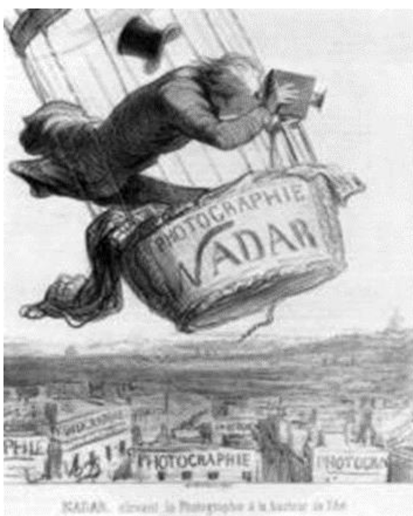
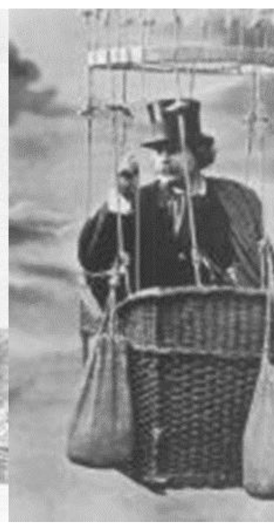
6 Year Integrated M. Tech. Geotechnology and Geoinformatics

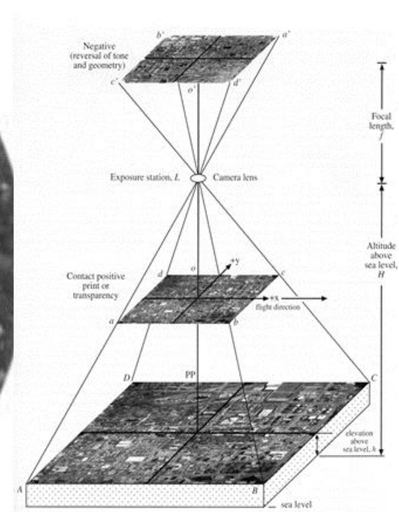
e-Learning Material

PAPER CODE: MTIGT0303

AERIAL REMOTE SENSING & PHOTOGRAMMETRY







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MTIGT0303: AERIAL REMOTE SENSING & PHOTOGRAMMETRY -- 4credits

1. **Aerial Photography:** History - Types of Photographs - Scale of Photographs, (Scale in Vertical & Tilted Photographs, Average Photo scale) - Relief displacement - Tilt displacement - Scale distortions - Radiometric characters. **12 Hrs.**

2. **Stereo Models** : Monoscopy - Stereoscopy - Pseudoscopy - Base height Ratio -Vertical Exaggeration - Stereoscopic Parallax & Height measurement - Analog Photogrametric Techniques. Photo Mosaics: Photo indexing - Photo mosaic (uncontrolled, semi controlled & Controlled mosaics) – Flight planning – Aerial triangulation.

   16 Hrs.

3. **Digital Photogrammetry I:** Data sources and input processes (Digital Cameras, Operation principles, Scanners for analog to digital conversion) - Digital Photogrammetric techniques & processes (Digital Photogrammetric equipment, Stereo viewing, image measurements, co-ordinate systems, image transformation, image orientation)

   16 Hrs.

4. **Digital Photogrammetry II :** Ortho Photo – Rectification – DEM- ALTM – LIDAR – SRTM, Cartosat. **10 Hrs.**

5. **Photo Interpretation Keys & Elements:** Photo Interpretation Keys (Definition, its parts, Key sets, Types of Study) - Photo Interpretation Elements (Photo elements - Tone, Texture, Color, Shadow) - Geotechnical / Geomorphic elements (Landforms, Drainage, Erosional pattern, vegetative cover, Landuse, Shape & size of objects).

   10 Hrs.

Text Books:

1. Wolf, P.R. Elements of Photogrammetry Mcgraw Hill Book Co., Tokyo. 1974.
2. Moffit H.F. And Edward, M.M, Photogrammetry, 3rd Edition, Harper and Row Publishers, New York. 1980.
3. Bhatt. A.B., Aerial Photography & Remote Sensing (An Introduction), Bishen Singh& Mahendra Pal Singh Pub., 1994.
4. Rampal, Handbook of Aerial Photography and Interpretation, Concept publishing. 1999.

References:

1. American Society of Photogrammetry, Manual of Remote Sensing (II Edition), ASP, Falls Church, Virginia. 1983.
2. Burnside, C.D., Mapping From Aerial Photographs, Collins Publishers. 1985.
3. John, T.Smith Jr, Manual of Colour Aerial Photography (I Edition) American Society of Photogrammetry, ASP Falls Church, Virginia, 1968.
4. Colwell, Robert, Manual of Photographic Interpretation, American Society Of Photogrammetry, ASP Falls Church, Virginia. 1960.
5. David Paine. Aerial Photography and Image Interpretation for Resource Management, John Wiley & Sons, New York. 2003.
6. Yves Egels; Digital Photogrammetry, Tailor & Francis Inc. 2002.
7. Yongru Huang A, Digital Photogrammetry system for Industrial Monitoring
8. George Joseph, Fundamentals of Remote Sensing, Cambridge University Press, 2nd Edition.
9. Shiv N. Pandey, Principles and Applications of Photogeology, Wiley Eastern Limited, India.1987.
10. Michel Kasser and Yves Egels, Digital Photogrammetry, Taylor & Francis Inc., 2002.

UNIT: 1 - Aerial Photography: History - Types of Photographs - Scale of Photographs, (Scale in Vertical & Tilted Photographs, Average Photo scale) - Relief displacement - Tilt displacement - Scale distortions - Radiometric characters.

Aerial Photography and Photogrammetry

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

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

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

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

Unique perspective of aerial imagery

- ❖ The aerial/regional perspective
- ❖ While human vision provides a unique perspective, it is a limited perspective
    - ➔ Humans primarily observe the world from a limited, ground-level view – Vertical perspective –Terrestrial
    - ➔ Aerial platforms allow the viewing of an area from a more synoptic, horizontal perspective - Bird’s eye view

Chronological History of Aerial Photography and Remote Sensing

Important dates in the chronological history of photography, aerial photographic interpretation, and remote sensing:

Circa 300 BCE - Greece, Aristotle philosophizing at some length about the nature of light, envisions light as a quality and not as an actual substance; as it was thought of by many at the time. He observed that some objects have the potential for transparency but this state is only rendered actual by the presence of light. He then defined light as the act of, or energy of, a transparent body as such.

10th Century - Al Hazan of Basra credited with the explanation of the principle of the camera obscura.

1666 - Sir Isaac Newton, while experimenting with a prism, found that he could disperse light into a spectrum of red, orange, yellow, green, blue, indigo, and violet. Utilizing a second prism, he found that he could recombine the colors into white light.

1802 - Thomas Young puts forth the basic concepts of the Young-Von Helmholtz theory of color vision: Three separate sets of cones in the retina of the eye, one attuned to red, one to blue, and one to green.

1827 - Joseph Nicephore Niepce takes the first picture of nature. (Exposure time was 8 hours, emulsion was bitumen of Jedea.)

- ❖ Created first photographic image in France
- ❖ Used a camera obscura, exposed the scene for 8 hours
- ❖ Photographic plate was made of pewter and was coated by bitumen suspended in lavender oil

- ❖ Bitumen is a tar like substance found in crude oil – today it is used in roofing tar and asphalt pavement
- ❖ When exposed to light, bitumen/oil hardened and adhered to the pewter plate
- ❖ Non-hardened areas washed away

1829 - Joseph Nicephore Niepce and Louis M. Daguere signed their partnership agreement (Nicephore Niepce had been working on Heliography, or sun drawing; Daguerre on dioramas, which he constructed with the aid of a camera obscura.)

1839 - Daguerre announces the invention of Daguerrotype (Niepce had died). Daguerre had discovered that mercury vapors could bring out an image on a silver plate and that sodicum thiosulfate ("hypo") could fix the image and make it permanent.

1939 - William Henry Fox Talbot describes a system of imaging on silver chloride paper using a fixative solution of sodium chloride. Talbot later found that the latent image could be developed in a solution of gallic acid, and he was the first person to employ a negative/positive process "Calotype" laying the groundwork for modern photography.

1830s - Invention of the stereoscope by the Germans. The device was used during the Victorian era for amusement.

1855 - Scottish physicist James Clark Maxwell, postulates the color additive theory for the production of color photographs.

1858 - First known aerial photograph is taken from a captive balloon from an altitude of 1,200 feet over Paris by Gaspar Felix Tournachon Nadar.

1861 - With the help of photographer Thomas Sutton, Maxwell demonstrates his techniques using a bow of multicolored ribbon. (Red filter - sulfo-cyanice of iron, blue filter - ammoniacal sulfate of copper, green filter - copper chloride, a fourth filter of lemon-colored glass was also used.)

1860s - Use of aerial observations from captive balloons in American War. Balloons used to map forest in 1862 not aerial photo though.

1870s - Pictures taken from greater heights, 33,000-34,000 feet, from free balloons.

1873 - Herman Vogel found that by soaking silver halide emulsions (which are naturally sensitive to only blue light) in various dyes, he could extend their sensitivity to longer and longer wavelengths, paving the way for photography in the near infrared.

1879 - S.P. Langley begins work to find a superior radiation detector.

1887 - Germans began experiments with photography for forestry.

1899 - George Eastman produced a nitrocellulose-based film which retained the clarity of the glass plates which had been used to that time.

1903 - Julius Neubronne patents breast mounted camera for pigeons.

1906 - Albert Maul takes first aerial photograph using a rocket propelled by compressed air which rose to a height of 2,600 feet and took pictures and then parachuted the camera back to earth.

1906 - G.R. Lawrence who had been experimenting with cameras for some time (some of which weighed more than 1,000 lbs.) which were hoisted into the air with the aid of balloon-kites and associated controls, takes pictures of San Francisco earthquake and fire damage from an altitude of some 600 meters. Many people have thought that these photos were taken from airplanes. Lawrence's camera alone weighed more than the Wright Brothers plane and its pilot combined.

1909 - Wilbur Wright takes first aerial photograph from an airplane of Centrocelli, Italy. WWI produced a boost in the use of aerial photography, but after the war, enthusiasm wanted.

1914 - Lt. Lawes, British Flying Service, first takes airplane over enemy territory.

1915 - Cameras especially built for aerial use are being produced. Lt. Col. J.T.C. More Brabazon designed and produced the first practical aerial camera in collaboration with Thornton Pickard Ltd.

1918 - By this time in WWI, French aerial units were developing and printing as many as 10,000 photographs each night, during periods of intense activity. During the Meuse-Argonne offensive, 56,000 prints of aerial photography were made and delivered to American Expeditionary Forces in four days.

1914-1919 - WWI produces boost in the use of aerial photography, but after war interest wanes.

1919 - Canadian Forestry Mapping Program begins.

1919 - Hoffman first to sense from an aircraft in thermal IR. First books: Lee 1922; Joerg 1923 (urban); Platt & Johnson 1927 (archaeology).

1924 - Mannes and Godousky patent the first of their work on multi-layer film which led to the marketing of Kodachrome in 1935.

1931 - Stevens development of an IR sensitive film (B&W).

1934 - American Society of Photogrammetry founded. Photogrammetric Engineering is first published. This journal of the American Society of Photogrammetry was later renamed Photogrammetric Engineering and Remote Sensing. The Society is now named the American Society of Photogrammetry and Remote Sensing.

1936 - Captain Albert W. Stevens takes the first photograph of the actual curvature of the earth - taken from a free balloon at an altitude of 72,000 feet.

1920s-1930s - Interest in the peaceful uses of aerial photography increases (ISDA, USAF, TVA). WWII brought about more sophisticated techniques in API.

1941-1945 - WWII brings about the development of more sophisticated techniques in aerial photographic interpretation (API). American, British and Germans all produce promising TIR devices.

1942 - Kodak patents first false color IR sensitive film.

1946 - First space photographs from V-2 rockets.

1950s - Advances in sensor technology move into multi-spectral range.

1954 - Westinghouse develops first side-looking airborne radar system.

1954 - U-2 takes first flight.

1956 - Lu Meuser makes first TIR motion picture employing an AN/AAS-4, a devise for air to ground strip mapping ("...features and vehicles move like an old keystone cops movie.")

1960 - U-2 is "shot down" over Sverdlovsk, USSR.

1960 - TIROS 1 launched as first meteorological satellite.

1960s - U.S. begins collection of intelligence photography from Earth orbiting satellites, CORONA and KH programs.

1962 - Zaitor and Tsuprun construct prototype nine lens multispectral camera permitting nine different film-filter combinations. ITEK employs camera to explore the potential value of multispectral photography.

1964 - SR-71 shown to the press in the Presidential campaign between Goldwater and LBJ.

Late 1960s - Gemini and Apollo Space photography.

1968 - Hemphill describes first use of laser for airborne sensing.

1972 - Launch of the first Earth Resources Technology Satellite (ERTS-1). This system is later renamed Landsat-1. ERTS carries a return beam vidicon (RBV) and a multispectral scanner (MSS).

1972 - Photography from Sky Lab precursor of manned space station whos first element launch is currently scheduled for 1998.

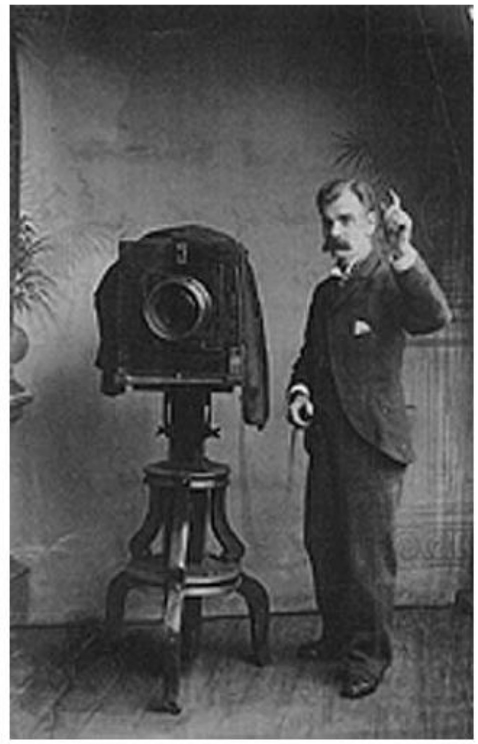
1975 - Launch of Landsat 2.

