light reflected from the scene photographed activates the blue-sensitive film layer forming latent image in the blue sensitive layer, but non in the other two layers.
2. The film is immerged in a B & W first developer that produces a developed image composed of pure silver in the blue-sensitive layer. At this point, the green and red sensitive layers of the film still contain unexposed silver halide grains.
3. The film is re-exposed by a source of white light, thus making the silver halide grains in the green and red sensitive layers developable. This step is called “flashing”. In many processes flashing is accomplished chemically.
4. The film is immersed in a color developer, where the silver halide grains in the green and red sensitive layers are reduced to silver and at the same time magenta and cyan dyes are formed in Proportion to the amounts of silver in each layer. This is called couple development. After the couple development, the blue sensitive layer

still contains the developed image. (Silver) resulting from the first developer and thus yellow dye is not formed in the image.



5. The film is immersed in bleach that, without affecting the dyes, converts the silver in all layers to soluble salts. These salts are then dissolved from all three layers in a fixer, leaving only the magenta and cyan dyes in the green-and red-sensitive layers. The film is washed to remove any remaining chemicals, then dried

6. When white light is passed through the film during viewing, the magenta dye absorbs the green component of the light source and the cyan dye absorbs the red component. Because the yellow-forming (blue absorbing) layer is clear, the blue component is transmitted through all three dye layers, resulting in the perception of a blue image. Other colors are produced in an analogous fashion, through various combinations of exposure and dye introduction in the three film layers.

Fig: Color reversal process

UNIT-3: Photographic measurement

Photogrammetry is defined as the science or art of obtaining reliable measurements by means of photographs (taken from calibrated cameras). Whereas Photo interpretation is the art of examining photo images for the purpose of identifying objects and judging their significance. Hence the latest definitions states Photogrammetry as the art, science and technology of obtaining reliable information about the physical objects and environment through processes of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena.

Aerial Photography

In Photogrammetry, the images are identified followed by measurements while in photo-interpretation the images are identified followed by their evaluation and deducing their significance.

Geometry of Aerial photographs and measurement of photo coordinates:

Fiducial marks: Fiducial marks are optically projected geometrical figures in the shape of fine crosses, dots or half arrow, located either in the four corners or on the middle sides of the aerial photographs. There are usually four fiducial marks on the sides of each photo but sometimes there are eight (four on the sides and four on the corners) depending on the type of aerial camera used. A standard 9”x9” (23cmx23cm) photograph comes with fiducial marks obtained on them. These fiducial marks are reference marks which define the co-ordinate axes and the geometric center of a single photograph. The fiducial marks are used to find out and draw co-ordinate axes and to find out the principal points of the aerial photographs.

Axes: Every photograph has two co-ordinate axes. The X-axis is the line on the photograph between opposite side fiducial marks which is most nearly parallel to the direction of flight and the Y-axis (direction) is the line on the photograph between opposite side fiducial marks which is perpendicular to the X-axis and is most nearly perpendicular to the flight line. Fig 2a.

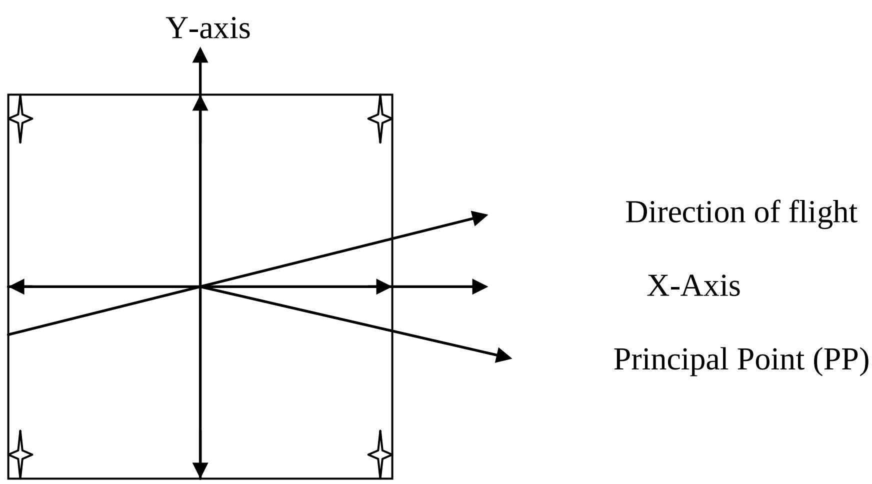
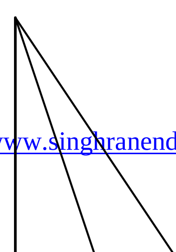


Fig: 2a Showing the fiducial marks, Principal points and co-ordinate axes of a single Aerial photo

Principal point (PP): It is the point where two co-ordinate axes intersects the photo image and it represents the geometrical center of the aerial photos and is assume to coincide with the intersection of the X-axis and Y- axis. We can locate the PP on a photo by intersection of lines drawn between opposite side or corner fiducial marks.

Nadir: The Nadir is the point where a plumb line dropped from the camera lens to the ground intersects the photo image. It is the point vertically beneath the exposure station

Isocenter: The Isocenter is a point on the aerial photo approximately half way between the PP and the Nadir. On a true vertical aerial photographs the *PP*, *Isocenter* and the *Nadir* all coincide at the geometric center of the photograph as defined by the intersection of lines between opposite fiducial marks.



Aerial Photography

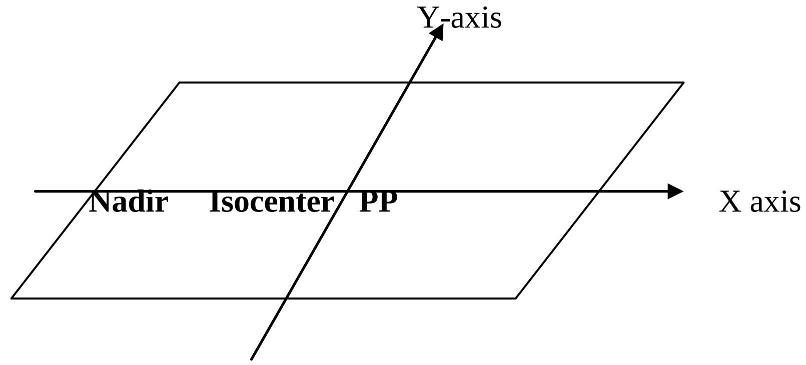
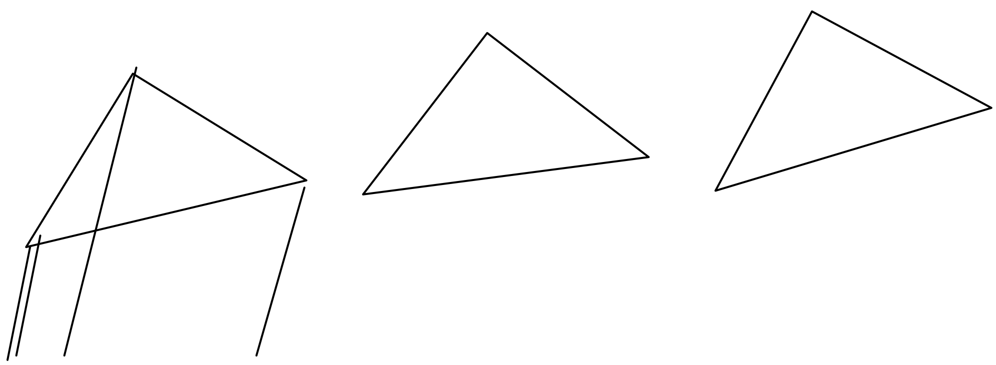


Fig 2: figure 2 showing the location of the PP, isocentre, and Nadir on a slightly tilted vertical APs



Distortion:

Distortion is defined as any shift in the position of an object image on a photograph which alters the appearance (perspective characteristics of the photograph).

Causes of distortion are due to a) lens distortion b) film shrinkage c) atmospheric reflection of light waves d) image motion.

The lens aberration degrades the quality or sharpness of the image, whereas lens distortion deteriorates the geometric quality or positional accuracy of the image.

Displacement:

Aerial Photography

Displacement is any shift in the position of an image on photograph which doesn't alter the perspective characteristics of the photograph. A vertical aerial photograph is not a map. A map is an orthogonal projection whereas a photo is a perspective or central projection. Unlike a map, an aerial photo is subject to certain distortion and displacement.

Types of distortion:

1. Film shrinkage or expansion
2. Atmospheric refraction of light rays
3. Lens distortion
4. Image motion

Types of displacement:

1. Curvature of the earth
2. Tip and Tilt
3. Topography or relief

The effect of atmospheric refraction and the curvature of the earth are usually negligible in most cases, except for very precise mapping projects, and will be ommited from our discussion. Rests are considered in brief.

Shrinkage and expansion of photographic films and papers:

In the photogrammetric work, the exact position of the images in the picture is required. Photo coordinated measured may contain errors due to shrinkage and expansion of the photographic materials. These coordinates must be corrected before use. If the material is paper a much lower degree of dimensional stability exists. The amount of shrinkage or expansion is a function of temperature and humidity. But to a large extent, it is also affected by material type as well as its processing techniques used, particularly the methods of drying the material. For e.g. if hot drum dryer id used to dry the paper prints less distortion is expected in comparison to the prints are hung to dry at room temperature.

Correction for shrinkage and expansion:

The shrinkage and expansion of a paper print can be rectified by comparing measured photographic distance between opposite fiducial marks on the print with their corresponding values given in the camera calibration report. The ratios of these measured values are used as correction factor to be applied to each X and Y photo co-ordinates measurements. Let Xm and Ym are measured fiducial distances of a given paper prints and Xc and Yc are corresponding calibrated fiducial distances, then the correction factor for X and Y coordinates are

Correction factor for X- coordinates (Xcf) =Xc/Xm and

Correction factor for Y- coordinates (Ycf) =Yc/Ym

Therefore, all measured coordinates on the photo must be corrected by multiplying correction factor before use.

Example:

The calibrated X and Y fiducial distances for s camera are 233.48 and 233.78 mm. The corresponding X and Y measured distances on photographic print for this camera are 232.37 and 232.36. The uncorrected Y and Y photo coordinates of a point measure 101.63 and 94.32mm. Find the corrected photo coordinates of the points.

Solution: Correction factors for (Xc)= Calibrated distance (Xc)/Measured distance (Xm)

= 223.48/233.27

=1.0048

Correction factors for (Yc)= Yc/Ym= 233.78/233.36=1.0061

Corrected X coordinate = 1.0048 x 101.63 = 102.12mm
Corrected Y coordinate = 1.0061 x 94.32 = 94.90mm

Measurement of Height

There are three general methods for measuring heights from aerial photographs.

1. Topographical displacement method
2. Shadow method
3. Parallax method

The first two methods can be used with single photographs while the 3rd method requires two photographs in a stereopair.