Aerial Platforms for Cameras

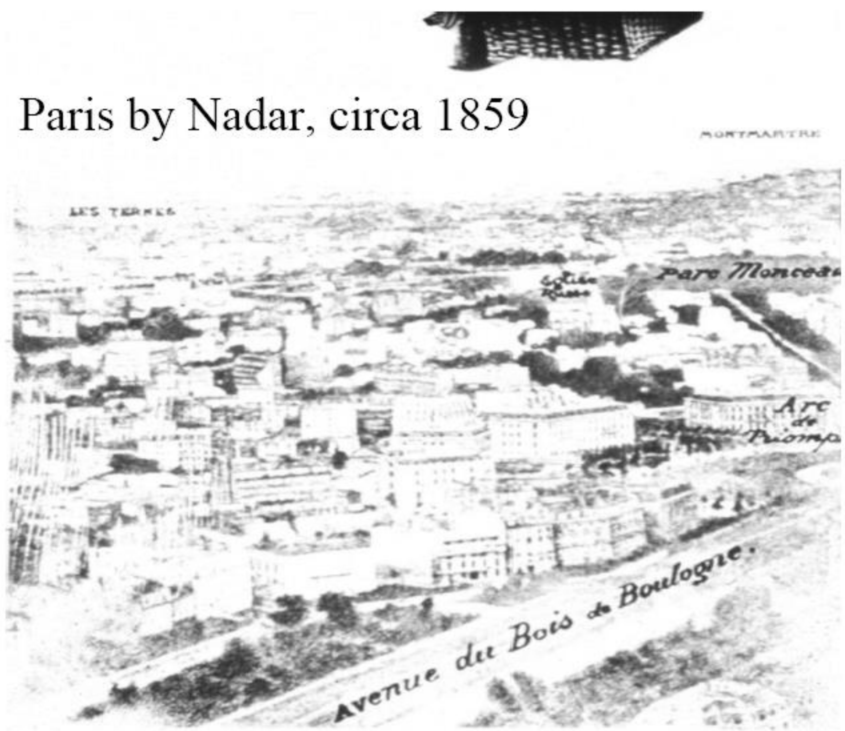
- ➔ Balloons/Blimps
- ➔ Pigeons
- ➔ Kites
- ➔ Airplanes

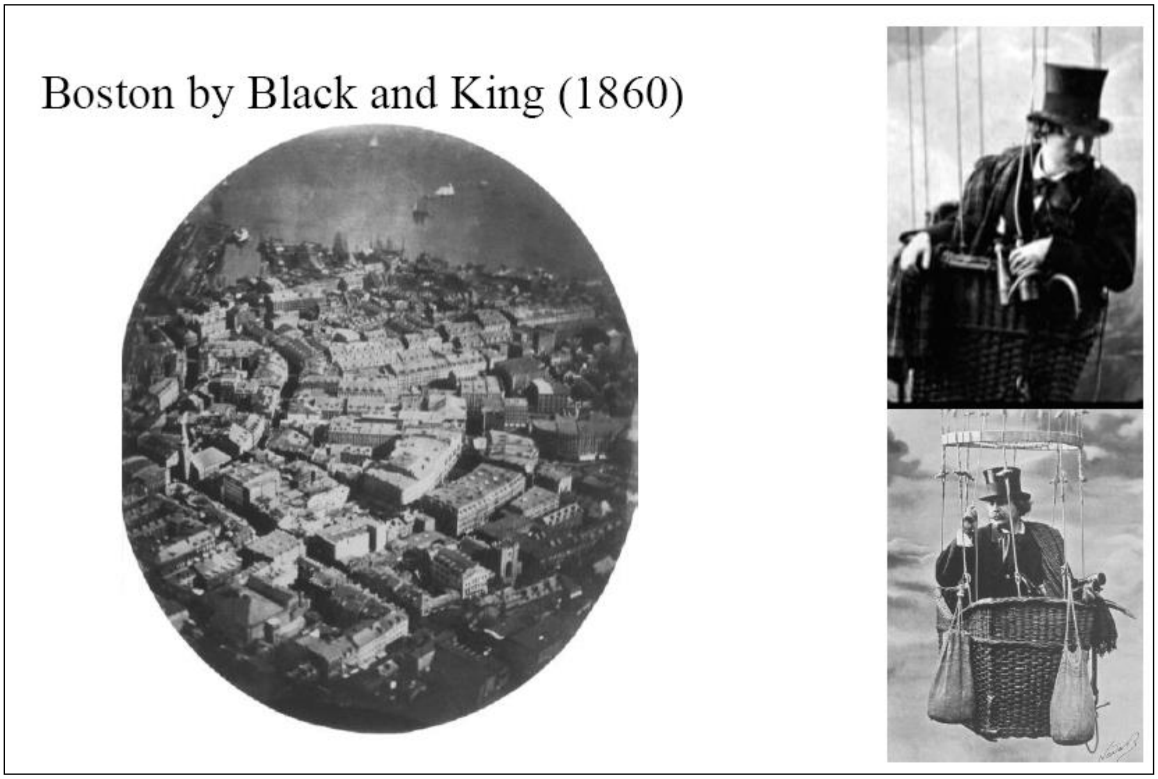
Origins of Remote Sensing

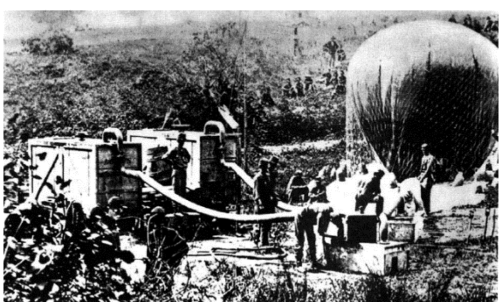
First photographs taken in 1839



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







Thaddeus Lowe's Civil War Balloons gassing the bag, Battle of Fair Oaks, June 1862

Pigeon camera system developed by Julius Neubronner of Germanyin 1908

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

Aerial Platforms - U-2 and SR-71

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

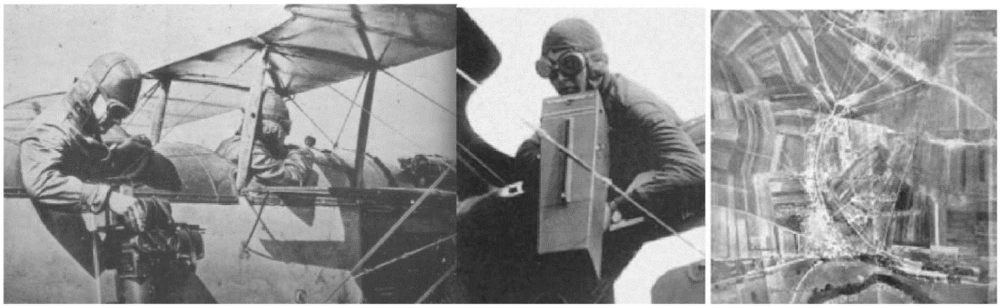
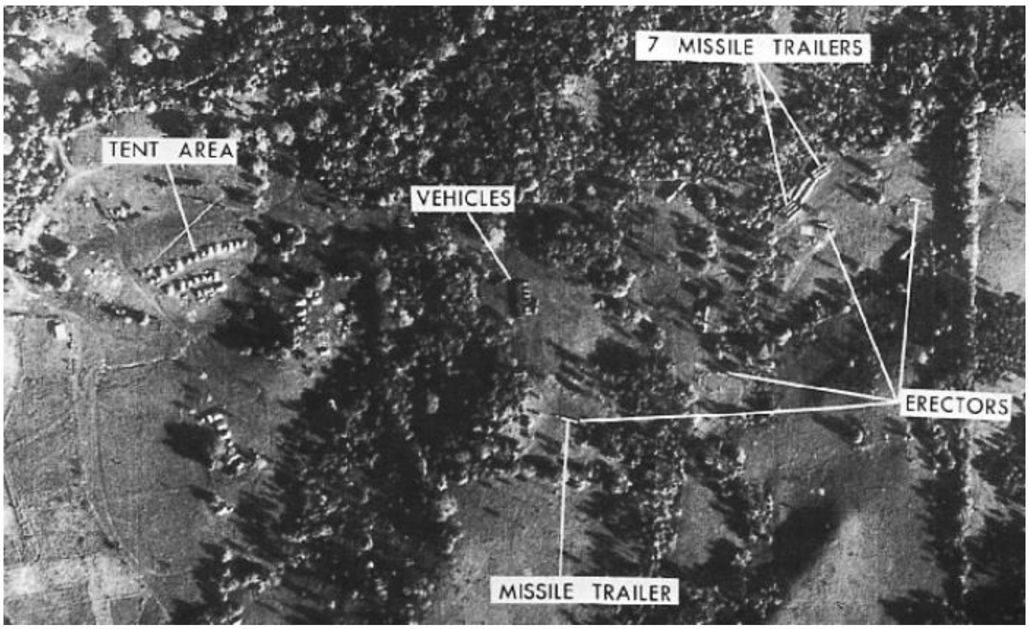
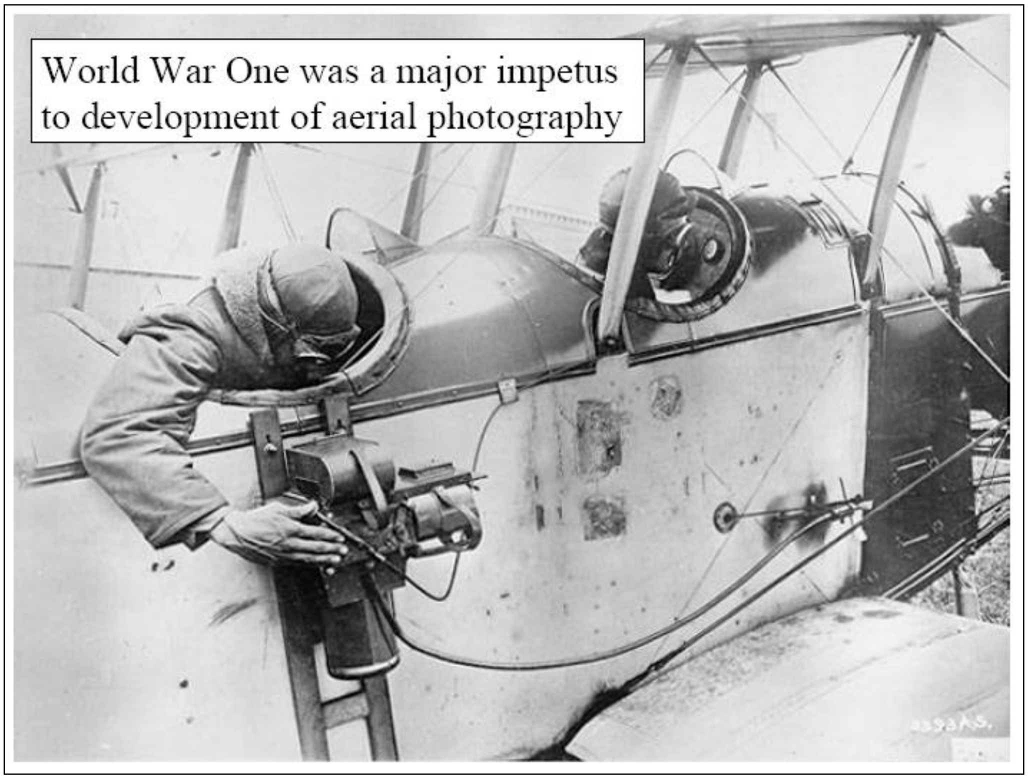
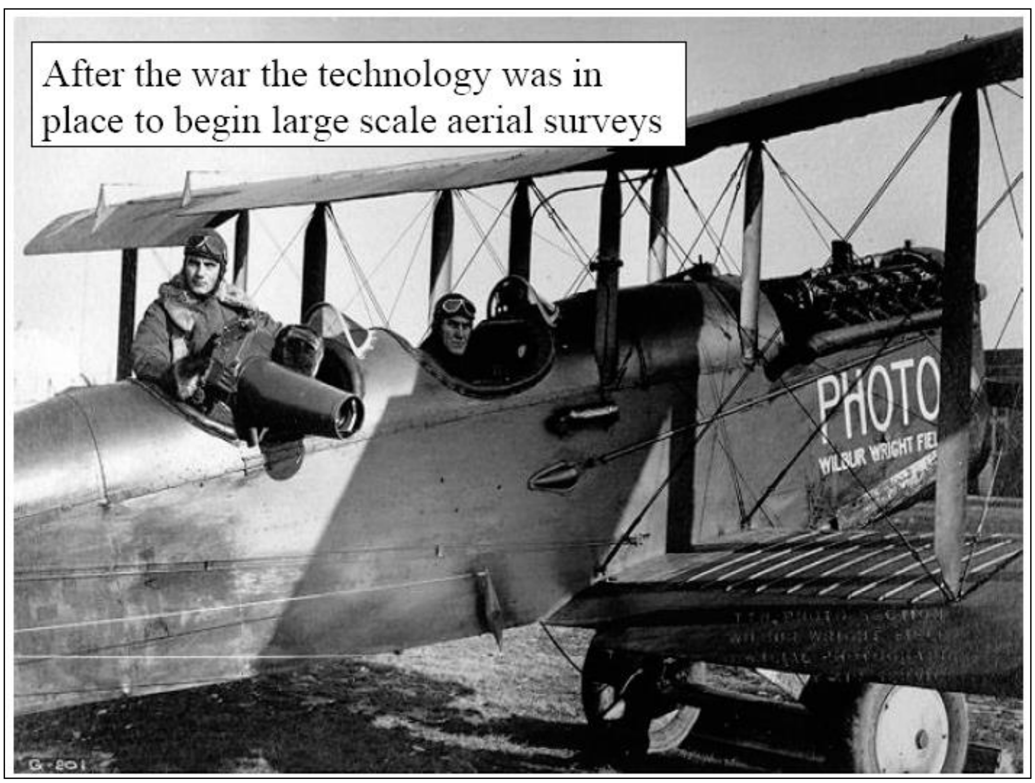


Figure 3-5: Reconnaissance during the World War-I (left), Graflex camera (middle) and an annotated photo of military locations in France during the World War-I, 1918 (right).




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


After the war the technology was in
place to begin large scale aerial surveys
PHOTO
WILBUR WRIGHT FIE

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

Type of Aerial Photography: On the basis of attitude of the camera axis, lens systems, types of camera and Types of films and filters, aerial photography may be classified as follows

1	According to orientation of camera axis	A) Vertical photography B) Low oblique Photography C) High oblique Photography
2	According to lens system	A) Single lens photography B) Three lens photography (Trimetrogon photography) C) Four lens photography D) Nine lens photography E) Continuous strip photography
3	According to special properties of films, filters or photographic equipment	A) Black and white photography B) Infra-red photography C) Colour photography D) Colour infra-red photography E) Thermal infra-red imagery F) Radar imagery G) Spectrazonal photography
4	Digital aerial photographs (Instead of films, using the CCD arrays	Digital data

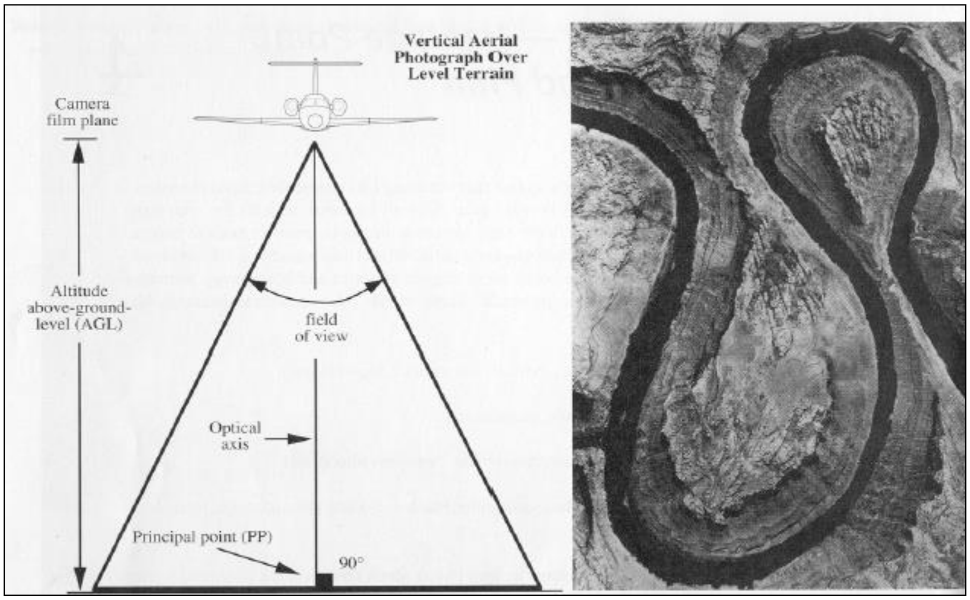
According to orientation of camera axis

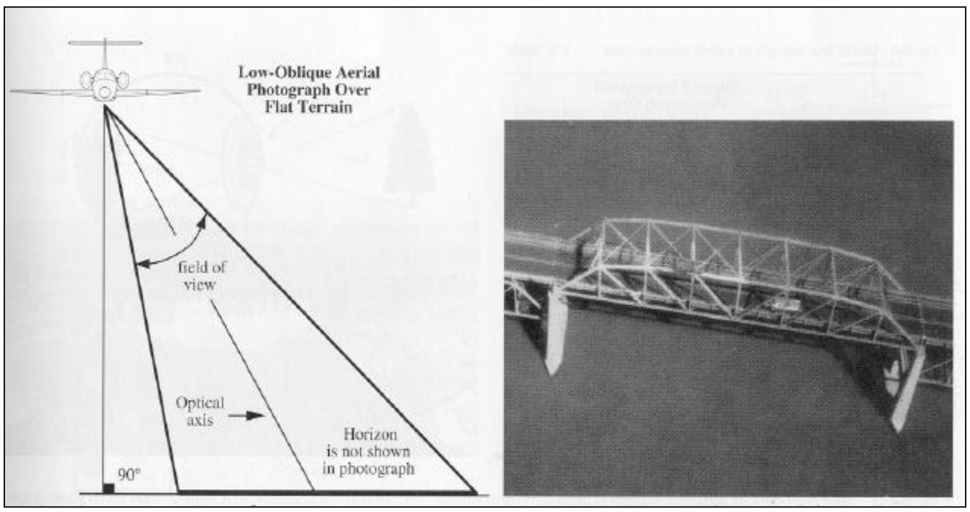
A) A Vertical photography is one taken with the axis of the camera as vertical as possible at the time of exposure. It is virtually impossible to take absolutely vertical photographs. Deviation of the optic axis from the vertical, which rarely exceeds 1 to 2 degree, results the **tilted photographs**.

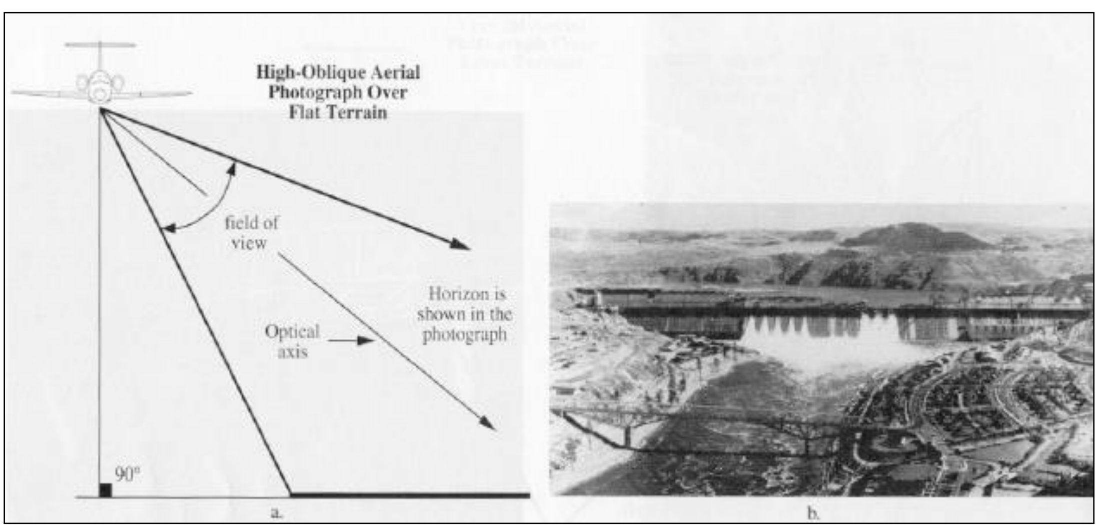
B) An oblique photograph is taken with the axis of the camera intentionally tilted from the vertical.

i) Low oblique photography:
In this type of photography, the camera axis is tilted intentionally to a certain low angle, such that the horizon is not photographed. (Max. angle of tilt is 35^o)

ii) High oblique photography:
Here the camera axis is tilted intentionally to certain greater angle such that horizon is seen on low resulted photograph (max. angle of tilt > 35^o). Such photographs are of importance in military purposes where scenery has to be appreciated with out stereo vision


Vertical Aerial
Photograph Over
Level Terrain
Camera
film plane
Altitude
above-ground-
level (AGL)
field
of view
Optical
axis
Principal point (PP)
90°


Low-Oblique Aerial
Photograph Over
Flat Terrain
field of
view
Optical
axis
Horizon
is not shown
in photograph
90°


High-Oblique Aerial
Photograph Over
Flat Terrain
field of
view
Optical
axis
Horizon is
shown in the
photograph
90°
a.
b.

Advantages of vertical over oblique aerial photographs

1. Vertical photographs present approximately uniform scale throughout the photo but not oblique photos.
2. Because of a constant scale throughout a vertical photograph, the determination of directions (i.e., bearing or azimuth) can be performed in the same manner as a map. This is not true for an oblique photo because of the distortions.
3. Because of a constant scale, vertical photographs are easier to interpret than oblique photographs. Furthermore, tall objects (e.g., buildings, trees, hills, etc.) will not mask other objects as much as they would on oblique photos.
4. Vertical photographs are simple to use photogrammetrically as a minimum of mathematical correction is required.
5. Stereoscopic study is also more effective on vertical than on oblique photographs.

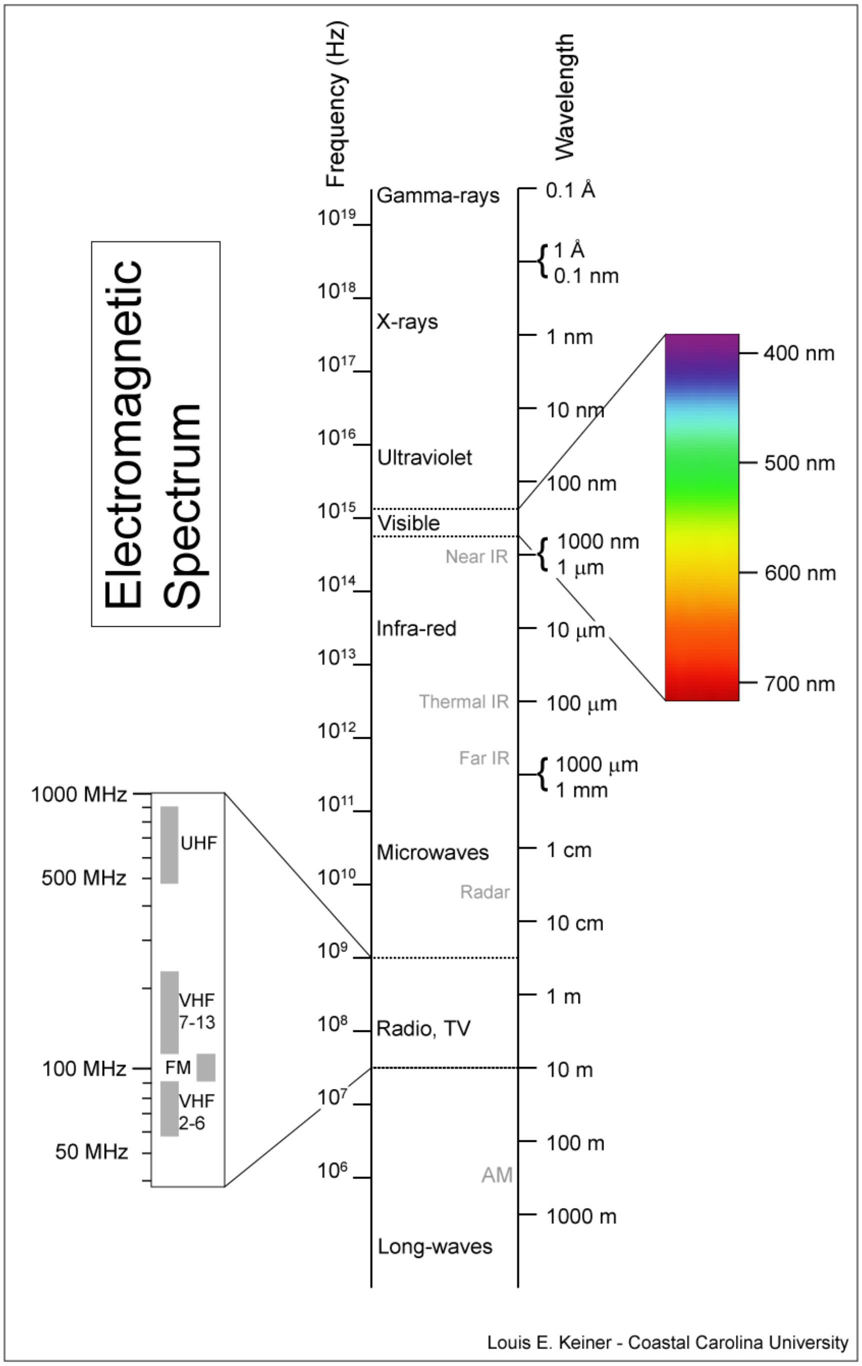
Advantages of oblique over vertical aerial photographs

1. An oblique photograph covers much more ground area than a vertical photo taken from the same altitude and with the same focal length.
2. If an area is frequently covered by cloud layer, it may be too low and/or impossible to take vertical photographs, but there may be enough clearance for oblique coverage.
3. Oblique photos have a more natural view because we are accustomed to seeing the ground features obliquely. For example, tall objects such as bridges, buildings, towers, trees, etc. will be more recognizable because the silhouettes of these objects are visible.
4. Objects that are under trees or under other tall objects may not be visible on vertical photos if they are viewed from above. Also some objects, such as ridges, cliffs, caves, etc., may not show on a vertical photograph if they are directly beneath the camera.
5. Determination of feature elevations is more accurate using oblique photograph than vertical aerial photographs.
6. Because oblique aerial photos are not used for photogrammetric and precision purposes, they may use inexpensive cameras.

Photography according to Lens System

Now a days single lens photography is most commonly used in most of the aerial photo-interpretation work. Two lens, three lens, four lens or nine lens photography have virtually become obsolete. However, some of the multilens photography, like trimetrogen (three lens), four lens or nine lens photography has been proved to be of significance in war reconnaissance or in aerial photography researchers.

Continuous strip photography: In this photography, the photo negative is made to pass continuously over a narrow slot in the focal plane of the camera.



EM Spectrum Regions Used in Remote Sensing

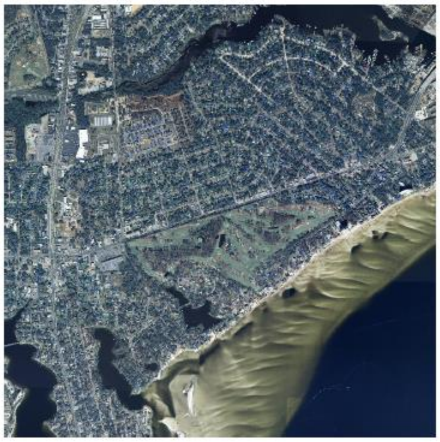
- **Ultraviolet – 0.3 to 0.4 μm**
- **Visible – 0.4 to 0.7 μm**
- **Near Infrared – 0.7 to 1.3 μm**
- **Middle Infrared – 1.3 to 2.8 μm**
- **Thermal Infrared – 2.4 to14 μm**
- **Microwave – 1 mm to 1 m**

Photography according to special properties of films, filters or photographic equipments

1	Panchromatic	Records all the reflections of visible spectrum	General photographic interpretation
2	Infra-red	Records only red and infrared part of the spectrum	Water and vegetations discriminations
3	Colour	Records all the reflections of visible spectrum in colour or near natural colours	Mineral prospecting, forestry,
4	Colour Infra-red	Records visible and infra-red in combination resulting in false colours	Plant and crop diseases, land-water-vegetation discriminations
5	Thermal infra-red imagery	Records only thermal infra-red emissions of objects	Temperature variation like geothermal, water pollution
6	Radar imagery	Records reflections of radar waves	Suited for topographic studies, morpho-tectonic studies and general conditions of ground
7	Spectrazonal	Records only the selective part of the spectrum	Different parts of the spectrum suited to different aspects of studies

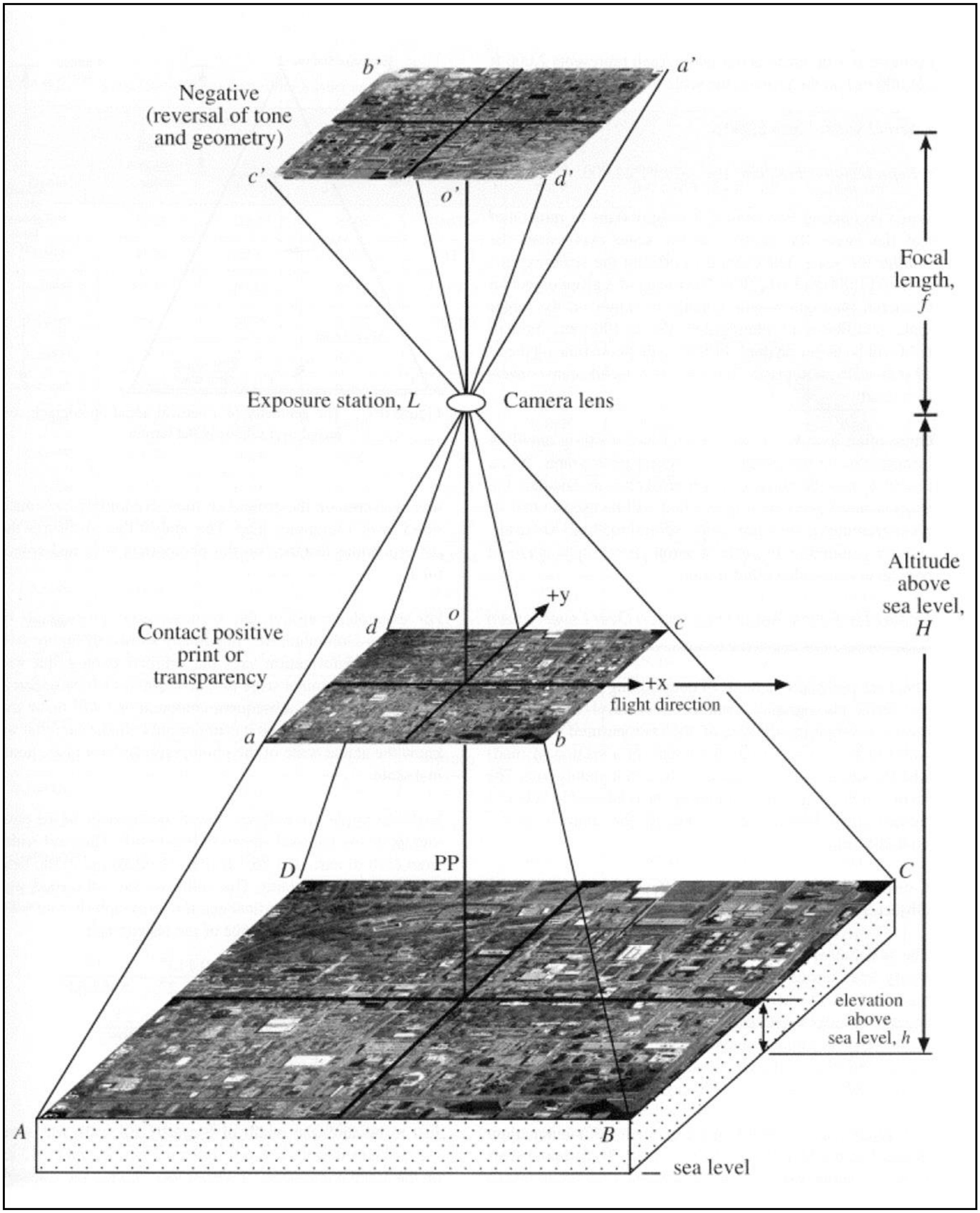
Panchromatic aerial photograph

Color aerial photograph



Infrared aerial photograph

Geometry of a vertical aerial photograph



➔ Incoming light rays from objects on the ground pass through the camera lens before they are imaged on the film in the focal plane.