1. **Topographical displacement method:** Height of an object from single photographs can be determined provided that.

a. Principal point and nadir are approximately the same (<3^o tilt)
b. The flight altitude is known
c. Both the tip and base of the objects are clearly visible
d. The amount of image displacement is great enough to measure with an engineer's scale

If these conditions are met then the height of an object can be expresssed as

h = d*H/r

Where,
h = height of the object in meter
d = length of displaced image in mm.
r = radical distance of the top of displaced image from nadir in millimeter
H = flying Height above the base of object in meter

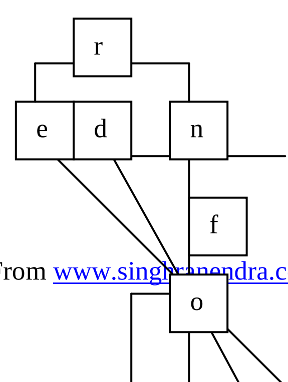


Fig: 1, Displacement due to elevation

By measuring the relief displacement the height of the object can be computed as
In similar Triangles oen and OEB

$$\frac{r}{f} = \frac{R}{H-h}$$

Rf = r (H-h) (i)
Similarly in similar triangles OND and ond

$$\frac{r-d}{f} = \frac{R}{H}$$

Rf =H(r-d) (ii)
From the above equations (i) and (ii) r (H-h) = H (r-d) or Hr – hr = Hr – Hd

$$\therefore \; h = \frac{d*H}{r}$$

2. Shadow method

Measurement of object height can also be done provided the inclination of sun at the time of exposure is known at that place. The height measurement by this method is possible provided following conditions are satisfied.

a) Scale of photograph at the point of measurement should be known.
b) Shadow should be clearly visible and should not be obstructed by details of surrounding objects (bushes , trees)
c) Shadow to be measured should be on level ground
d) Exposure of time and geographical position of locality should be know to calculate solar inclination, shadows of conifers can be measured more accurately but is not useful for irregular crowns of broad-leaved species.

Aerial Photography

The shadow length of an object at any given time (on a levelled ground) is directly proportional to its height and to the solar inclination.

Thus from given figure: ii

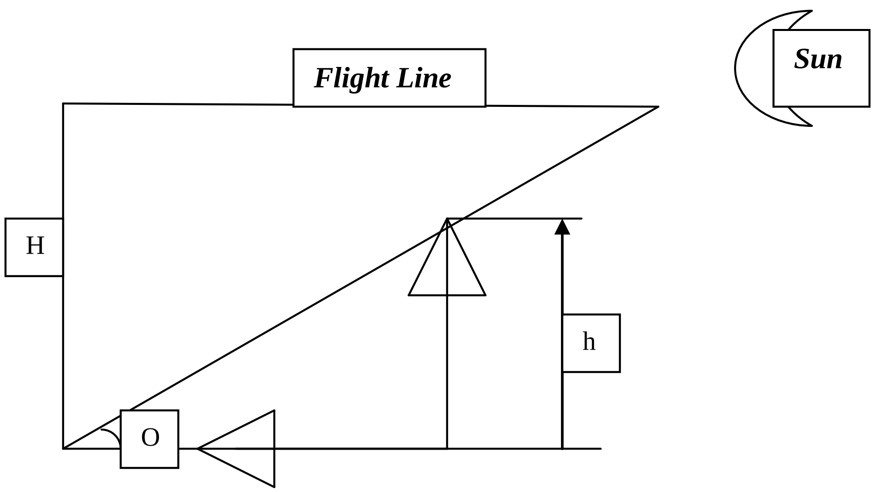
$$h = \frac{H * \tan O * S}{f}$$

$$= \frac{HS \tan O}{f}$$

where

h = height of object
H = flying height
S = Shadow length
O = solar inclination
f = focal length

h = PSR * shadow length



Measurement of height by parallax difference method using parallax Bar

We know that if an object is observed seperately by left and right eyes, its position appears to shift from one place to other, i.e. , there is displacement of object due to change in observation and this is called parallax. When we view two overlapping stereopair, there is a displacemwent and hence parallax. It is the basis of three dimentional viewing.

Parallax bar consists of two plates of glass engrave with measuring marks and is connected by a bar. The seperation between these marks can be changed with the help of micrometre screw in such a way that a point with larger parallax gives higher reading. Parallax bar should be used in the following way:

1. The photograph should be oriented for 3D observation
2. The axis of stereoscope should be parallel to the flight line
3. The movable dot should be so placed that it merges with the other dot when seen through a steroscope.
4. First of all, the floating dot is raised or lowered in such a way that it is at the bottom of an image in 3D model.
5. The above operation is then repeated for the top of the image .
6. The difference between above two readings is parallax difference

dp1

Aerial Photography

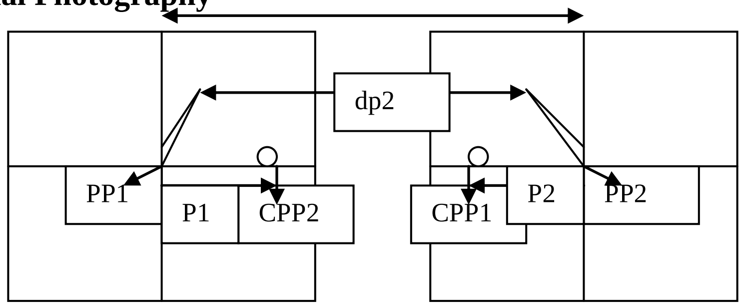


Fig:iii

$$P = \frac{p1+p2}{2}$$

dp = dp1-dp2

$$h = \frac{H*dp}{P+dp}$$

Where,
h = height of object
H = flying height of aircraft
dp =dp1-dp2 = difference in elevation between base and top of the object (parallax difference)
P = distance between the principle point and conguged principle point(absolute parallax) or Photo Base Length(PBL)

Measurement of slope

Slope: Rise in altitude per unit of horizontal distance.
If the horizontal D between two points is known and the difference in elevation, h is also known the slope Q can be determined as tan Q = h/D.
The slope can be determined by determing the horizontal distance between two photographs on aerial photographs(d), which can be converted to ground distance by the following formula:
D = d*H/f
And the vertical distance(height, h) which is given by the following formula
h = H*dp/p+dp
Hence, the slope is given by the following formula

$$\text{Tan } Q = \frac{H*dp*f}{(p+dp)*d*H}$$

$$= \frac{f*dp}{d(p+dp)}$$

as dp is much smaller compared to P, the slope can be given by the formula
tan Q = f*dp/p*d
where,
d = horizontal distance on the photo which can be determined
p = absolute stereoscopic parallax which can be measured on oriented photograph
dp = parallax difference which can be obtained by means of a parallax bar
f = focal length of aerial camera which is given on Aps.

Unit-4

Stereoscopes and their uses:
The stereoscope is a great aid in reading and interpreting aerial photographs. It is a binocular optical device, used for viewing two properly oriented overlapping photographs to obtain a mental impression of three dimensional models.
The two overlapping images or a photograph that may be viewed stereoscopically is called *stereo pair*. The three dimensional visual impression produced by viewing a pair of overlapping photograph by stereoscope is called *stereo model*.

There are two basic types of stereoscopes
(1) Pocket or lens stereoscope and (2) Mirror stereoscope.

(1) Pocket stereoscope: is a simplest and least expensive piece of equipment, is used to view stereo pair to produce three dimensional images. It usually consists of two simple magnifying plane-convex lenses, upper side flat with a separation equal to the average inter-pupillary distance of the human eye. A provision is also made to change this separation to suit the individual user.

The focal length of the lens is 100mm, so the light rays entering the eyes are focused at a distance of 100mm.Since the normal viewing distance is 250mm, a closer view, i.e. at 100mm result in a magnification. The magnification is thus 250mm/100mm = 2.5 times.
The two lenses are mounted in a frame so that they are supported at a fixed distance above the photo on which the stereoscope is placed. The more expensive type has a changeable eye base. Such a refinement is not necessary for operators with an average eye base of 60 to 68mm.It has large field of view, relatively cheap, and small so that when its legs are folded it can be carried in a pocket for use in the field.

Disadvantages:
(*a) Limited magnification*: Pocket stereo scope with more than three times magnification can not be equipped with simple plane-convex lenses.
The distance between the head and the photos becomes too small for adequate illumination without undue complications.
(b) The distance between corresponding points on the photos must be equal to or smaller than the eye base with normal size photographs. This becomes difficult or impossible without bending or folding the photos.

(2) Mirror stereo scope:
The two above mentioned drawbacks have led to the development of the mirror stereo scope. The normal size photos (23cmx23cm) can be separated and seen under the mirror stereo scope without folding them. It consists of a pair of small eye piece mirror and a pair of larger wing mirrors, each of which is oriented at an angle of 45^0 with respect to the plane of photos. A pair of magnifying lenses can be placed above the two small mirrors to produce a

magnification of a limited portion of the stereo scopic image. The path of the bundle of rays has been diverted and brought to the eyes at 65mm separation. This is achieved by reflecting mirrors.

Normally the distance between corresponding points is kept at 240mm so that photographs are placed separately, i.e., it effectively increases the eye base from 65mm to 240 mm. The two mirrors (µ1) are placed in such a way that the picture distance via the small two mirrors µ2 (generally prisms) becomes equal to the focal length of the lens, usually 300mm. This gives approximately 250/300 = 0.8 x magnification the picture observed. To magnify the image additional oculars of magnification 3 x to 8 x can be used over the prism or lens placed before each prism giving a magnification of 1.8 x .The advantage of the mirror stereo scope is that the entire overlap area can be seen stereoscopically without folding the photos. However, because of its size it is not portable to carry in the field and thus its use in the field is limited.

Depth perception:

In our daily activities we unconsciously measure depth or judge distances to a vast number of objects about us through our normal process of vision. Methods of judging depth may be classified as either stereoscopic or monoscopic. Persons with normal vision (those capable of viewing with both eyes simultaneously) are said to have *binocular* vision, and perception of depth through binocular vision is called stereo scopic viewing. *Monocular* vision is the term applied to viewing with only one eye and method of judging distances by one eye are termed monoscopic. A single eye can not accurately determine whether one object is nearer or farther than other. A person having normal binocular vision can, of course, view monocularly by covering one eye.

Distances to objects, or depth, can be perceived monoscopically on the basis of (i) relative size of objects, (ii) hidden objects, (iii) shadows, and (iv) difference in focusing of the eye required for viewing objects in varying distances.

Monoscopic methods of depth perception enable only rough impressions to be gained of distances to objects. With stereoscopic viewing, on the other hand, a much greater degree of accuracy in depth perception can be attained. Stereoscopic depth perception is of fundamental importance in photogrammetry, for it enables the formation of a three dimensional stereo model by viewing a pair of overlapping photographs. The stereo model then can be studied, measured and mapped

With binocular vision, when the eyes are focused on a certain point, the optical axes of the two eyes converge on that point intersecting at an angle called *parallatic angle*. The nearer the object, the greater the parallatic angle and vice versa. Let us take an example, when the eyes are focused on point A, the optical axes converge, forming parallatic angle Φa. Similarly, when sighting an object at B, the optical axes converge, forming parallatic angle Φb. The brain automatically and unconsciously associates distances DA and DB with corresponding parallatic angles Φa and Φb. The depth between objects A and B is (Db-Da) and is perceived as the difference in the two parallatic angles.