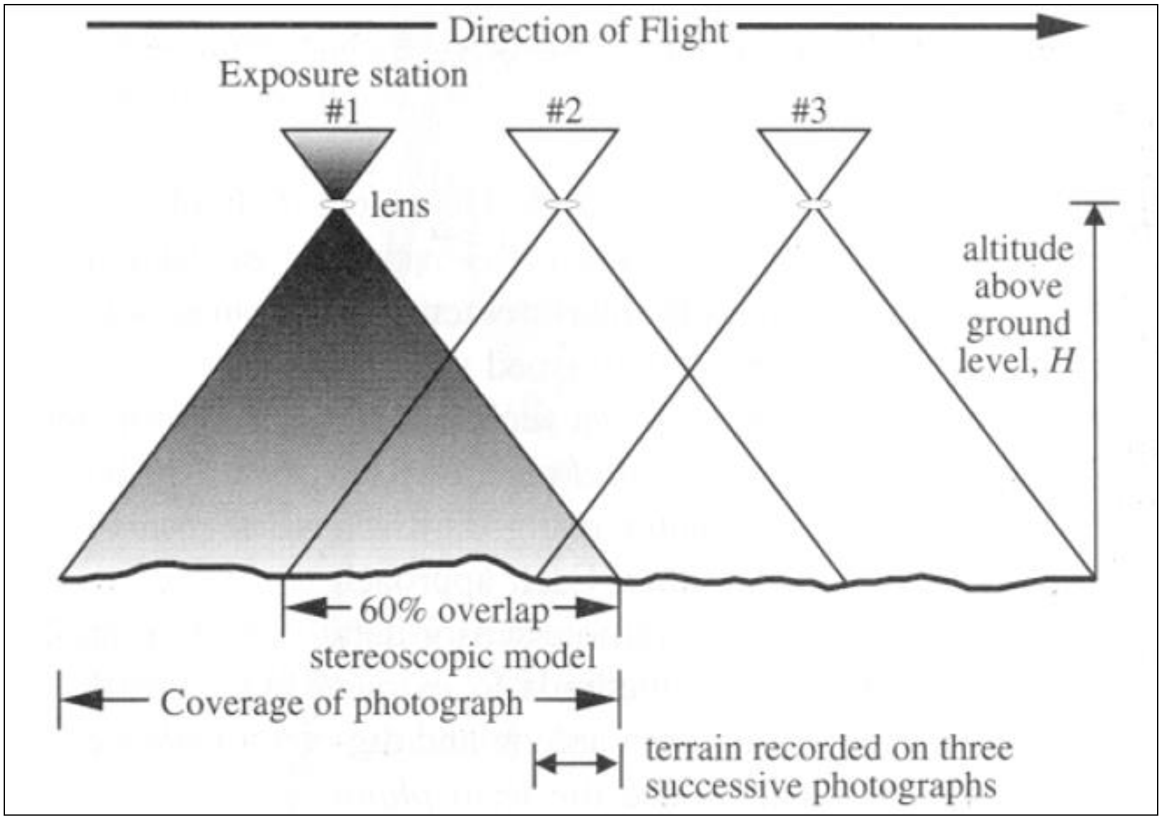
➔ The distance between the lens and the focal plane is termed ***focal length***

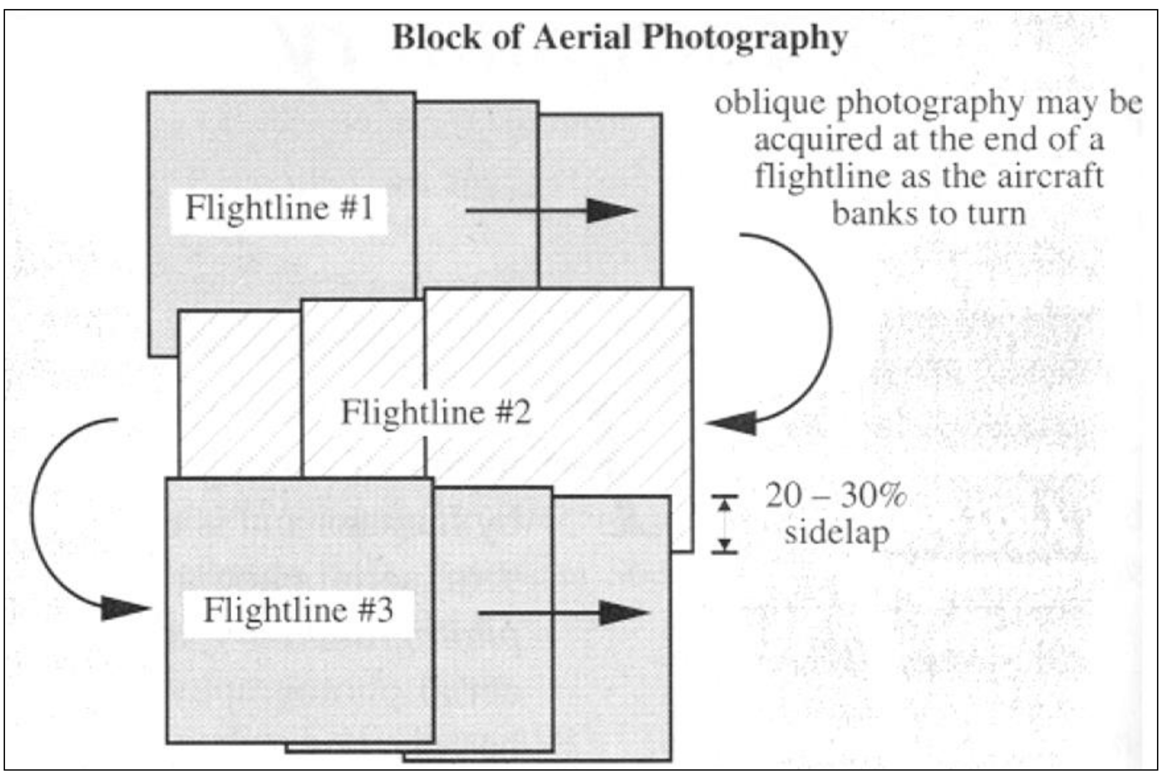
➔ The *x* coordinate axis is arbitrarily assigned to the imaginary flight line direction on the photograph and the *y*-axis is assigned to a line that is perpendicular to the *x*-axis

➔ These two axes usually correspond to the lines connecting the opposite ***fiducial marks*** recorded on each side of the print (i.e., positive image)

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

<u>Flightline of Aerial Photography</u>





Drift and Crab

In an ideal aerial survey it is intended to take a flight in a straight line complete a run parallel to the adjacent run. Unfortunately, at high altitude strong wind currents called side winds influence the aeroplane in maintaining the pre-determined direction and straightness of run. If no correction is made by the pilot, the flight path shall deviate from its original flight line in the direction of wind. This is known as **drift**.

An uncorrected drift will give a displaced pattern of photographs in which the subsequent photograph covers more area in the direction of prevailing wind at the time of photography.

However, if the pilot wants to maintain the pre-determined direction of flight, he has to turn the nose of the aeroplane slightly against the wind direction

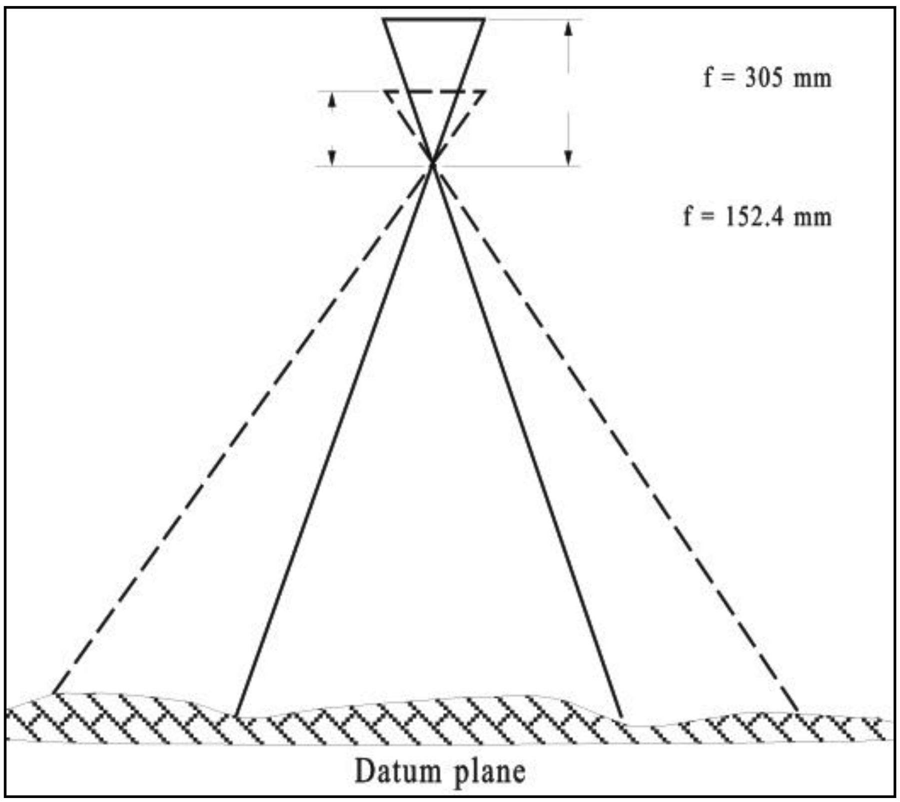
This makes the aeroplane to rotate on its vertical axis.

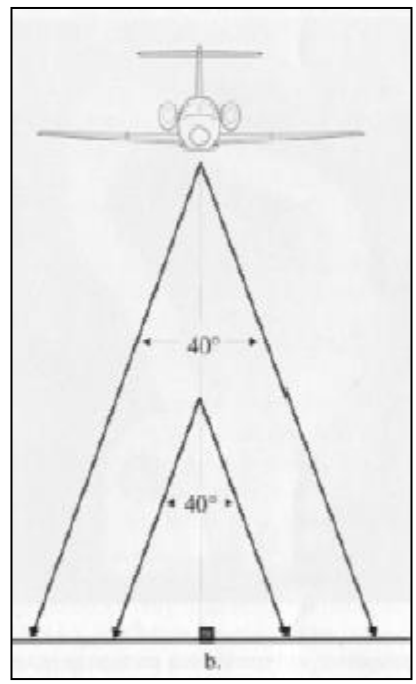
In this side wind correction, the original flight path is maintained but the aerial coverage is much different than originally planned. This defect in aerial photography is known as crab.

An element of drift and crab finally results in reduced stereoscopic coverage in the overlap and sidelap.

Relationship between aircraft altitude and ground coverage

- ➔ Changing the focal length of the camera lens will alter the angular coverage of the system – as the focal length gets smaller, the angular coverage increases
- ➔ As the angular cover increases (focal length decreases), the FOV increases
- ➔ Changing the aircraft altitude will alter the ground coverage of the system





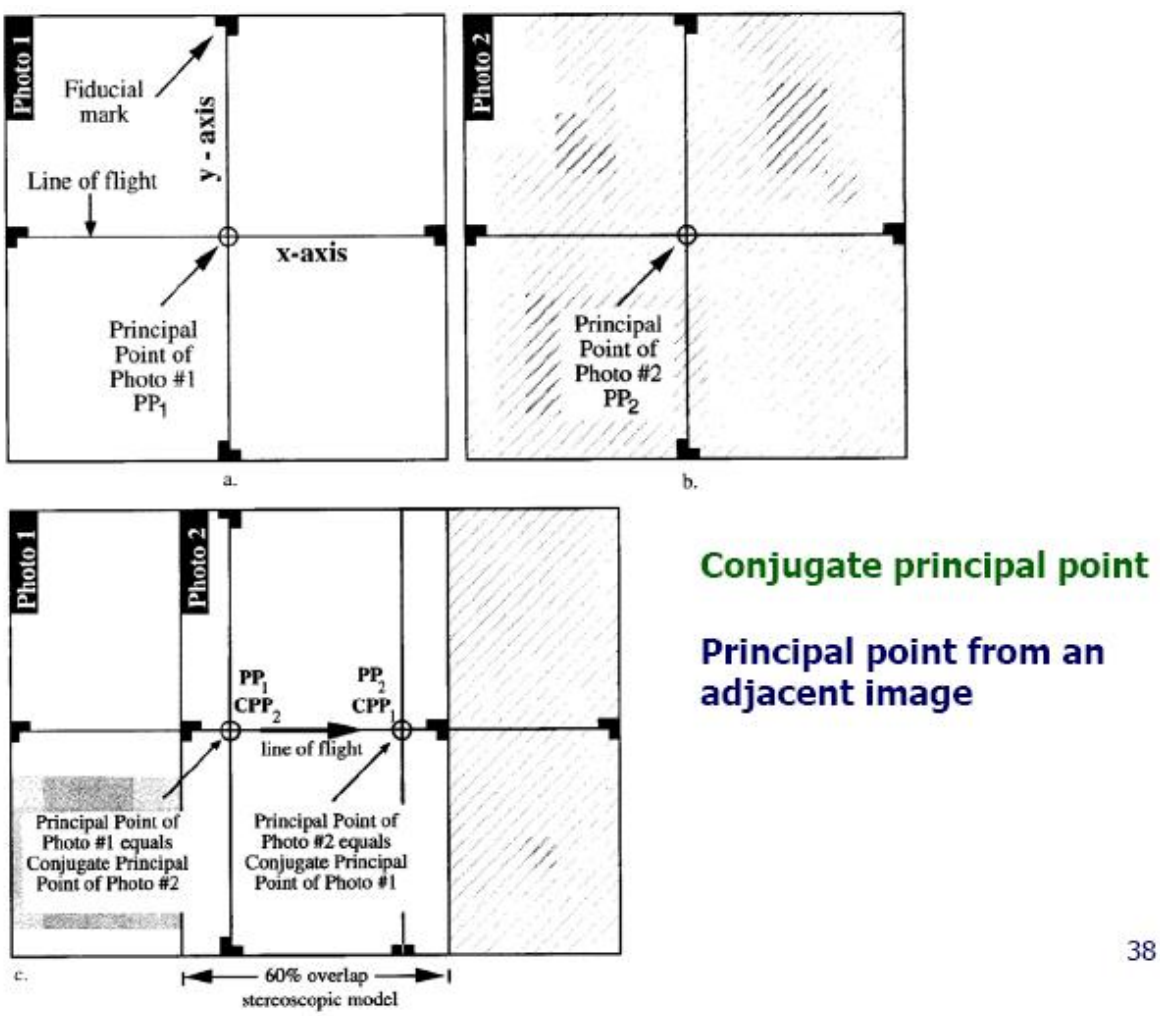
THE CENTERS OF AN AERIAL PHOTOGRAPH

The most of the aerial photographs are not perfectly vertical,

There are three different photo centers: the principal point, the nadir, and the Iso-center.

Each one of these centers plays a specific role and is of great importance to the photogrammetrist because different types of distortion and displacement radiate from each of these points.

If an aerial photograph is perfectly vertical, the three centers coincide at one point (i.e., the principal point), which is the geometric center of the photograph defined by the intersection of lines drawn between opposite *fiducial marks*



Principal point

The principal point is the optical or geometric center of the photograph.

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

The principal point is assumed to coincide with the intersection of the *x* and *y* axes.

We can locate the principal point (PP) on a single photo by the intersection of lines drawn between opposite side or corner *fiducial marks*.

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

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

Nadir Point

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

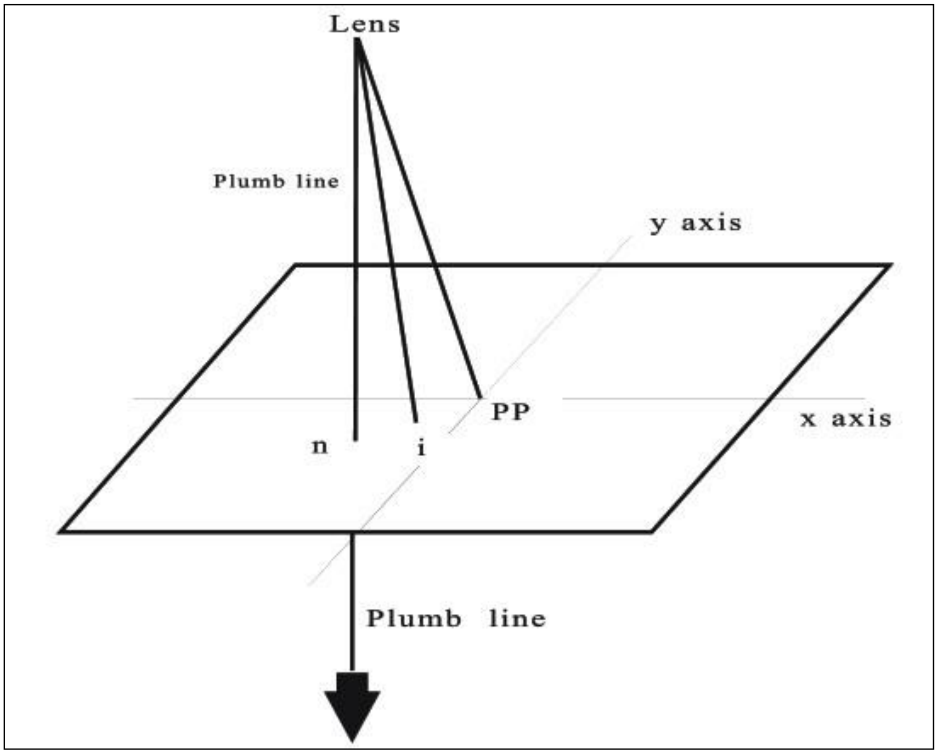
It is the intersection point between the plumb line directly beneath the camera center at the time of exposure and the ground.