The ability of human beings to detect changes in parallatic angles, and thus judge difference in depth, is quite remarkable, although it varies some what from individual to individual. Thus phtogrammetric procedures for determining heights of objects and terrain variations based on depth perception by comparisons of parallatic angles can be highly accurate.

Conditions for viewing photos stereoscopically:

Suppose while gazing object A, a transparent medium containing image marks a1 and a2 is placed in front of the eyes. Assume further that the image marks are identical in shape to the object A, and that they are placed on the optical axes so that the eyes are unable to detect whether they are viewing the object or the two marks. Object A could therefore be removed without any noticeable change in the image that is received in the retina of the eyes. If the image marks are moved closer together to say, a1'and a2', the parallatic angle increases and the object is perceived to be nearer the eyes at A'. If the marks are moved farther apart to a1'' and a2'', the parallatic angle decreases and the brain receives an impression that the object is farther away, at A''.This phenomenon of creating the three –dimensional or stereo scopic impression of objects by viewing identical images of the objects can be achieved photographically. Suppose a pair of aerial photographs is taken from exposure stationsL1 and L2 so that the building appears on both photos, flying height above ground is H' and the distance between the two exposures is B, the air base. Object points A and B at the top and bottom of the building are imaged at a1 and b1 on the left photo and a2 and b2 at right photo. Now , if the two photos are laid on a table and viewed so that the left eye sees only left photo and the right eyes sees only the right photo, a three dimensional impression of the building is obtained. The three dimensional impression appears to lie below the table top at a distance h from the eyes. The brain judges the height of the building by associating depth to point A and B with the parallatic angles Φa and Φb respectively. When eyes gaze over the entire overlap area, the brain receives a continuous three dimensional impression of terrain. This is achieved by continuous perception of changing parallatic angles of the infinite number of image points which make up the terrain. The three dimensional model is called stereo scopic model or simply a stereo model, and the overlapping pair of photograph is called a stereo–pair.

Causes of Y- parallax:

Parallax: Displacement of the position of a target in an image caused by shift in the observation position.

An essential condition that must exist for clear and comfortable stereo scopic viewing is that the line joining corresponding images be parallel with the direction of flight. This condition is fulfilled with the corresponding images A1 and A2 as shown in the below figure.

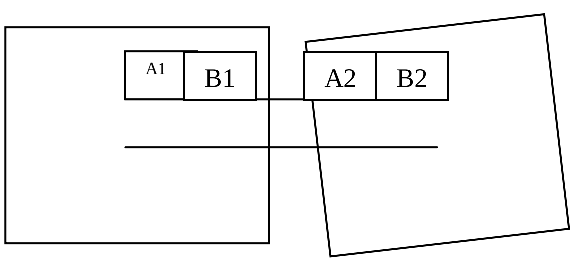


Fig: **Parallax caused by improper orientation of the photos:**

When corresponding images fail to lie along a line parallel to the flight line, *y parallax* (*Py*) is said to exist. Any slight amount of y parallax causes eyestrain, and excessive amounts prevent stereo scopic viewing altogether.

If a pair of truly vertical overlapping photos taken from equal flying heights is oriented perfectly, then no y parallax should exists any where in the overlapping area. Failure of any of these conditions to be satisfied will cause y parallax. In the above figure for example, the photos are improperly oriented and the principal points and conjugate principal points do not lie on a straight line. As a result, y parallax exists at both points A and B. This condition can be prevented by proper orientation.

Parallax caused by variation in flying heights: Suppose in the above photos, if left photo was exposed from a lower flying height than the right photo, and consequently its scale is larger than the scale of the right photo. Even though the photos are truly vertical and properly oriented, y parallax occurs at both points A and B due to variation in flying heights. To obtain a comfortable stereo scopic view, the y parallax can be eliminated by sliding the right photo upward transverse to the flight line when viewing point A and sliding it downward when viewing point B.

Parallax cause by tilt of the photo: Assuming in a pair of photos, the left photo which is truly vertical, and if they are having a square rice field on a flat terrain , then the square rice field will appear in the square shape in the left photo. Now if the right photo is tilted, say by 15^0 then the same rice field will appear like a trapezoidal in shape and which causes y parallax. In practice the direction of tilt is random because it is so well controlled by maintaining a constant flying height that y parallaxes are seldom noticeable.

VERTICAL EXAGGERATION (VE) (seen larger) IN STEREOVIEWING:

Under normal conditions the vertical scale of a stereo model will appear to be greater than the horizontal scale; i.e., an object in stereo model will appear to be too tall. This apparent scale disparity is called *vertical exaggeration*. It is usually of greatest concern to photo interpreter, who must take this condition into account when estimating heights of object, interpreting the photos, estimating the rates of slopes etc.

Although other factors are involved, Vertical exaggeration is mainly caused by the lack of equivalence of the photographic base-height ratio (B/H) and the corresponding stereo viewing base-height ratio (be/h)

B/H: is the ratio of the air base (distance between the two exposure stations) to flying height above average ground, and

be/h: is the ratio of the eye base(distance between the two eyes) to the distance from the eyes at which the stereo model is perceived. An equation developed for calculating the magnitude or amount of vertical exaggeration is given by

VE =B/H x h/ be approximately.

Where,

VE = Vertical exaggeration

B = Air base

H = Flying height

be = Eye base

h = distance from the eyes to perceived stereo model.

From the above equation it can be seen that the magnitude of VE in stereo viewing can be approximated by multiplying the B/H ratio to the inverse of be/h ratio.

An expression for B/H ratio can be developed with reference to figure 4.1

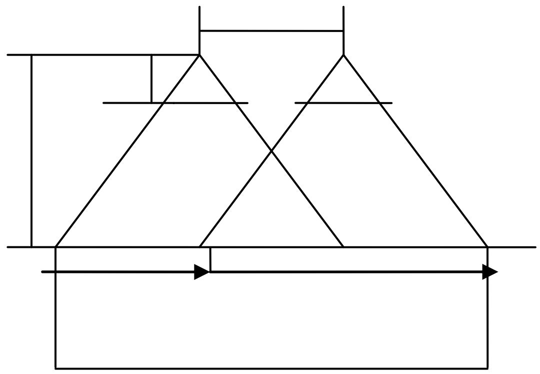
In this figure, G represents the total ground coverage of a vertical photograph taken from an altitude of H above ground.

Air base (B) is the distance between two exposure stations.

F is the camera focal length

d is the format dimension

From above fig, B = G- G (PE/100) = G (1-PE/10-0) …….(i)



Where PE = percent End lap(forward lap) which gives amount that the second photo overlaps the first photo.
Also from similar triangles in above fig, H/G = f/d, Hence, H = f G/D ……. (ii)
Dividing i by ii and reducing
B/H = G (1-PE/100)/f.G/d = (1-PE/100) x d
The stereo viewing base height ratio (be/h) is somewhat difficult variable to measure, because it differs slightly among individuals. Repeated tests, however, indicate that its value is approximately, 0.15.

Problem: calculate the approximate vertical exaggeration for vertical air photos taken with a 6 inch focal length camera having a 9 inch square format (23cmx23cm), if the photos were taken with 60 percent end lap. Assuming be/h = 0.15.

Solution: We have B/H **=** (1-PE/1000 x d/f = (1-60/100) x9/6 =40/100 x9/6 = 0.6
Now, VE = B/H x h/ be = 0.6 x 1/0.15 = 4

Monoscopic and stereoscopic methods of parallax measurement:
Parallaxes of points in a stereo pair may be measured either monoscopically or stereo scopically. There are certain advantages and disadvantes associated with each method. In either method the photographic flight line axes must first be carefully located by marking principal points and conjugate principal points.
The simplest method of parallax measurement is the monoscopic approach in which direct measurement of parallax difference in the two photographs can be measured with a simple engineering scale.
Parallaxes of points can be measured while viewing stereoscopically. Stereoscopic measurement of parallax makes use of the ***principal of floating mark***. When a stereo model is viewed through a stereoscope, two small identical marks etched on clear glass called *half marks* may be placed over the photographs – one on the left photo and one on the right photo. The left mark is seen with the left eye and the right mark with the right eye. The half marks may be shifted in position until they fuse together into a single mark which appears to exist in the stereo model and to lie at a particular elevation. If the half marks are moved closer together, the parallax of the half marks is increased and the fused mark will therefore appear to rise. Conversely, if the half marks are moved apart, parallax is decreased and the fused mark appears to fall. This apparent variation in

the elevation of mark as the spacing of half marks is varied is termed as the basis for the term "floating mark".

The spacing of the half marks (parallax of the half marks) may be varied so that the floating mark appears to rest exactly on the terrain. This produces the same effect as though an object of the shape of the half marks had existed on the terrain when the photos were originally taken. The floating marks may be moved about the stereo model from point to point, and as the terrain varies in elevation, the spacing of the half marks may be varied to make the floating mark rest exactly on the terrain.

Stereoscopic methods of parallax measurement:
Through the principal of the floating mark, parallaxes of the points may be measured stereoscopically. This method employs a stereoscope in conjunction with an instrument called a *parallax bar*, also frequently called a stereo meter. A parallax bar consists of a metal bar which are fastened two half marks. The right half mark may be moved with respect to the left mark by turning a micrometer screw. Readings from the micrometer are taken with the floating mark set exactly on points whose parallaxes are desired. From the micrometer readings, parallaxes or differences in parallax are obtained.

When a parallax bar is used, the two photos of a stereo pair are carefully oriented for comfortable stereoscopic viewing, in such a way that the flight line of the each photo lies along a common straight line. The photos are then fastened securely and the parallax bar is placed on the photos, The left half mark, called the fixed mark, is unclamped and moved so that, when the floating mark is fused on a terrain point of average elevation, the parallax bar reading is approximately in the middle of the run of graduations. The fixed mark is then clamped, where it will remain for all subsequent parallax measurements on that particular stereo pair. After the fixed mark is positioned in this manner, the right half mark or movable mark may be moved left e or right with respect to the fixed mark (increasing or decreasing the parallax) as required to accommodable high points or low points without exceeding the run of parallax bar readings.

Various Steps Involved in Aerial Photo Interpretation

Indexing of Aerial Photograph
Preparation of Aerial Photograph for Interpretation
General Reconnaissance of the Area
Photo Analysis/ interpretation
Field Checking
Post Field Interpretation

1. Indexing of Aerial Photograph**: The indexing of Aerial Photograph on map sheet is done with the help of a photo index which shows the relative position of Aerial Photograph with reference to maps as well as each other.**
   The photo indices (index) used for this purposes are of two types.

a. **Photographic Index**: Prepared for the areas where maps are not available
b. **Line index**: Shows the location of flight lines. It is prepared on 1:25,000 scales showing the photo numbers of beginning and with every 5th photo in between.

Following information is given on the top of each index.

Aerial Photography

a. Task Number
b. Scale of index
c. Scale of photography
d. Aerial camera
e. Focal length of lens
f. Period of photography

In legend the following information is given

i) Sortie number
ii) Date of flight
iii) Strips flown in each sortie

Preparation of Aerial Photographs for Photo Interpretation:

The preparation of aerial photographs is done in the following steps.

- Principal point (PP) is marked by intersecting the lines joining opposite fudicial marks appearing on aerial photographs.

- The PP is then transferred to the adjoining photograph. This transferred PP is called conjugate principal Point (CPP).

- The PP and CPP of the adjoining photograph is joined by a neatly drawn fine line. This line is called the flight line.

- The effective area is marked on the photographs. Though the entire area which appears on two consecutive aerial photographs can be used effectively for stereoscopic vision for the purpose of interpretation. But to reduce the effect of relief displacement particularly in the mountainous terrain only half of this area which is nearer to the PP is marked as effective area and interpretation is limited to this area only.

2 General reconnaissance of the area:

First of all the existing information about the area in respect to its climate, drainage, geography, vegetation etc. is collected and studied. The APs of study area and different photo patterns are marked separately on them.

The photo interpreter then visits the area alongwith APs and maps to familiarize himself with the general features and other information of interest. The interpreter learns to correlate the ground features with photographic images with the help of pocket stereoscope.

Photo Analysis (interpretation):

Photo interpretation is classified into two main groups of activity:

a) Method of search:-It involves close examination of all the relevant details on APs. In this search one may study all the details on APs which lead to generation of large amount of information, part of this information will be irrelevant for the specific objectives. For example, if some one is interested in identification of chir-pine areas in Himalayas the interpretation should be restricted to the altitudinal zone where the chir-pine is available.

b) Convergence of evidence:- The interpreter may recognize objects on APs either

i. By correlating the photo patterns with ground features, the information of which is obtained during reconnaissance survey or,
ii . By correlating the objects with similar objects seen by him on APs earlier or,
iii . Because he knows the objects.

Aerial Photography

An interpretation key of the area is then prepared and the photo interpretation of entire area are completed.

Field Checking

In order to prepare correct maps, it is essential that the accuracy of interpretation is checked in the field. Besides, the sample areas, where there is some confusion, in the interpretation necessary corrections are made in the field.

Post Field Interpretation

On the basis of information collected in the field, corrections are incorporated in the aerial photographs.

Air Photo interpretation

Photographic interpretation is the act of examining photographic images for the purpose of identifying objects and judging their significance (American society of photogrammetry).

Preparation of Aerial Photographs for Photo Interpretation:

Preparation of Aerial Photographs is done in following steps

i) Interpreting the lines joining opposite fudicial marks appearing on aerial photographs marks the principal point.

ii) The principal point (PP) is then transferred to the adjoining photograph. This transferred PP is termed as conjugate principal point (CPP).

iii) Join the PP and CPP of the adjoining photograph by a neatly drawn fine line. This is called flight line.

iv) Mark the effective area on the photographs through the entire area, which appears on two consecutive APs, can be used effectively for stereovision for the purpose of interpretation. But to reduce the effect of relief displacement particularly in mountainous area only half of this area, which is nearer to the PP, is marked as effective area and interpretation is limited to this area only.

Elements of object recognition:

The recognition of objects on APs can be done with the help of a number of terrestrial and pictorial elements.

i) **Colour or tone or hue:** refers to the relative brightness or colour of objects on photographs. Different coloured objects on the earth reflect and emit different amount of radiant energy. These differences are recorded as color variations on photograph. The lighter tone is topographically higher and drier, the darker tone is lower and wetter. Young stands are lighter compared to matured stands. Phonological changes such as leaf shedding, new flush of leaves, flowering and fruiting also affect tone of trees species. Teak trees, photographed in flowering condition appear whitish on APs. Sal trees when in new flush of leaves appear silvery Grey. Conifers and Broad-leaved species are distinguished by their Grey and white tones.

ii) **Shape:** Refers to the general form or outline of individual object, and this characteristic help in identifying the different objects. For example, roads, buildings, rivers, trees etc. The shape of a tree crown is important in identification of the tree species. Most of the conifers and young broad-leaved species have an ovate shaped (conical) crown. While matured hardwoods have a dome shaped (circular) crown.

iii) **Size:** Size of an object image depends upon the object size, scale of the photograph and resolving power of the camera. The minimum size of object to be visible on aerial photograph should be about 1/20th mm.

A super highway should not be confused with a rural road, a small residence with an apartment building. Relative sizes among objects on photographs of the same scale must also be considered.

iv) **Pattern**: refers to spatial arrangement of objects like orchards, plantation, etc is a characteristic of manmade objects, and some natural objects such as natural forest, different drainage pattern on different geological and soil types. It is important in assessing land use type.

v) **Shadow**: Mainly depends upon the time of photography and direction of flight. It provides a profile image of tree or building or tower, etc. Shadows of trees falling on ground help in knowing the shape of crown and even length of shadow is useful in height determination. Similarly main features can be recognized from their shadows such as tower, trees, bridges, monument, etc.

vi) **Texture:** Is a degree of coarseness or smoothness exhibited by a photo image. As the scale is reduced the texture of an object becomes finer. In forestry smooth texture is associated with younger trees and coarser texture with older trees. It is more useful in interpretation of larger groups of objects like tree stands. Branching habit and age of trees decide the texture of trees.

vii) **Location or site:** Topographical location, and relative elevation can be helpful in identifying objects, for example the permanent snow line is generally above 4000m in Himalayas. Species like Fir, Spruce, Chirpine, and Deodar occur at certain elevations and on certain aspects.

viii) **Association**: Refers to the occurrence of certain features in relation to others. Some tree species are so closely associated that each helps to confirm the presence of others. Certain tree spp. can be identified by recognition of other spp. which grow together e.g. Khair and Sisso is associated with fresh alluvial deposits, Silver oak, Crythrina spp. are associated with tea plantation.

UNIT-5: MAPPING WITH VERTICAL AERIAL PHOTOGRAPHS:

Aerial Photography

PLANIMETRIC MAPPING: Planimetric Maps are those which show the correct horizontal or plan position of natural and cultural features.
Maps which also show elevation differences (e.g. contour lines) are known as Topographic maps.

Transferring details from aerial photos where maps of area are available:
In many cases aerial photographs are needed not to make new maps but to revise old ones and/or add further details, such as changes in crop canopy, forest cover area, vegetation types, marking of felling coupes, marking of plantation sites, marking of forest fire area, marking of some forest patch diseased area, marking of newly built roads, marking of cultural area, etc. This can be done by following methods.

1**. Planimetric mapping by direct tracing after reduction or enlargement of the photograph to the map scale:** This is the simplest method of planimetric mapping in areas of flat terrain where photographic scales can be precisely determined. Direct print tracing may serve many useful purposes, but such tracing can not be technically referred to as true maps. For this process, some reflecting projector or similar device capable of enlarging or reducing the photograph to the desired map scale is required. The photograph is projected, duly enlarged or reduced as necessary, on to the map which is to be amended and the details are then sketched in. A sketch master may be used for transferring of details from photo to base map.

Features are directly traced out over a transparent sheet which has been placed on a light table superimposed over a vertical photo. To maintain a satisfactory level of accuracy, a number of photo control points, uniformly distributed throughout the photo, are plotted on the overlay at a scale equal to the average scale of photo

Before tracing, the transparent sheet should be adjusted in position so that the plotted control points nearest the feature to be traced matches its corresponding photo image. Other nearby control should also be fitted. Since a vertical photo is not a map and contains scale variation due to tilt, relief displacement, distortion, therefore, by matching control in localized area, errors from these sources are minimized.

The map manuscript produced using direct tracing will of course have scale equal to the photo. But the manuscript can be enlarged or reduced to make it to desired final map scale. Or before tracing, the photo can first be enlarged or reduced to an average scale of map and then tracing is done as has been described before..

RADIAL LINE TRAINGULATION:

It is one of the earliest photogrammetric mapping procedures, done initially by graphical methods called radial-line plotting. This can be done in uncomplicated manner where only a few photographs are available, and where lower accuracy is needed.

FUNDAMENTAL OF RADIAL LINE TRAINGULATION: The basic principal upon which radial line triangulation is based is that the angles measured, at the principal point (PP) of a vertical photograph is the true horizontal angles to these points on the ground. On a vertical photograph, relief displacement, radial line distortion, atmospheric refraction all displace images along radial lines from the PP and do not affect size of photographic angles at PP. Also variation in flying heights of vertical photograph affect photo scale but not angle size.

GRAPHICAL METHOD OF RADIAL LINE TRAINGULATION: It is an easily visualized procedure. In fig: 1, five photos of a flight strip are laid out in their overlapping positions. PPs and CPPs are marked on the photos. Points a and b are images of two horizontal ground control points (GCPs) A and B. A transparent overlay is placed over photo no. 1 and a template is prepared, as shown in Fig; 2 (a), by ruling lines on the overlay from the principal point o_1 through points a, b, c, d, and conjugate principal point o_2.Angles with vertexes at o1 are true horizontal angles on the template.