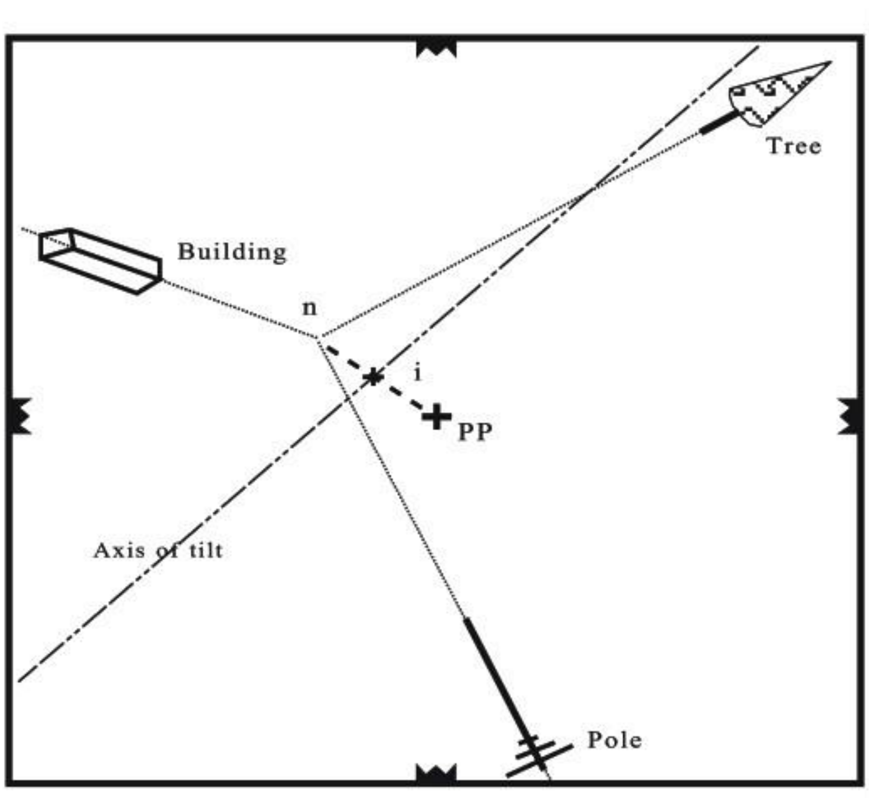
The nadir is important because relief displacement is radial from this point

Unlike the principal point, there are no marks on the photograph to locate the nadir point.

Locating the nadir on a tilted aerial photograph usually requires sophisticated stereoscopic plotting techniques involving expensive instruments and ground control information.

However, in certain situations, the nadir is easily located. The nadir point is at the intersection of lines extended from the top to bottom of tall and perfectly vertical objects.


Lens
Plumb line
y axis
PP
x axis
n
i
Plumb line


Tree
Building
n
i
PP
Axis of tilt
Pole

Isocentre

The isocenter is the point halfway between the principal point and the nadir and on the line segment joining these two points on the photograph.

It is a point intersected by the bisector of the angle between the plumb line and the optical axis.

The isocentre is the point from which tilt displacement radiates.

MAP SCALE

“Map Scale” is the ratio between the map distance and the corresponding distance on the ground.

Similarly, the “Scale of an Aerial Photograph” is the ratio of a distance on the photo to that same distance on the ground.

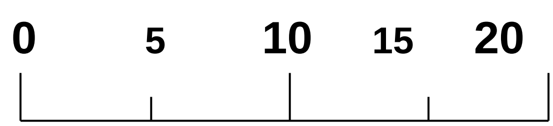
On a map, scale is uniform everywhere because of its orthographic projection.

But on the aerial photograph, since it is a perspective projection, scale varies with terrain elevations.

Expressed in 3 ways,

1) **Unit equivalents : 1 in. = 1,000 ft.**
2) **Dimensionless representative fractions : 1/10,000**
3) **Dimensionless ratio : 1: 10,000**

Drawn as “Linear Scale” in map.



The photo scale can be determined in 3 ways

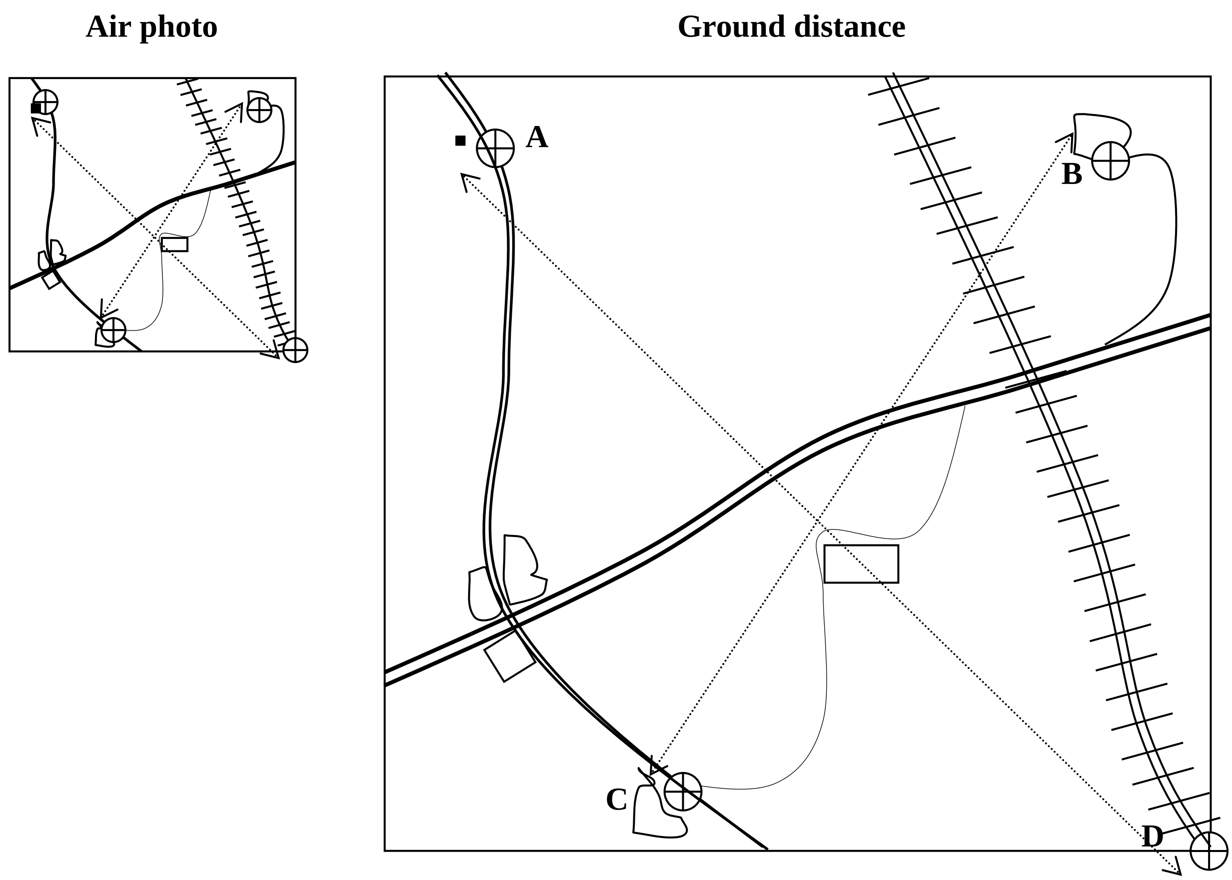
- ➔ **By establishing the selection between the photo distance and ground distance**
- ➔ **By establishing the relation between photo distance and Map distance**
- ➔ **By establishing the relation between the focal length of the camera and flying height**

By establishing the selection between the photo distance and ground distance

- ➔ **This method is usually adopted when the focal length and flying height of the camera are not known.**
- ➔ **The scale is calculated by comparing the photo distance and ground distance**
- ➔ **Scale = Photo distance : Ground distance**
- ➔ **or Scale = Photo distance / Ground distance**

CALCULATION OF SCALE IN AERIAL PHOTOGRAPH

1. Measurement of Scale by Feature Matching method



(a) Scale = Photo distance : Ground distance

For example,

The distance between points A and D in ground = 6 km and in air photo = 10 cm

6 km = 6 x 1000 x 100 cm

= 6,00,000 = 6 lakhs cm

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

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

Scale = photo dist. : ground dist. i.e., 10 cm : 6,00,000 cm

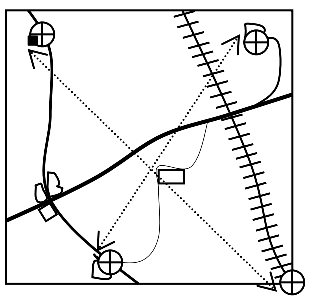
Thus, the scale of the aerial photograph is 1 : 60,000.

➔ **By establishing the relation between photo distance and Map distance**

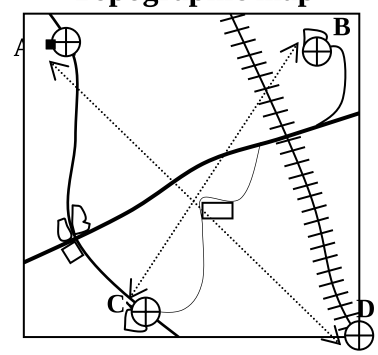
(b) <u>Using Topographic map sheet</u>

- **Minimum of four points with wider separations is preferable**
- **The scale of the topographic sheet is used, e.g. 1: 50,000.**

Air Photo



Topographic map



(b) Scale $= \dfrac{\textbf{Photo distance}}{\textbf{Map distance}} \times$ **Map Scale**

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

Then, scale $= \dfrac{10}{12} \times \dfrac{1}{50000}$

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

Thus, the scale of aerial photo is = 1 : 60,000

(ii) The distance between points B and C in toposheet = 10.5 cm and in air photo = 8.7 cm

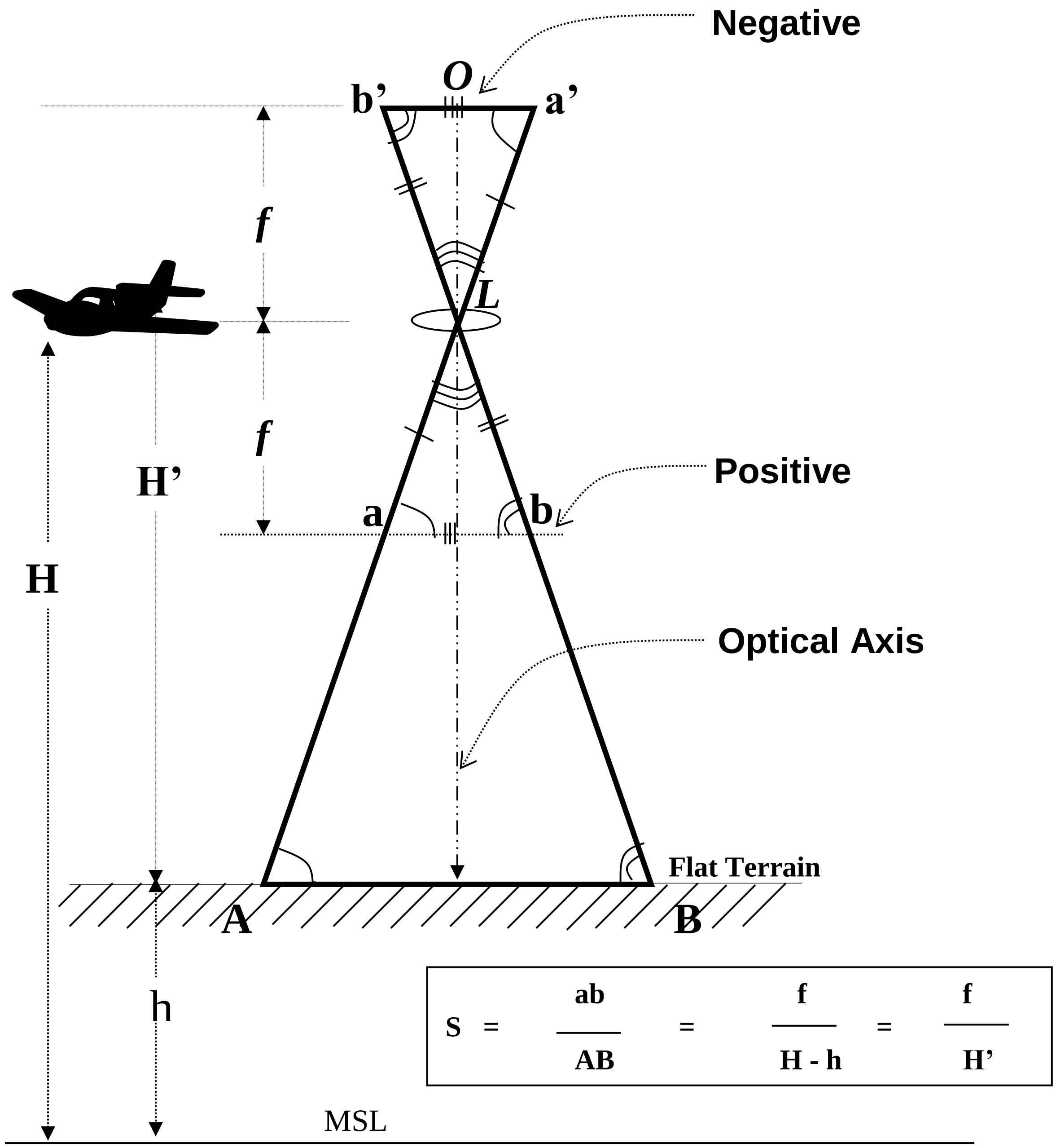
Then, scale $= \dfrac{8.7}{10.5} \times \dfrac{1}{50,000}$

= 8.2 / 5,25,000 = 1 / 60,344. 83

Thus, the scale of aerial photo is = 1 : 60,345

- ➔ **By establishing the relation between the focal length of the camera and flying height**

A) <u>SCALE OF A VERTICAL AERIAL PHOTOGRAPH OVER FLAT TERRAIN</u>



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

Scale of a vertical photograph over flat terrain is simple the ratio of the photo distance ‘ab’ to the corresponding ground distance ‘AB’.

The scale may be expressed in terms of camera focal length (f), and flying height above ground (H') by equating the similar triangles 'Lab' and 'LAB',

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

i.e., the scale of a vertical photo is

- ✓ **directly proportional to camera focal length (image distance)**

and

- ✓ **inversely proportional to flying height above ground (object distance).**

Problem 1: Given: 1. Exposure station height = 5200 ft. above MSL
2. Ground elevation = 980 ft.
3. Focal length = 8 inches.