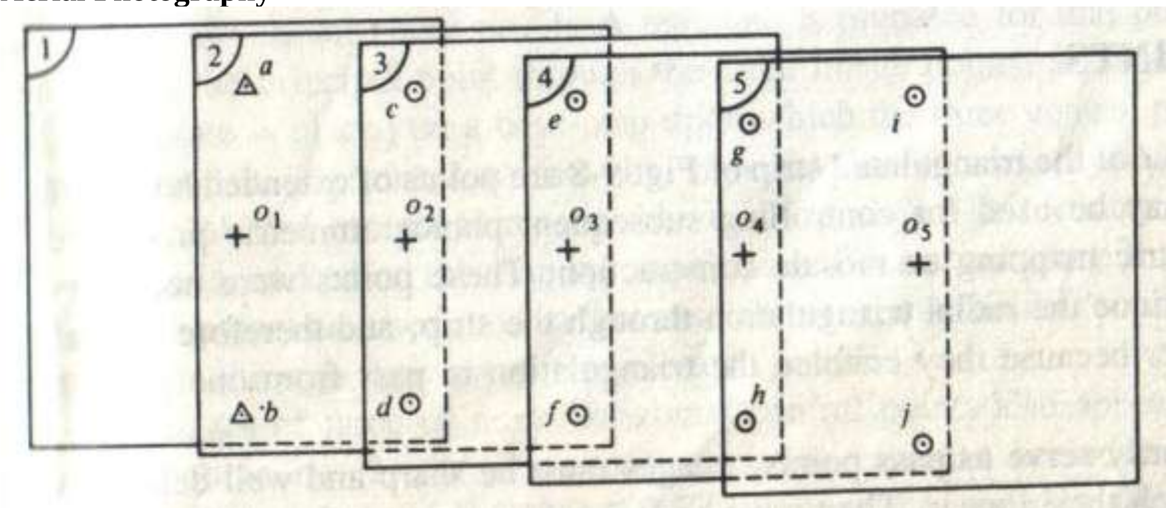


Fig1: Five photos of a flight strip

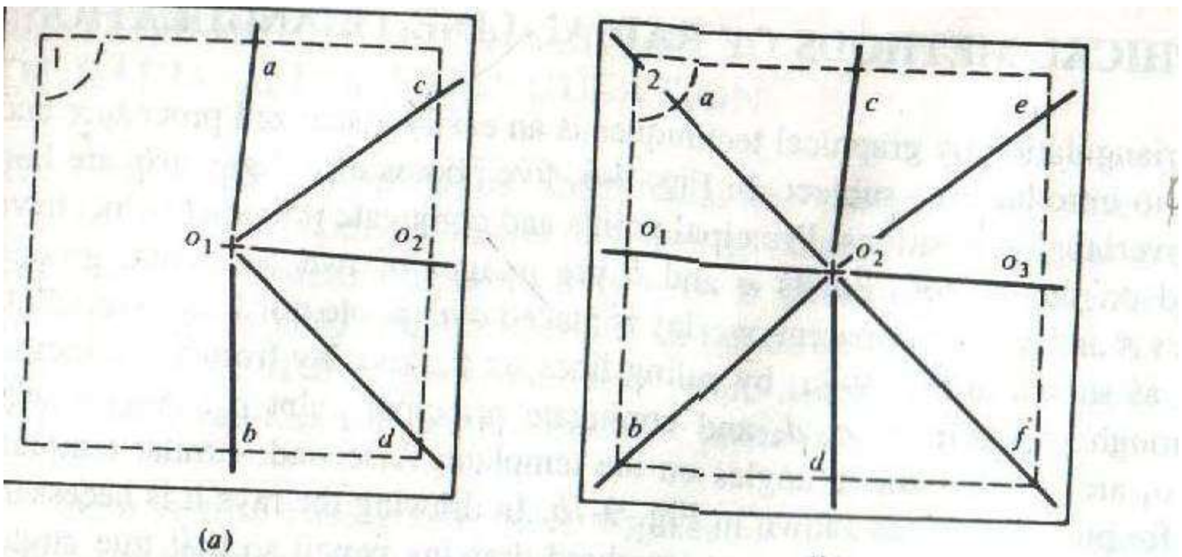


Fig: 2: (a): Template of photo (1) (b): Template of photo (2)

A second, similar template is prepared for photo no. 2, as shown in Fig: 2(b). In drawing the rays it is necessary to hold the overlays firmly and use a sharp, hard drawing pencil so that true angles are obtained between rays.

A base map upon which the radial line triangulation will be prepared is prepared next and ground control points A and B are plotted thereon, Fig: 3.The scale of the base map is chosen quite arbitrarily, but it should not normally differ greatly from photo scale.

If map Scale is chosen larger than photo scale, then the templates must be prepared larger in size than the photos to make possible an increase in scale from photo to map. Template no.1 is oriented on the base map so that rays o_1a and o_1b simultaneously pass through their respective plotted control points A and B. At the same time template no. 2 is oriented on the map to make rays o_2a and o_2b pass through their respective plotted control points and, in addition, rays o_1o_2 on template no.1 and o_2o_1 on template no.2 are made to coincide. With these conditions established, the locations of o_1 and o_2 define the true planimetric map positions of ground principal points (exposure stations) P_1 and P_2. Their positions are marked on the map by pricking through the templates with a pin. The direction of P_1 P_2 on the map represents the flight direction for that stereo pair, and the distance from P_1 to P_2 represents the air base. This procedure for locating exposure station positions is called *resection.* More specifically *two-point resection*, since it requires two control points.

With the exposure stations of a pair of overlapping photographs fixed on the map, any number of other points whose images appear in the overlap area of the stereo pair can be established by *intersection*. When the two templates were originally prepared, rays through new points c and d were also drawn. With the two templates oriented on the map as previously described, the intersection of the rays o_1c and o_2c fixes the two planimetric position of point C. Likewise the intersection of rays o_1d and o_2 d locates point D. Map locations of any points in the overlap area can be established by this procedure.

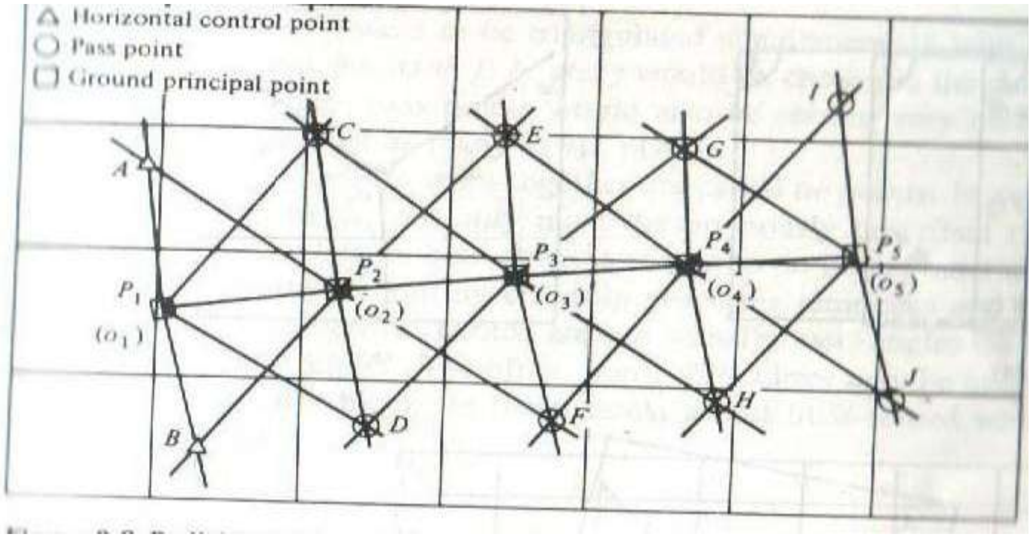


Fig 3: Radial-line triangulation assembly of five-photo strip

Once C and D are established on the map; they become new horizontal points. These points should have been carefully selected so that their images appeared not only on photos 1 and 2 but also on 3. (This condition requires greater than 50% end lap in the photos) If C and D are treated as control points, a template can be prepared for photo 3 and resection performed, as previously described to locate exposure section P3. With P3 located, new points E and F can be fixed on the map by intersection from photo 2 and 3. Carefully selecting images e and f so that their images appear on photo 4 enables exposure station P4 to be located. This procedure of successive resection and intersection may be continued through the entire strip of photos. The completed radial line triangulation for the five photo strip is shown in figure 3.

Pass Points

Points C through J of the triangulated strip of figure 3 are points of extended horizontal control. They may be used for controlling subsequent photogrammetric procedures such as planemmetric mapping or mosaic construction. These points were necessary, however, to continue the radial triangulation through the strip, and therefore they are called ***pass points*** because they enabled the triangulation to pass from one photo to the next.

To satisfactorily serve as pass points, images must be sharp and well defined on all photos in which they appear. They must be located in desirable positions on three successive overlapping photographs. The most ideal positions are opposite the principal points and conjugate principal points, as illustrated in fig 1. This placement creates the strongest geometrical strength and yields highest accuracy. For radial line triangulation of a block of two or more strips, pass points common to two strips should be chosen in the centre of the side lap area.

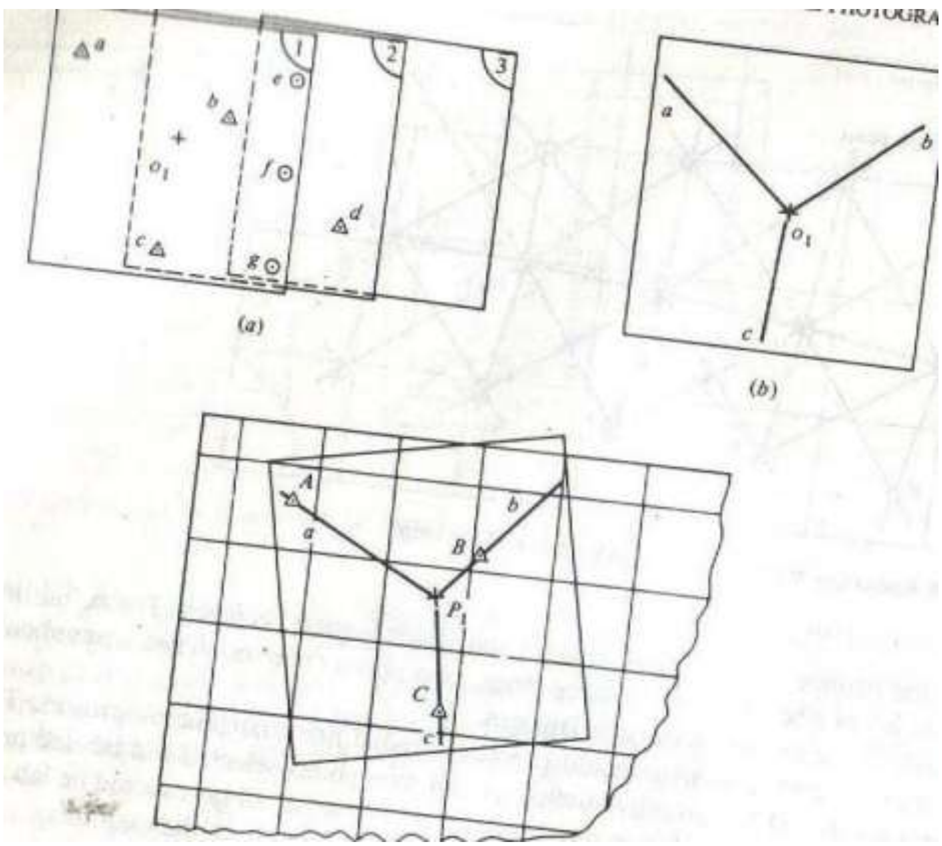
Careful overall planning should precede a radial line procedure. The photographs should be carefully studied and all pass points selected and leveled prior to constructing templates. When the templates are prepared, all rays should be leveled on the templates to prevent confusion when assembling them on the map.

Control points/ Ground Control Points for Aerial Photography: Ground control point (GCP) refers to any physical points on the ground whose ground positions are known with respect to a reference or some horizontal coordinate system and/ or vertical datum and whose images can be identified in the photographs. Thus photo control points are the actual images in the photo that are used to control photogrammetric operation.

Ground Control provides the means for orienting or relating photographs to the ground, thus it is established on the ground to provide triangulation network. And on the APs it provides the means for orienting or relating APs to the ground, when mutually identified on the ground and on the photograph. It can be used to established exact spatial position relative to the ground. The established ground control points are then plotted on the base map to the desired scale. All ground control points must be located on the aerial photographs. A minimum of two GCPs are essential to establish scale but three are better. With a three GCPs on a single photo it is possible to remove a certain amount of tilt provided that all three points are at the same altitude.GCP is generally classified as either

1. **Horizontal Control:** The position of the point in object space is known with respect to a horizontal datum. For example, road crossings or intersections monument or bench mark of vertical control.
2. **Vertical Control:** The elevation of the point is known with respect to a vertical datum. For example mean sea level (MSL), bench mark.
3. **Horizontal and Vertical Control**: some times both horizontal and vertical object space positions of the positions are known called horizontal and vertical control, so these points serve a dual control points.

THREE POINT RESECTION: The two point resection procedure described in Fig 1 requires that a stereo pair be resected simultaneously and that two horizontal control points appear in the overlap area of the stereo pair. If three or more horizontal control points appear anywhere in a single vertical photo, its exposure station can be located by *three- point resection*. In Figure 4 (a), images a, b, and c of horizontal control points, A, B, and C appear in vertical photo no.1 A template is prepared for that photo by drawing rays from the principal point through the three image points, as shown in fig 4(b). The template is placed on a base map upon which the three control points have been plotted, and it is oriented so that the three rays simultaneously pass through their respective plotted control points as shown in fig 4 (c). This locates exposure station P_1, which is marked on the map by pricking. If images of three or more control points also appear on photo no 2, then its exposure station can also be located by three points resection.



(c)

Fig 4: (a) Photos with ample control for three-point resection. (b) Template prepared for three-point resection. (c) Locating an exposure station by three-point resection.

.**FLIGHT PLANNING AND SPECIFICATIONS FOR AERIAL PHGOTOS**:

If the photography is to satisfactorily serve its specific objectives, the photographic mission must be carefully planned and faithfully executed according to the flight plan. A flight plan is simply a reliable map depicting the area to be photographed. Besides that a flight plan consists of specification or variables of photographic missions which includes scale, flying height, focal length, side lap, end lap, number of flight lines needed, total number of exposure required, type of film to be used, type of camera best suited for the mission, time, season , weather condition and season of photography.

Average photographic scale is one of the most important variables that must be selected in planning aerial photography, since it largely determines the spacing of photo centers over the area to be photographed and therefore, the total number of photographs required. The scale must be large or small enough to meet the objective of the mission.

An average photographic scale is one of the most important variables that must be selected in planning aerial photography. Once camera focal length and required average photo scale have been selected, required flying height above average ground is automatically fixed in accordance with scale. Since we can define RF as focal length divided by H-h. Also, its direct effect on the image displacement of objects photographed controls the degree of three dimensional exaggerations that the interpreter sees when viewing the exposures stereoscopically. Selecting an optimum scale/focal length combinations is therefore an item of direct interest to the image interpreter. Two things to consider when choosing a focal length is its effect on parallax and altitudinal requirements of the aircraft for a specific scale.

Flight lines are normally oriented in a cardinal direction and are usually parallel to each other. To photograph the desired area on the ground, the aircraft flies along the entire length of one strip, and then makes a 180^{0} turn and flies back along the entire length of the next adjoining strip. This procedure is repeated until the desired area is completely photographed.

Similarly, the amount of end lap (the overlap between photos in the same flight strip) and side lap (the overlap between photos in the adjacent parallel flight strip) is the factor to be considered. Both terms refer to the amount by which one photograph covers the same area on the ground as covered by another. If stereoscopic coverage of an area is required, the absolute minimum end lap is usually 60% and side lap is about 30% are considered in most of the projects. However, to prevent gaps from occurring in the stereoscopic coverage due to crab, tilt, flying height variations, and terrain variation, end laps greater than 50%(about 60%) is used. Also, if photos are to be used for photogrammetric control extension, images of some points must appear on three successive photographs – a condition requiring greater than 50% end lap. For these reasons aerial photography for mapping purposes is normally taken with about 60% end lap, plus or minus about 5%.. Thus, end lap is necessary to view the photos and make measurements on them in the third dimension. Side lap is largely a safety factor to ensure that there are no skipped areas between flight lines.

Drift and crab are the two primary causes of unsatisfactory photographic ground coverage. Drift is the deviation or later shift of the aircraft from its planned flight direction. It is caused by failure of pilot to fly along planned flight lines due to strong wind. Excessive drift cause gap into photo coverage between adjoining strips of photographs. Crab is condition caused by failure to orient the camera with respect to the flight line of the aircraft. Due to crab the edge of consecutive photo not being parallel to the line of flight. It causes reduction in stereoscopic coverage. In vertical photo, it is indicated by the edges of the photographs not being parallel to the air base- base line.

The film and shutter speed of the camera is also an important consideration, because it relates to image motion. Each discrete point on the photograph is imaged as a line because the aircraft and hence the camera is in the motion during the time the shutter is open. Photographs of good pictorial quality are obtained using good quality lens cameras and film having fine-grained, high-resolution emulsions. For photographic mapping, photography is preferably taken with a wide or super wide angle (short-focal-length) camera so that a large base-height (b/H) ratio is obtained. The B/H ratio is the ratio of the air base of a pair of overlapping photographs to average flying height above ground. Special effects can also be obtained using filters in combination with various types of films. Timber types, for example, can be delineated quite effectively using a red filter in combination with black- and- white infrared film. We can calculate the amount of the movement by the equation

$$M = (17.6) \times v \times t \times f/H-h$$

Where
M = image movement on the photo in inches or cm
17.6 = a constant with units; inch hours/ miles second
v = ground speed of the aircraft in miles per hour or km per hour
t = shutter speed in fraction of a second
f = focal length in inch or cm
H-h = flying height of the aircraft above datum in feet or km

The maximum acceptable limit for image motion for clear and sharp photography is 0.002 inches. Image motion value more than the acceptable limit results in definite blurred photo. One way to eliminate the problem is to use a faster shutter speed which requires either a larger aperture or a faster film. Another solution is to use slower flying aircraft

Aerial Photography

Another consideration of the camera which must be considered is camera cycling time. Cycling time refers to the amount of time required for the camera to advance the film and prepare for the next exposure. In many aerial cameras this cycling time is 2 to 5 seconds.

The time of the day and season of the year must be considered for aerial photography. In most cases, an ideal day for aerial photography is one which is free from clouds; although if the sky is less than 10 percent cloud-covered, the day may be considered satisfactory. Flights are usually scheduled between 10 A.M. and 2 P.M. for maximum illumination and minimum shadow. The time of the day may influence the color or tone balance especially when color film is used. If the photography is being taken for topographic mapping, the photos should be taken when the deciduous trees are bare, so that the ground is not obstructed by leaves. In many places this occurs twice a year for short periods in the late fall and in early spring. Normally aerial photography is not taken when the ground is snow covered. Heavy snow not only obscures the ground but also causes difficulties in interpretation and in stereo viewing.

A sample of flight plan: The example that follows illustrates the various calculations involved in preparing an aerial flight plan for an area of 20km east-west by 30km north-south, or 600 km^2. Basic information required is as follows:

Desired negative scale: 1: 25, 000 or 250m/cm
Scale of base map: 1: 50,000 0r 500m/cm
Average ground elevation above mean sea level: 500m
Average forward lap (end lap): 60%
Average side lap: 30%
Format size: 23 by 23 cm, or 5,750 by 5,750m on the ground
Camera focal length: 153 mm or 0.153m

Flight map computations
Items to be computed in preparing the flight plan are:

Flying height above ground datum: Height = focal length x scale denominator

Or H = 0.153 x 25,000 = 3, 825 m

Flying height above mean sea level: 3,825 + 500 = 4,325 m

Direction of flight lines: North-south, following long dimension of tract.

Number of flight lines: Since the average side lap is 30%, the lateral gain from one line to another is 70% of the format (on the ground) or 0.70 x 5,750 = 4,025m between lines. The number of intervals between lines is found by division of the tract with (20km or 20,000m) by 4,025. The result is 4.97 or *5 intervals* and six *flight lines*.

Actual (adjusted) ground distance between flight lines: Tract width (20,000m) / 5 intervals = 4,000m between lines.

Actual (adjusted) percentage of side lap:

$$\text{Side lap percentage} = \frac{\text{Format width (m)} - \text{Spacing (m)}}{\text{Format width (m)}} \times (100)$$

$$\text{Side lap percentage} = \frac{5,750 - 4,000}{5,750} \times (100) = 30.4\%$$

Map distance between flight lines (map scale is 500 m/cm):

1cm /500 m = X cm /4,000 m; X =8. 00 cm between lines on map

Ground distance between exposures on each line: Since an average forward lap is 60%, the spacing between successive exposures is 40% of the format size (on the ground), or 0.40 x 5,750 = 2,300 m between exposures.

Map distance between exposures on each line:

1cm/500m =X cm /2,3200m; X = 4.60 cm between exposure centers on map

Number of exposures on each line: Number of *intervals* between exposures is found by division of tract length (30 km or 30,000m) by 2,300 = 13.04 *intervals* This will require 14 exposures inside the area, assuming that the first exposure is centered over one tract boundary. In addition, 2- extra exposures are commonly made at the ends of each flight line; thus, a total of 14 +2 +2 =18 exposures would be taken on each flight line.

Total number of exposures required to cover entire tract: 6 lines x 18 exposures per line = 108 exposures.

The calculation procedures and interval/ side lap adjustments employed here (i.e., for direction and number of flight lines, actual ground distance between flight lines, and actual percentage of side lap) will result in the two exterior flight lines being centered precisely over the tract boundaries. Thus, there will be a safety factor to ensure boundary coverage, since exposure locations are planned to over lap the boundaries by 50 percent.

UNIT 6: Application of Aerial photographs

Forest Interpretation

Aerial Photography
-Vegetation Classification

-Species Identification

Forestry is concerned with the management of forests for wood, forage, water, wildlife and recreation. Wood being the principal raw product from forest, forestry is especially concerned with timber management, maintenance and improvement of existing forest stands, and fire control.

Air photo interpretation provides a feasible means of monitoring many of the world's forest conditions, principally to tree species identification, timber cruising and assessment of disease and insect infection. Depending upon their amenability for photo interpretation two types of forests has been distinguished.

(a) Homogeneous forest and (b) heterogeneous forest

(b) Homogeneous forest: In this type of forests only one or a few special and pure stands are common. One species constitute about 80 percent growing stock. For example, Sal forest of terai, coniferous forest of Himalaya.

(a) Heterogeneous forest: Such types of forest comprise many species. This could be further subdivided into (i) Deciduous forest and (ii) Evergreen forest

(i) Deciduous forest: This type of forest covers a major part of the tropical forest. The important economic species is Teak.

(ii) Evergreen forest: This type of forest covers about 10% of the tropical forest area. The forest consists of much greater number of species and is thick canopies.