Flying height, H' = H – h

Where, H = Height above MSL
h = ground elevation

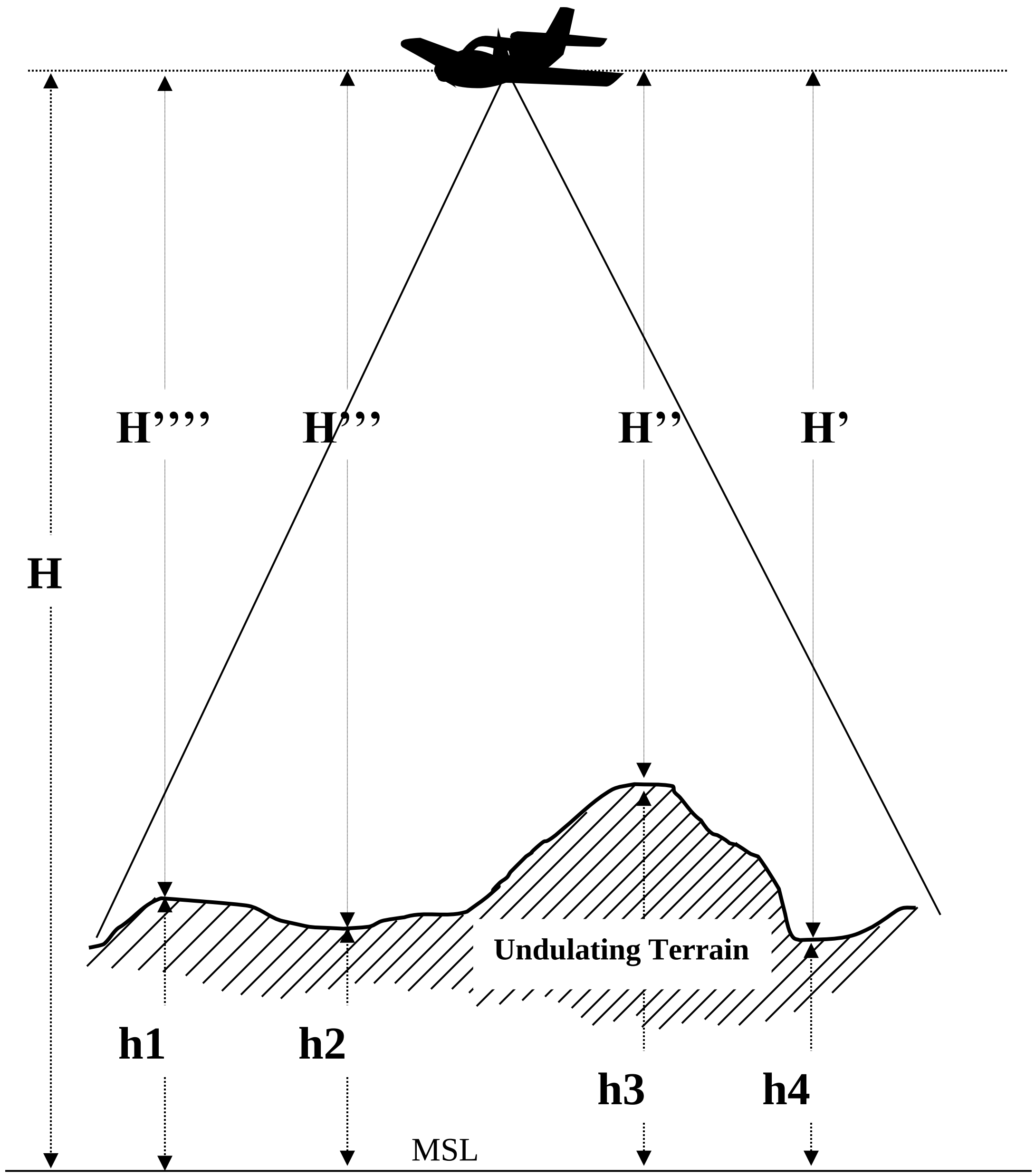
Therefore, H' = 5200 – 980 = 4220 ft. = 4220 x 12 = 50640 inches

$$\text{Scale} = \frac{f}{H'}$$

Where, f = focal length of the camera, H' = Flying height

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

B) SCALE OF A VERTICAL AERIAL PHOTOGRAPH OVER VARIABLE TERRAIN



In an undulating terrain, the object distance varies from place to place

H' <> H'' <> H''' <> H''''

Photo scale, increases with increasing terrain elevation and decreases with decreasing terrain elevation.

H’, H”, H’”, and H”” can be calculated by deducing the terrain height from datum / MSL.

$$H' = H - h1; \quad H'' = H - h2; \quad H''' = H - h3; \ \& \text{ so on} \ldots H^{n'}$$

Hence,

Photo Scale at different points can be calculated using the following equation

$$\boxed{S = \frac{f}{H^{n'}}}$$

C) <u>Average Photo Scale</u>

Calculate the average terrain elevation as below:

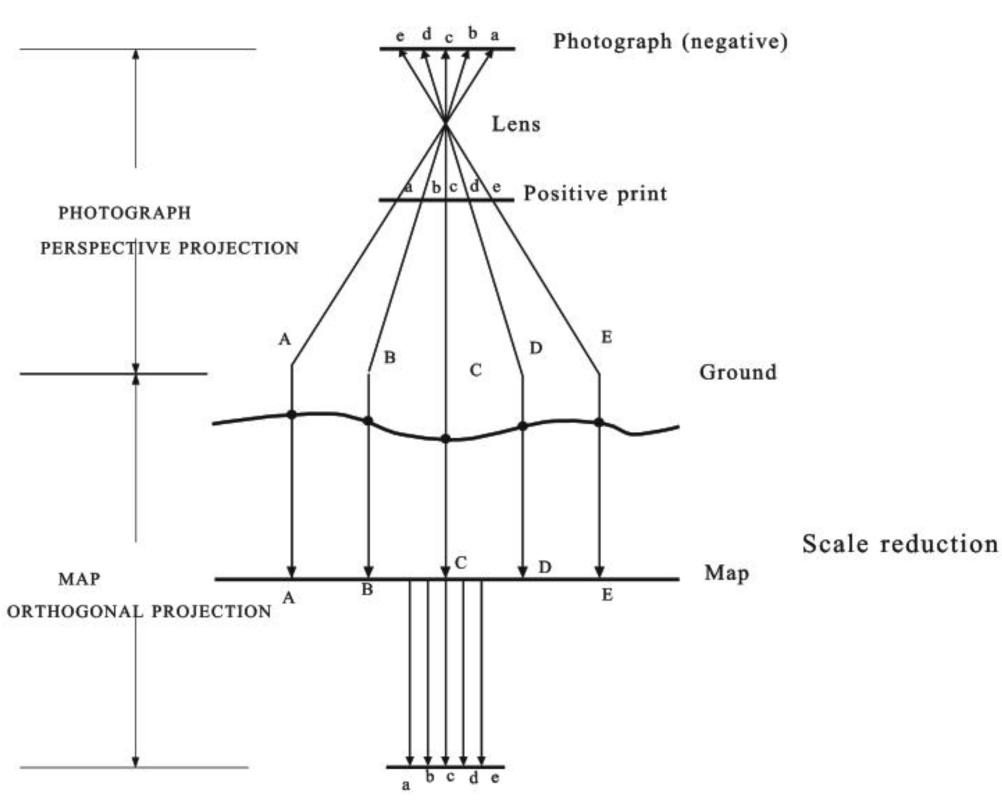
Average Object Height $h_{avg} = (h1 + h2 + h3 + h4 + \ldots . h_n) / n$

Then, calculate Average Flying Height $H' = H - h_{avg}$

Average photo scale can be calculated.

DISTORTION AND DISPLACEMENT

Because of the optical characteristics inherent in a vertical aerial photograph and the anomalies from the camera components, a vertical photograph is not a map.



According to Paine (1981), distortion in aerial photography is defined as any shift in the position of an image on a photograph that alters the perspective characteristics of the image and displacement is any shift in the position of an image on a photograph that does not alter the perspective characteristics of the photograph.

Displacement results mainly from the perspective viewing of the camera resulting in a perspective or central projection on the photograph. In contrast, a map is the product of an orthographic projection.

Types of Distortion

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

Types of Displacement

1. Curvature of the Earth
2. Tilt
3. Topographic or relief

Film and print shrinkage or expansion: the quality of the film and paper print is very important to the quality of data storage and accuracy.

Dilatation or shrinkage of film and print under heat or cold may change the scale of the photographs and the actual position of the objects on the photographs.

Fortunately, most photographic films used for photogrammetric purposes have excellent dimensional stability. Therefore, film dimension changes are relatively small, amounting to about 0.025 mm (less than 0.001 inch) in most cases, but photographic papers are far less stable.

A stable film and paper would minimize these distortions. For this reason, diapositives printed on film base are preferred for precision mapping and glass plates are used rather than film whenever extreme accuracy is desired.

To determine the shrinkage or expansion of a paper we compare the measured distances between opposite fiducial marks on a print with their corresponding values obtained during camera calibration. Then, a correction factor is computed by dividing the calibrated distances by the measured distances and the resulting factor value is applied to each *x* and *y* photocoordinates employed in any subsequent analysis. The computation equations are expressed as:

$$x = \frac{x_c}{x_f} . x_m \qquad (7.1)$$

$$and \quad y = \frac{y_c}{y_f} . y_m \qquad (7.2)$$

where: x is the corrected photocoordinate along the x-axis for a point a,
y is the corrected photocoordinate along the y-axis for a point a,
x_c is the calibrated fiducial distance along x-axis,
y_c is the calibrated fiducial distance along y-axis,
x_f is the measured fiducial distance along x-axis,
y_f is the measured fiducial distance along y-axis,
x_m is the measured photocoordinate for point a along the x-axis,
y_m is the measured photocoordinate for point a along the y-axis, and
x_c/x_f and y_c/y_f are the correction factors along x-axis and y-axis respectively.

Scale distortions due to Lens Thickness

Lens distortion causes imaged positions to be displaced from their ideal locations. lens distortion radiates from the principal point, which causes object displacement either toward (closer to) or away (farther) from the principal point (the optical or geometric center) of the photograph than it actually is.

Because this distortion is radial from the principal point, objects near the edge of the photograph are more distorted.

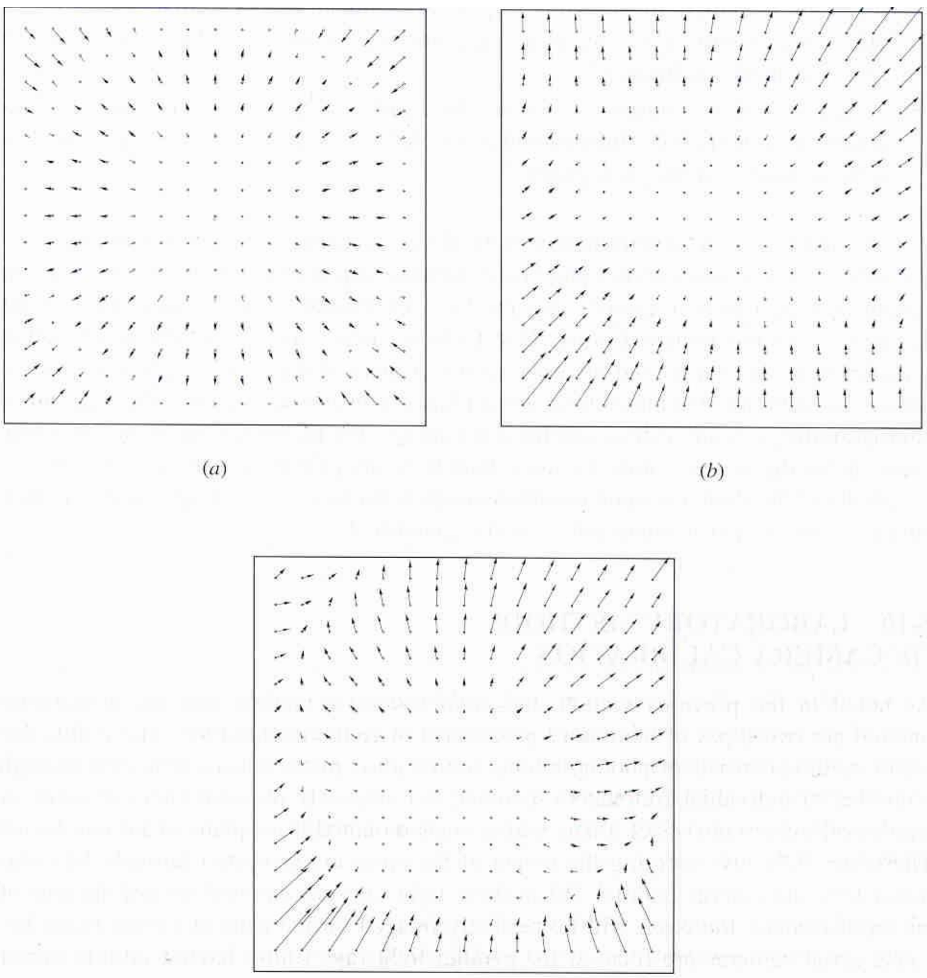
There are two type of lens distortion one is symmetric radial distortion and decentring distortion. In modern precision aerial mapping cameras, lens distortions are typically less than 5 micro meters.

Symmetric radial lens distortion is an unavoidable product of lens manufactures although with careful design its effects can be reduced to a very small amount.

Decentering distortion is primarily a function of the imperfect assembly of lens elements, not the actual design.

This anomaly can be corrected by calibrating the lens. One way of doing this is to fly a plane area at an accurate flying height and computing the exact scale between several known points located radially between the principal point and the edge of the photograph.

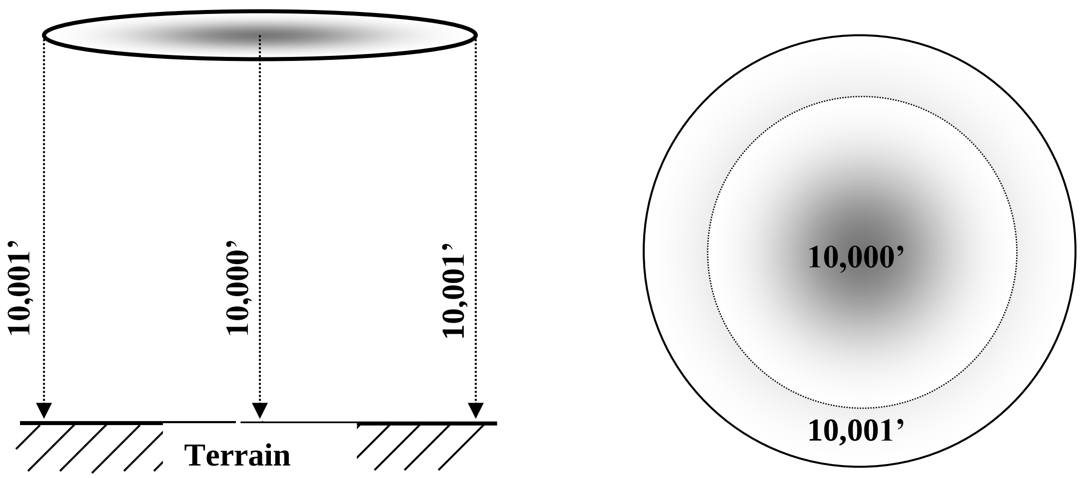
Through this technique, we can obtain a distortion curve that shows us how the distortion varies with the radial distance from the principal point and allows us to make corrections accordingly.