Besides, that the photo interpretation and delineation of different vegetation types can be carried out into different vegetation classes on aerial photographs. It is possible to identify them separately on aerial photographs as

Forest land: This class is formed by trees of greater than 5 to 8 meter in height and crown closure of more than 10%.

Coppice regrowth: This class is formed by the natural regrowth of species. The crown closure of top canopy is generally less than 10%

Scrub land: In this class the area is covered by scrub growth when the plant height is less than 5 to 8 meter and tree cover, if present is less than 10%.

Bamboo: Area of pure Bamboo growth.

Plantation: Plantation of different forest species.

Grass land: Area covered by grass growth and tree cover if present, is less than 10%

Barren land: Area is more or less devoid of vegetation.

Agriculture land: Area under cultivation including fallow land can be distinguished from barren land because of the presence of terraces and furrows, absence of rocky outcrops, etc.

Wet land: Area is generally flooded and is marshy in nature.

Gardens: This will include orchards, tea gardens etc.

Shifting cultivation: Current shifting cultivation and old shifting cultivation.

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Water bodies: Area covered by water i.e., Lakes, ponds, rivers etc.

Habitation: Area covered by rural, urban, or industrial houses and factories etc.
On large-scale aerial photographs, it is also possible to identify a number of forest species in plantation and a number of non-forest species in gardens.

Species identification: Air photo interpretation process for tree species identification is generally more complexes than for agricultural crop identification. A given area of forest land is often occupied by a complex mixture of many tree species as compared with agricultural land where large and relatively uniform fields are encountered. Also, the under story of forest tree species is often blocked from view on air photos by the crowns of the large trees in the area.

For tree species identification of the aerial photographs season of photography, quality of camera and lens, and scale has been the main limiting factors. It requires much more detailed information. A tree location with regards to water source, slopes and parent material can be used as clues in proper species identification.

Tree species can be identified on aerial photographs through the process of elimination.

The first step is to eliminate those species whose presence in the area is impossible because of location, physiography or climate. For example, Fir, Spruce Chir pine can not occur in the terai similarly Sal and Sissoo can not occur in the temperate climate.

The second step is to establish which groups of species do occur in the area, based on knowledge of the common species association and their requirements. For example, Khair occurs in association with Sissoo in the reverine forest.

The final stage is the identification of individual tree species. Using basic photo interpretation principles, the photographic characteristics (elements) of shape, size, pattern, shadow, texture etc are used by the interpreter in tree species identification. Individual tree species have their own characteristic crown, shape and size. Some species have rounded crown, some have cone shaped crown. In dense forest, the arrangement of tree crowns produces a pattern that is distinct for many species.

Some interpretation keys/clues for species identification are given as follows.

(i) Chirpine: Light Grey tone with rounded crown and coarse texture

(ii) Blue pine: Lighter in tone than bluepine, big rounded crown and coarse textured. Two pines seldom occur together and have distinct altitudnal zonation.

(iii) Deodar: Appear in medium Grey tone with fine mat like structure and more pointed crown.

(iv) Spruce: Appear in dark Grey tone with globose and diffused crown.

(v) Fir: Crown is dark in tone with pencil like shape.

(vi) Hardwood Oaks (Quercus species): Dark tone with irregular crown.

(vii) Broad-leafed tropical forest (like Sal): Appears darker in tone with defined rounded crown and coarse texture. If photographs are taken in March Sal also appear in lighter tone because of yellowing of leaves

Detailed interpretation of forest area: Depending on the scale of the aerial photographs, the forest area can be classified into a number of species classes, height classes, crown classes, slope classes, erosion classes, crown diameter classes, etc.

(a)Small scale photographs (Smaller than 1:40,000): Small scales are not very useful in identification of species but using aerial photographs of good contrast, appropriate time and season, it is possible to identify and delineate species which occur gregariously. The rate and nature of change in forest cover and land use can be monitored using aerial photographs of small scale and critical aspects for developmental planning and environmental conservation can be identified. Some forest species can be identified accurately and delineated separately when their percentages in the total mixture is high say, more than 50%. Forest species classes which can be identified on this scale are as given under.

The following species groups can be identified with fair degree of accuracy on small-scale photographs.

Sub tropical and temperate forest	Tropical forest
Fir/Spruce Bluepine Chirpine Khasi pine Deodar Mixed conifers Conifers with broad leafed Mixes broad leafed forests Oaks	Sal Teak Depterocarpus Mixed miscellaneous forests Sissoo Khair

Besides, forests are divided into a number of crowns, density classes. While giving crown density classes, the density of dominant and co dominant trees, i.e. top canopy, is considered, as most of the economically important trees are present in this canopy. In open formation, with crown closure less than 40% under story e.g. bamboo etc can also be identified. The following crown closure classes may be adopted

1. Closed forests: Crown closure more than 80%

2. Medium density forests: Crown closure 40 to 80 %

3. Poor density forests: Crown closure 10 to 40%

In addition, the information about the erosion status of the area can also be given. The areas may be divided into three erosion classes.

Type	code
1. High (areas with gullies & rills etc)	I

2. Moderate (Areas with sheet erosion) II

3. Poor or absent III

(b)Medium scale photographs (Scale 1:20,000 to 40,000): On medium scale photographs, height, crown diameter and maturity classes can also be identified in addition to species and erosion classes. The details of these classes are given below.

Sub tropical and temperate forest	Tropical forest
Fir/Spruce	Sal
Blue pine	Teak
Deodar	Depterocarpus
Chirpine	Mixed miscellaneous forests
Khasi pine	
Mixed conifers	
Conifers mixed with broad leafed	
Mixes broad leafed forests	
Oaks	

In forestland following structural and other classes can be identified.

Crown density classes: (i) Closed forest, crown closure < 80 %(ii) Wood land, crown closure 40 to 80 %(iii) crown closure 10 to 40%

Height classes: (i) <10-meter (ii) 10 to 20-meter (iii) 20 to 30-meter (iv) > 30 meter

Crown diameter classes: (i) < 10m (ii) > 10m

Maturity classes: (i) Young crops (ii) Middle aged crops (iii) Mature crops

Erosion classes: (i) High (ii) Moderate (iii) poor or absent

(c) Large scale photographs (Scale larger than 1: 20,000): On large-scale photographs detailed classification in regards to species, crown closure, height, crown diameter and maturity classes, is possible. These classes are given as follows.

(i) Sub tropical& temperate forest: Fir, spruce, Blue pine, Deodar, Chir pine, Khasi pine, Cryptomeria, Birch, Mixed conifers, Rhododendron, Oaks, Mixed hard woods, Conifers mixed with hard woods.

The forests with different species of a particular species can be delineated depending upon the objective of survey.

(ii)Tropical broad-leafed forests: Sal, Teak, Semal, Salai, Depterocarpus, and mixed species.

(iii)Plantations: Teak, Sal, Conifers, Eucalyptus, Khair, Sissoo, Semal, others

(iv)Non forests: Gardens, Rubber, Tea, coffee, Cardamom, Coconut, Palm, Others.

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In forestland following structural and other classes can also be identified and delineated.

1. Crown density classes: (i))> 80% (ii) 60 to 80 % (iii) 40 to 60 % (iv) 10 to 40 %.

2. Canopy Height classes: (i) < 5 meter (ii) 5-10 meter (iii) 10- 15 meter (iv) 15- 20 meter (v) 20- 25 meter (vi) 25- 30 meter (vii) > 30 meter

3. Crown diameters: (i) < 10-meter (ii) 10- 20-meter (iii) > 20 meter

4. Maturity classes: (i) Regeneration or regrowth (ii) Young (iii) Middle aged (iv) Mature

5. Land forms and slopes:

(i)Flat-slope< 5% (ii) Undulating- slope 5 to 10 % (iii) Hilly- slope 10 to 25 % (iv) Very high- slope 25 to 50 % (v) Mountainous –slopes exceeding 50 %

6. Erosion classes: (i) High (ii) Moderate (iii) Poor or absent

Geological interpretation: The first aerial photographs taken from an air plane for geologic mapping purposes were used to construct a mosaic covering Bengasi, Libya, in 1913. In general, the earliest uses of air photos were simply as base maps for geologic data compilation. Some interpretive use of aerial photographs began in the 1920s. Since the 1940s, the interpretive use of air photos for geologic mapping and evaluation has been widespread.

Geologic mapping involves the identification of landforms, rock types, and rock structure and the portrayal of geologic units and structure on a map or other display in their correct spatial relationship with one another. For detailed geological mapping, stereoscopic aerial photographs at scales as large as 1:20,000 may be utilized.

Terrain analysis is the study of geomorphologic features of an area. Air photo interpretation for terrain analysis is based on systematic observation and analysis of key elements that are studied stereoscopically. Geomorphologic features or elements of terrain analysis are: a) topography b) drainage pattern and texture c) photo tone d) erosion pattern e) vegetation features.

Systematic study of these features on aerial photographs can provide us information about the parent material, soil types and appropriate land use of that area. Therefore it is a very important tool for land use planners.

Topography: refers to the shape of an area. Slope can be measured from aerial photograph by several methods. Determination of slope is important to know whether the area is suitable for cultivation or it is subjected to land slides. Such information is useful for resource manager for reforestation projects and agricultural planning.

Drainage pattern and texture: A detail study of the drainage pattern provides information about a) landform b) bed rock types c) soil characteristics d) drainage condition. The common drainage pattern includes a) dendritic b) trillis c) rectangular d) radial e) centripetal f) deranged.

Drainage pattern: The pattern and texture seen on aerial photographs are indicators of landform and bed rock type and also suggest soil characteristics and side drainage conditions. Most common drainage patterns are

Aerial Photography

a) **Dendritic drainage**: The dendritic drainage pattern is well integrated pattern formed by a main stream with its tributaries drainage branching and rebranching freely in all directions and occurs on relatively homogeneous materials such as horizontally bedded sedimentary rocks and granites.

b) **Rectangular drainage**: It is basically a dendritic pattern modified by structural bed rock control such that tributaries meet at right angles and is typically of flat lying massive sand storm formations with a well developed joint system. Such type of pattern is found in areas which have parent material of horizontally bedded sedimentary rocks.

c) **Trillis drainage pattern**: It consists of streams having one dominant direction, with subsidiary direction of drainage at right angles, and occurs in areas of folded sedimentary rocks.

d) **Radial drainage**: It is formed by streams that radiate outward from a central area as is typical of volcanoes, rare in nature.

e) **Centripetal drainage**: It is the reverse of radial drainage pattern. It is directed towards a central point and occurs in areas of limestone sink holes, glacial kettle holes, volcanic crates and other depressions.

f) **Deranged drainage**: It is a distorted pattern of aimlessly directed short streams, ponds and wetland areas. All the above described drainage patterns are destructive drainage patterns resulting from the erosion of land surface.

Texture: Refers to the density of stream channel per unit area of land. Fine textured pattern develops where the soil and rock have poor internal drainage and high surface run off. Thus it has many streams per unit area found in arid area. Coarse texture pattern develops where the soil and rock have good internal drainage with little surface run-off. Thus it has few streams for unit area associated with hard parent material such as granite.

Erosion: Two general types of erosion pattern can be recognized on aerial photographs.

i) Gully erosion: Gully is the smallest drainage feature that can be seen on APs and refers to the shape of stream beds on cross section. The gully shape is dependent on type of soil in which the gully is formed. V-shaped gully is formed in sandy and gravely areas. U-shaped gully is formed in silty soils and low U-shaped gully with gently rounded is found in silty clay and clay soils.

Sheet erosion: Refers to the loss of top layers of soil. An extreme example of sheet erosion is land slide.

i) Photo tone: Tone of an object on APs refers to the relative brightness or darkness of the object as it appears on the photo print. The film and filter type and exposure can affect the absolute tone of image on film. The tone of an object compared to other objects in the picture is the quality we are concerned with in terrain analysis. Areas with lighter tone, in general, signify higher position on a slope, coarser texture soils, well drained soils and soils with lower organic matters. All of these conditions are characteristics of dry soils. Darker toned areas are generally lower on slopes, have higher organic matter content, and are finer textured and poorly drained soil. These are characteristics of soils having high moisture content.

Vegetation: Vegetation and land use patterns are also assessed for terrain analysis. Difference in natural and cultivated vegetation often indicates difference in terrain condition. Knowledge of the vegetation characteristics and what crops are grown in an area can be used to provide information about bad rock types, soil types, and drainage. This information can be used for land use planning whether the area can be developed for some purpose other than its current land use. The use of aerial photography to obtain geological information is referred to as photo geology.

Soil interpretation: It is an admitted fact that in a normal soil survey about 80% of the field work consists of locating the soil boundaries, the other 20% being used to describe the soils. Although aerial photographs play a limited role in the actual study of soils, they considerably reduce the time spent for locating the soil boundaries, which is the most laborious and time consuming part of the soil survey.

Detailed soil surveys are the product of an intensive study of soil resources by trained scientists. The delineation of soil units utilizes air photo interpretation coupled with extensive field work. A soil scientist travels the landscape on foot, identify the soils and delineate soil boundaries. This process involves the field examination of numerous soil profiles and the identification and classification of soil units. The soil scientist's experience and training are relied on to evaluate the relationship of soils to vegetation, geological parent material, and landform and land scape position. Reflection of sun light from bare soil surfaces dependents on many interrelated factors, including soil moisture content, soil texture, surface roughness, the presence of iron oxide and the organic matter content. A unit of bare soil may show different photo tones on different days, depending on its moisture condition and content. As the area of vegetated surfaces increases during the growing season, the reflectance from the scene is more the result of vegetative characteristics than the soil type. The most soil show nearly uniform dark surface tone and hence, distinct pattern of dry soil surface (light tone) could be differentiated from areas of wet soil surface (dark tone).

Until recently, soil surveyors have relied on conventional panchromatic photography in conjunctions with large amount of field work, to delineate soil boundaries. However more promising and reliable results are now being obtained with color photography. Photo scales of 1:6,000 or larger are usually preferred and aerial flights are ideally scheduled soon after agricultural fields have been plowed.

Wind erosion: Features produced by wind and water are important aids in photo interpretation because they are diagnostic of surface soil textures, soil profile characteristics and soil moisture conditions. Evidences of wind erosion include blowouts, which are smoothly rounded and irregularly shaped depressions; sand streaks, which are light, toned. Climate is important because it provides some indication of probable soil moisture conditions. Any surface unprotected by vegetation and not continuously moist may be eroded by the wind.

Plowed fields, alluvial fans and floodplains are examples of surfaces especially susceptible to wind erosion. In general finer the grain size, the greater the distance surface material is transported many small erosional forms resulting from wind erosion are difficult to identify on aerial photos. As a rule only the larger blowouts are readily picked out. Evidence of deposition is more easily detected, because resulting dunes or sheets present distinctive shapes or light toned streaks and blotches. In any given locality, wind deposited materials tend to be of uniform size resulting in homogenous soils.

Water erosion: Moving water is the major agent in the development of the earth's surface configuration, moving water is responsive to variations in environment and modest changes in the material being eroded, and therefore, the landscape patterns produced through the action of moving water are of great importance to the photo interpreter. In addition the interpreter should have a basic knowledge of the inter relations between climate, surface materials, surface configuration, vegetation cover, the pattern of drainage and other related functions.

Water Resource Applications

Whether for irrigation, power generation, drinking, manufacturing, or recreation, water is one of our most critical resources. Airphoto interpretation can be used in a variety of ways to help monitor the quality, quantity, and geographic distribution of this resource. In this section, we are concerned principally with the use of air photo interpretation in water pollution detection, lake eutrophication assessment, and flood damage estimation. Before describing each of these applications, let us review some of the basic properties of the interaction of the sunlight with clear water.

Aerial Photography

In general, most of the sunlight that enters a clear water body is absorbed within about 2m of the surface. The degree of absorption is highly dependent on wavelength. Near- infrared wavelength are absorbed in only a few tenths of a meter of water , resulting in very dark image tones of even shallow water bodies on infrared photos. Absorption in the visible portion of the spectrum varies quite dramatically with the characteristics of the water body under study. From the standpoint of photography of bottom details through clear water, the best light penetration is achieved between the wavelengths of 0.48 and 0.60µm. Penetration of 15 to 20m in clear, calm ocean water has been reported in this wavelength band [53]. Although blue wavelengths penetrate well, they are extensively scattered and an "underwater haze" results. Red wavelengths penetrate only few meters.

The analysis of underwater features is often permitted by using films sensitive to at least the wavelengths of 0.48 to 0.60 µm. Excellent photographs of bottom details in clear ocean water can be achieved using both normal color and color infrared photography. White sand bottoms under clear ocean water will appear blue-green using normal color film and blue using color infrared film (with a yellow filter). Bottom details are somewhat sharper using color infrared film because the blue wavelengths are filtered out and, thus, the effects of "underwater haze" are minimized. With such photography, the color infrared film becomes essentially a two-layer film because there is almost no infrared reflection from the water and, therefore, virtually no image on the infrared-sensitive film layer.

It is rarely possible to make a positive identification of the type and concentration of a pollutant by airphoto interpretation alone. However, it is possible to use airphoto interpretation to identify the point at which a discharge reaches a body of water and to determine the general dispersion characteristics of its plume. In some instances, such as the case of sediment suspended in water, it is possible to make valid observations about sediment concentrations using quantitative photographic radiometry coupled with the laboratory analysis of selective water samples.

Sediment pollution is often clearly depicted on aerial photographs. The lake water has a low reflectance of sunlight, similar to that for water. The spectral response pattern of the suspended solids resembles that of "Dry Bare Soil (Gray-Brown)". Because the spectral response pattern of the suspended materials can be readily distinguished on the photograph.

When point-source pollutants – such as domestic and industrial wastes – enter natural water bodies, there is typically a dispersed plume. If pollutants have reflectance characteristics different from the water bodies, their mixing and dispersal can be traced on aerial photographs.

Materials that form films on the water surface, such as *oil films*, can also be detected through the use of aerial photography. Thin oil slicks have a distinct brown or black color. Thinner *oil sheens* and *oil rainbows* have a characteristic silvery sheen or iridescent color banding but do not have a distinct brown or black color. The principal reflectance differences between water bodies and oil films in the photographic part of the spectrum occur between 0.30 and 0.45 µm. Therefore, the best results are obtained when normal color or ultraviolet aerial photography is employed.

Lake Eutrophication Assessment :A lake choked with aquatic weeds or a lake with extreme-nuisance algal blooms is called a eutrophic (nutrient- rich) lake. A lake with very clear water is called an *oligotrophic* (low nutrient, high oxygen) lake. The general process by which lakes age is referred to as *eutrophication.*

The use of airphoto interpretation coupled with selective field observations is an effective technique for mapping aquatic macrophytes. Macrophyte community mapping can be accomplished through the use of airphoto interpretation keys.

Other applications: Additional water resource application of air photo interpretation include, **f**lood damage estimation, hydrologic watershed assessment, reservoir site selection, shoreline erosion studies, snow cover mapping, and survey of recreational use of lakes and rivers.

ENVIRONMENTAL ASSESSMENT: Many human activities produce potentially adverse environmental effects. Examples include the construction and operation of highways, railroads, pipelines, airports, industrial sites, power plants, and transmission lines; subdivisions and commercial developments; sanitary landfill and hazardous waste disposal operations; and timber harvesting and strip mining operations.

With concern for the environmental effects of such activities in the mind, the U.S. Congress passed the N*ational Environmental Policy Act* (NEPA) of 1969. This established as national policy the creation and maintenance of conditions that encourage harmony between people and their environment and minimize environmental degradation. This act requires that environmental impact statements be prepared for ay federal action having significant impact on the environment. The key items to be evaluated in an environmental impact statement are (1) the environmental impact of the proposed action; (2) any adverse environmental effects that cannot be avoided should the action be implemented; (3) alternatives to the proposed action; (4) the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity; and (5) any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. Since the passage of NEPA, many states have also passed environmental impact assessments legislation. These cover other-than-federal actions at the local level.

The principal biophysical effects of human activity on the environment include (1) interruptions and other changes in natural drainage conditions causing ponding., fluctuations of the groundwater table, alternations to stream flow characteristics, soil erosion, and siltation; (2) changes in water turbidity, suspended load, and temperature; (3) increase in chemical pollutants such as salt, heavy metals, and insecticides; (4) changes in vegetation caused by site clearing and alterations to site conditions; and (5) changes in wildlife population and distribution caused by opening up new habitat, destroying existing habitat, altering migratory habits, and disrupting breeding and spawning .

Environmental impact statements are usually required to contain specific information on the magnitude and characteristics of environmental impact,. An assessment of physical site characteristics involves an inventory of physiographic, geologic, soil, vegetative, wildlife, watershed and airshed conditions. The assessment will typically draw on expertise of persons from many areas such as civil engineering, forestry, landscape architecture, geography, geology, seismology, soils engineering, pedology, botany, biology, zoology, hydrology, water quality chemistry, water quality biology, environmental engineering. Many of the remote sensing and image interpretation techniques set forth can be utilized to assist in the preparation of environmental impact statements.

Both normal color and color infrared photographs at a scale of around 1:8000 have been used for the detection of such situations. Open areas can be photographed throughout much of the year. Areas with sparse tree cover should be photographed during early spring (after grasses have emerged but before tree leaves have appeared) or late fall (after tree leaves have dropped). Areas of dense tree cover may be impossible to analyze using airphoto interpretation at any time.

An analysis of the photo characteristics of color, texture, site, and association, along with collateral soil information, is important for the identification of failing septic systems. Stereoscopic viewing is also important because it allows fore the identification of slope, relief, and direction of surface draining.