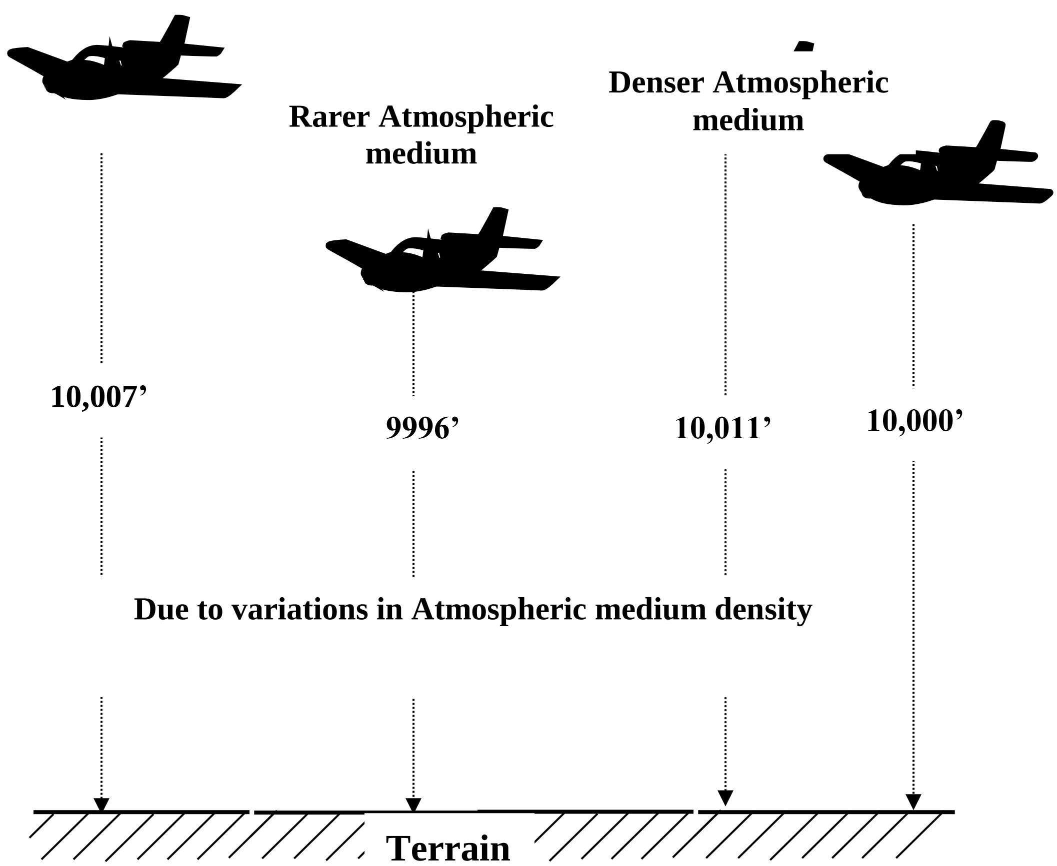
(a) (b) (c)

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

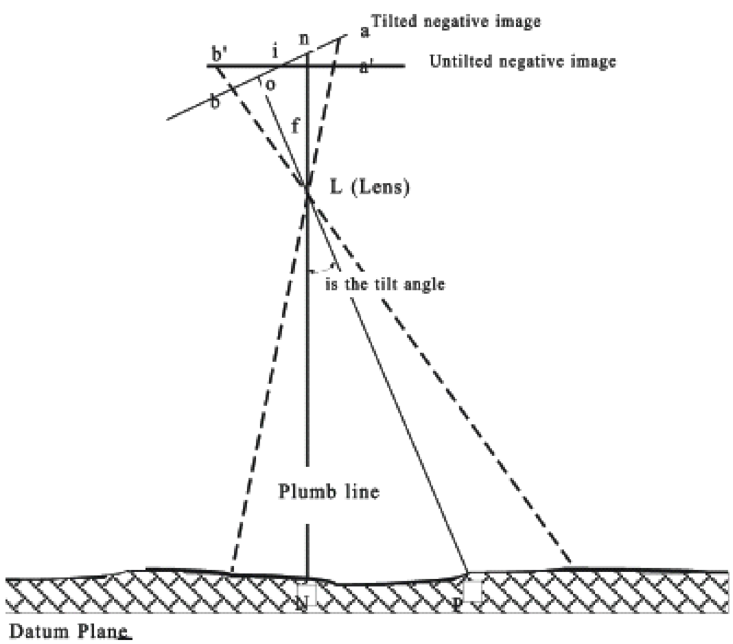
Vertical Cross Section View of Biconvex Lens **Top view**



Scale distortions due to sudden change in Flying height



Scale displacement due to Tilt in the Aircraft



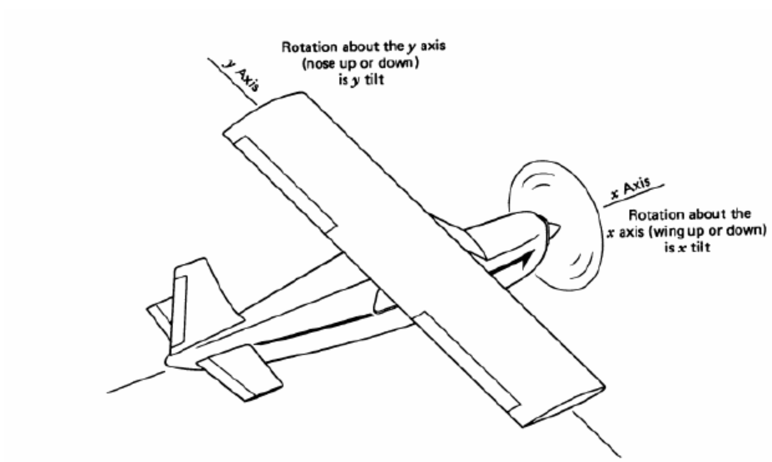
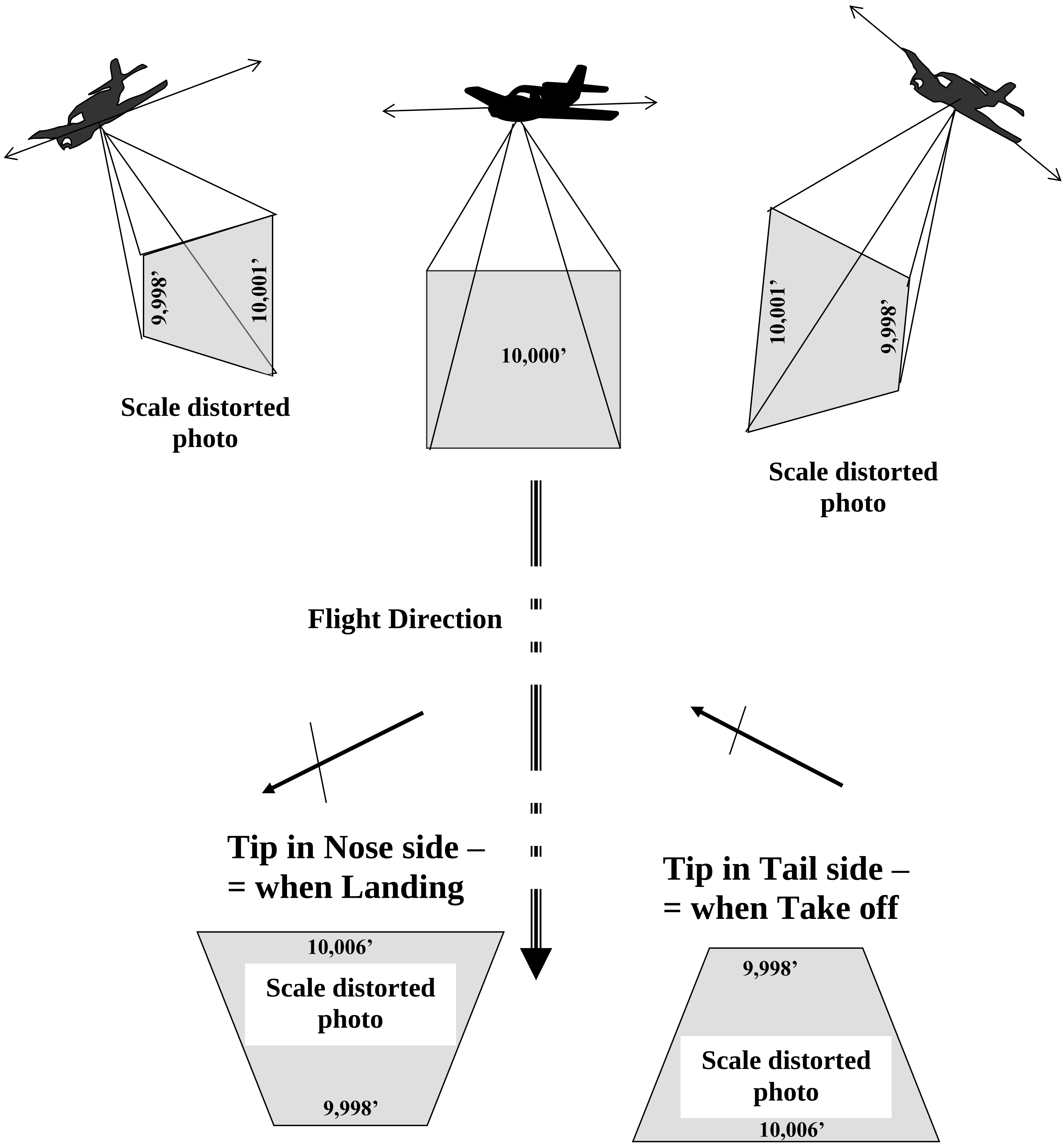


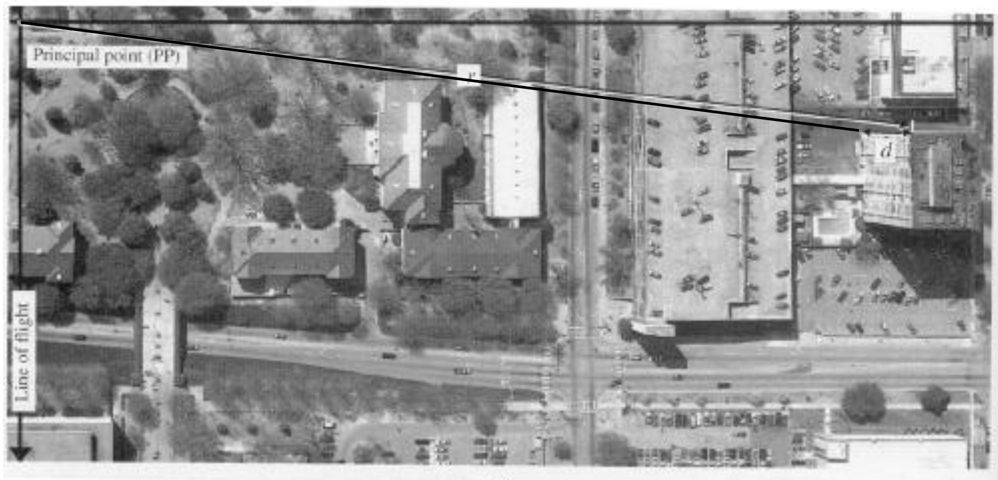
Figure 2.9. *x* and *y* tilt caused by the attitude of the aircraft (actually the camera) at the instant of exposure.

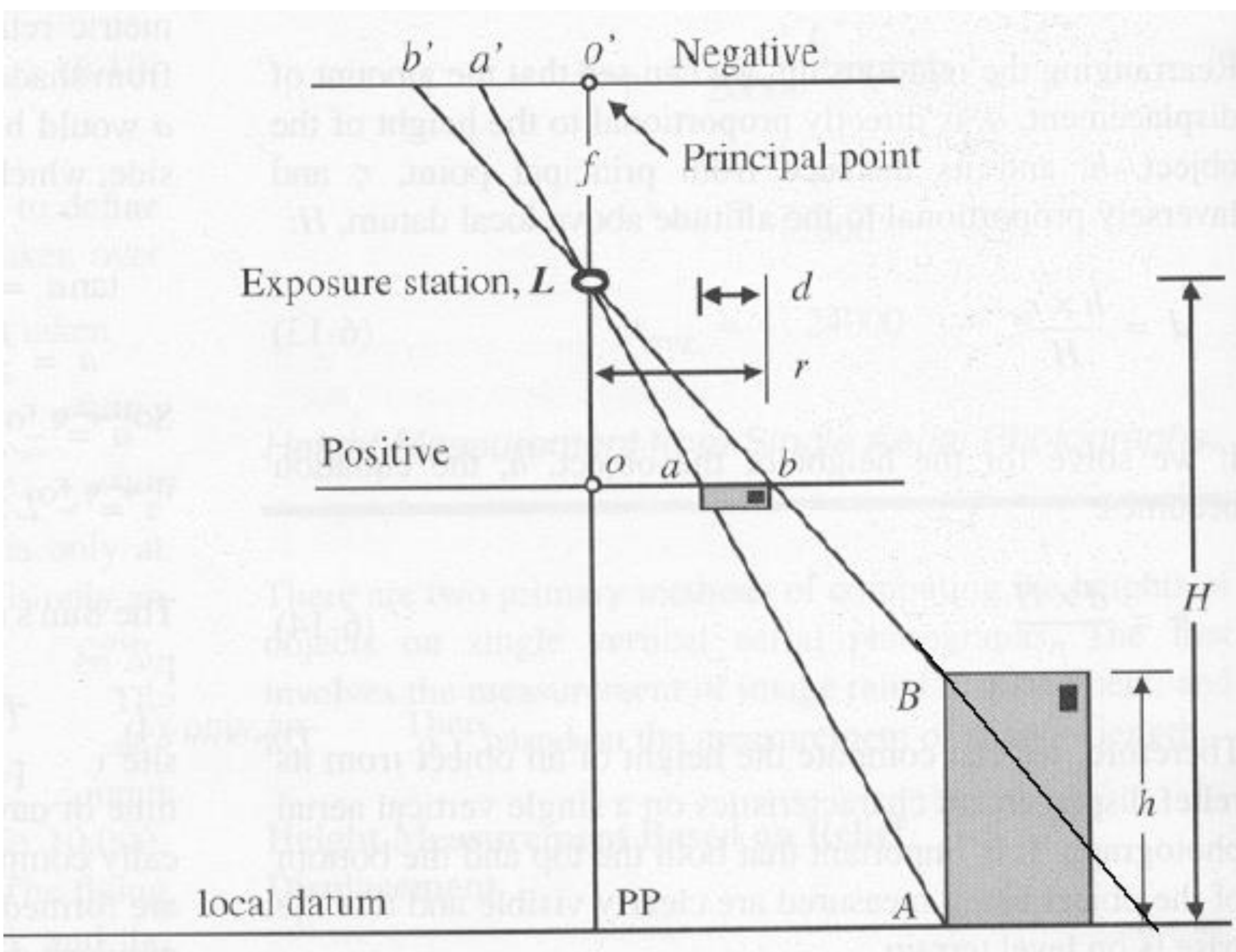
Displacement due to tilt is caused by the aircraft or other airborne platform not being perfectly horizontal at the moment of exposure. Rotation of the camera about the y axis (nose up or down) is y tilt and rotation about the x axis (wing up or down) is x tilt

Both radiate from the isocentre and cause images to appear to be displaced radially toward the isocentre on the upper side of the photo positive (not the negative) and radially outward or away from the isocentre on the lower side.

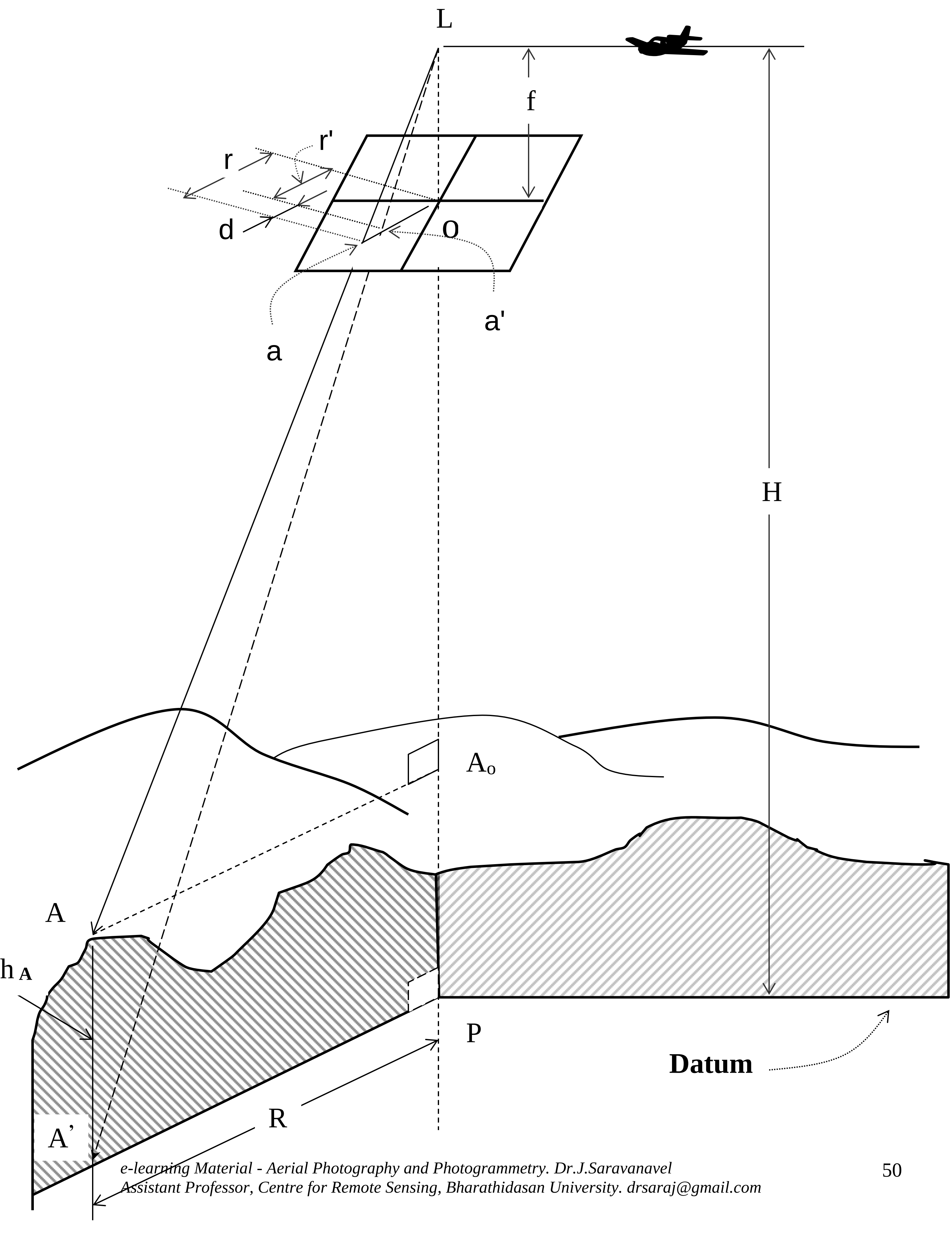

9,998’
10,001’
Scale distorted photo
10,000’
10,001’
9,998’
Scale distorted photo
Flight Direction
Tip in Nose side –
= when Landing
10,006’
Scale distorted photo
9,998’
Tip in Tail side –
= when Take off
9,998’
Scale distorted photo
10,006’

Relief Displacement on a vertical aerial photograph





b.



L
f
r'
r
d
o
a'
a
H
A_o
A
h_A
P
Datum
R
A'

Relief Displacement on a vertical aerial photograph

Relief displacement is the shift or displacement in the photographic position of an image caused by the relief of the object,

i.e., its elevation above or below a selected datum.

With respect to datum,

Relief displacement is outward for points above datum and Inward for points below datum.

In the above figure,
An imaginary point A' is located vertically beneath A in the datum plane and Its corresponding imaginary image position is at a'.

Both A'A and P L are vertical lines and therefore, A'AaLoP and A'a'LoP are vertical planes.

Since these planes intersect the photo plane along lines oa and oa' respectively,

Line aa' (– relief displacement of point A due to its elevation h_A –) is radial from the principal point.

Triangles are similar if their corresponding (matching) angles are equal and the ratio of their corresponding sides are in proportion.

By relating similar triangles Lao and LAA_o

$$\frac{r}{\quad} = \frac{f}{\qquad} \qquad \textbf{rearranging;} \quad r(H - h_A) = fR$$

$$\frac{?}{R} \quad H - h_A$$

R H – h_A

Also by relating similar triangles La'o and LA'P,

$$\frac{r'}{R} = \frac{f}{H} \qquad \text{rearranging;} \quad r'H = fR$$

Thus equating the above expressions,

$$r(H - h_A) = r'H$$

Rearranging the above equation, dropping subscripts , and substituting the symbol of d for (r – r'), the results,

$$\boxed{D = \frac{rh}{H}}$$

Where h = height above datum of the object point whose image is displaced

d = relief displacement

r = radial distance on the photograph from the principal point to the displaced image (the units of d and r must be the same).

H = flying height above the datum selected for measurement of h

To calculate the vertical heights of objects appearing on aerial photographs, the above equation may be rearranged as below:

$$\boxed{h = \frac{dH'}{r}}$$

Two towers were identified on a perfectly vertical photograph taken from 2500 m above the datum. The distances from the base of the towers to the photo center are equal and are measured to be 8.35 cm. If the height of tower1 is 120 m and that of tower2 is 85 m above the datum, find the relief displacement of the summit of these towers on the photograph? Conclude.

$$\mathbf{D = \frac{rh}{H}}$$

Where h = height above datum of the object point whose image is displaced
d = relief displacement
r = radial distance on the photograph from the principal point to the displaced image (the units of d and r must be the same).
H = flying height above the datum selected for measurement of h

Solution:

First of all, because the photograph is perfectly vertical, the photo center is the nadir point using equation 6.12, we obtain:

$$d = \frac{8.35\, cm \,.\, 120\, m}{2500\, m - 120\, m} = 4.21\, mm$$

for tower 1:

$$d = \frac{8.35\, cm \,.\, 85\, m}{2500\, m - 85\, m} = 2.94\, mm$$

for tower 2:

Conclusion: Relief displacement varies directly as the height of the object. Because tower1 is higher than tower2, its image is displaced more.

In example 6.6, suppose that tower1 and tower2 have the same height of 100 m above the datum but the distances from their summit to the center of the photograph were found to be 6.55 cm and 9.21 cm respectively for tower1 and 2. The height of the flight above tower is 2500 m. Find the relief displacement for both towers and conclude.

Solution:

$$d = \frac{6.55\,cm\,.\,100\,m}{2500\,m} = 2.62\,mm$$

for tower1:

$$d = \frac{9.21\,cm\,.\,100\,m}{2500\,m} = 3.68\,mm$$

for tower2:

Conclusion: Relief displacement varies directly as the distance of the object from the nadir Because tower2 is farther from the nadir than tower1, its image is displaced more.

A vertical photograph taken from an elevation of 535 m above MSL contains the image of a tall vertical radio tower. The elevation at the base of the tower is 259 m above MSL. The relief displacement ‘d’ of the tower was measured as 54.1mm, and the radial distance to the top of the tower from photo centre was 121.7 mm. What is the height of the tower?.

$$d = rh/H$$

$$h = dH/r$$

d-relief displacement, **h-**height above datum of object point whose image is displaced, **r-**radial distance on photograph from principal point to displaced image

H = 535 - 259

d = 54.1mm, r = 121.7 mm, H = 535 – 259 = 276 m

$$h = \frac{54.1 \text{ mm} * 276 \text{ m}}{121.7 \text{ mm}} = 122.69 \text{ or } 123 \text{ m}$$

h = 123 m

The images of the top and bottom of a utility pole are 129.8 mm and 125.2 mm respectively from the principal point of a vertical photograph. What is the height of the pole if the flying height above the base of the pole is 875 m.

$$d = rh/H, \quad h = dH/r$$

d = 129.8 mm – 125.2 mm = 4.6 mm, r = 129.8 mm, H = 875 m

$$h = \frac{4.6 \text{ mm} * 875 \text{ m}}{129.8 \text{ mm}} = 31.00 \text{ m}$$

UNIT: 2 - Stereo Models : Monoscopy - Stereoscopy - Pseudoscopy - Base height Ratio -Vertical Exaggeration - Stereoscopic Parallax & Height measurement - Analog Photogrametric Techniques. Photo Mosaics: Photo indexing - Photo mosaic (uncontrolled, semi controlled & Controlled mosaics) – Flight planning – Aerial triangulation.

STEREO MODELS

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

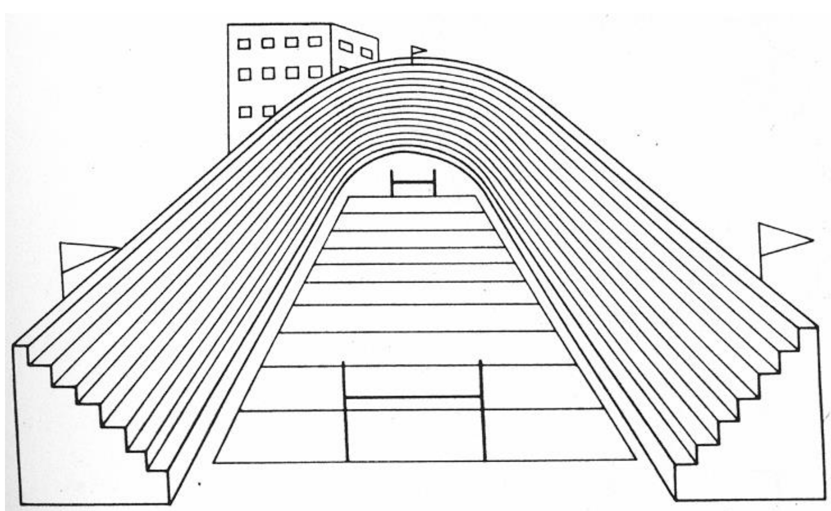
Methods of judging depth may be classified as either **stereoscopic or monoscopic**.

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

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

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

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



Depth perception by relative sizes and hidden objects

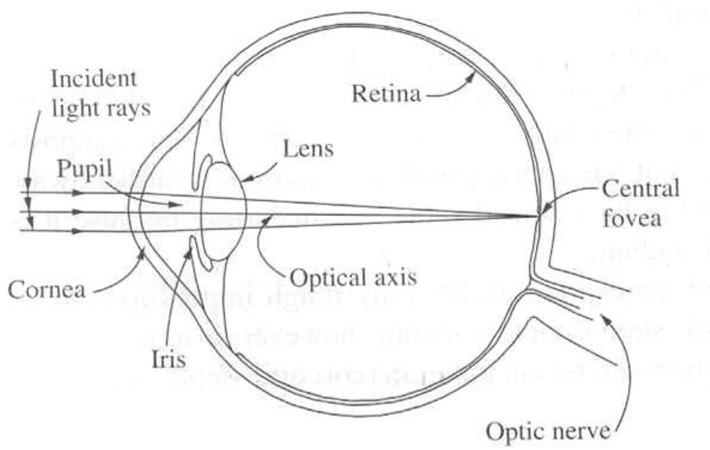
Monoscopic methods of depth perception - Enable only rough impressions to be gained of distances to objects.

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

STEREOSCOPIC VISION

The Human Eye

The phenomenon of stereoscopic depth perception can be more clearly understood with the help of a brief description of the anatomy and physiology of the human eye. The human eye functions in much the same manner as a camera



The eye is essentially a spherical organ having a circular opening called the **pupil**. The pupil is protected by a transparent coating called the **cornea**. The incident light rays pass through the cornea enter the eye through pupil and strike the lens which is directly behind the pupil.

The **lens** of the eye is biconvex and is composed of a refractive transparent medium. It is suspended by many muscles which enable the lens to be moved so that the optical axis of the eye can be aimed directly at an object to be viewed.

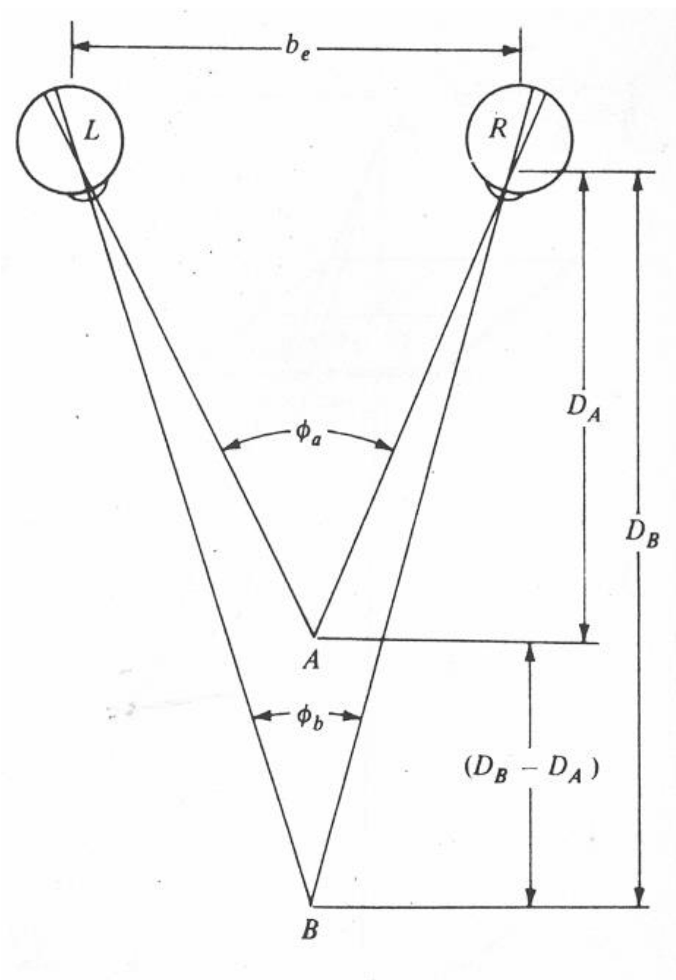
When distance object is viewed, the lens muscles relax causing spherical surfaces of the lens to become flatter. The eye's ability to focus for varying object distances is called **accommodation**.

As with a camera, the eye has a diaphragm called the iris. The **iris** automatically contracts or expands to regulate the amount of light entering the eye.

The cornea partially refracts incident light rays before they encounter the lens. The lens refracts them further and brings them to focus on the **retina**, there by forming an image of the viewed object. The retina is composed if very delicate tissue. The most important region of the retina is the **central fovea**, a small pit near the intersection of the optical axis with the retina. The central fovea is the area of sharpest vision. The retina is similar to photographic film. When it is stimulated by light, the sense of vision is caused which is transmitted to the brain via the optic nerve.

STEREOSCOPIC DEPTH PERCEPTION

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



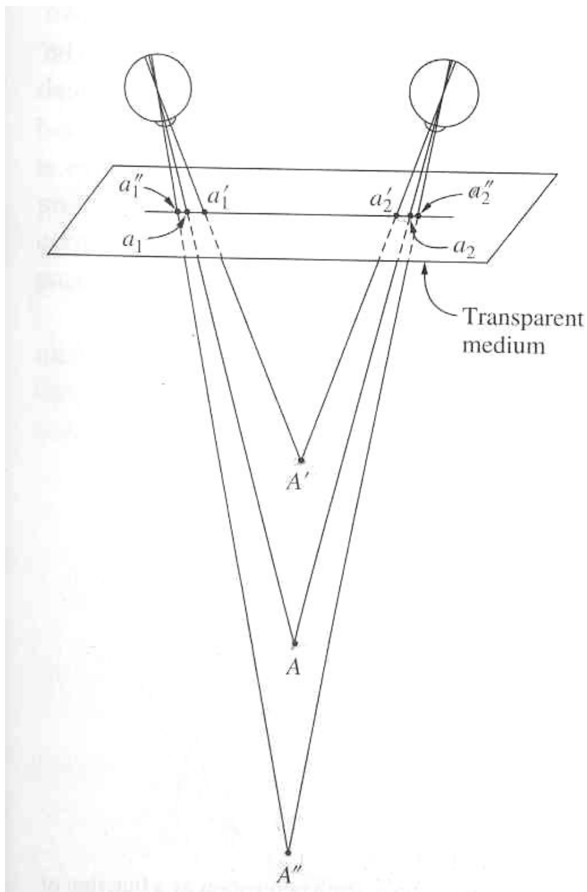
The optical axes of the two eyes L and R are separated by a distance b_e called the eye base. For the average adult, the distance is between 63 and 69 mm or approximately 2.6 in.

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

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

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

VIEWING PHOTOGRAPHS STEREOSCOPICALLY



The apparent depth to the object A can be changed by changing the spacing of the images

Suppose that while a person is looking at object **A,** a transparaent medium containing image mark **a_1** and **a_2** is placed in front of the eyes as shown. Assume further that the image marks are identical in shape to 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.

If the image marks are moved closer together to say **a'_1** and **a'_2**, the parallactic angle increases objects is perceived to be nearer the eyes at **A'**. If the marks are moved farther apart to **a''_1** and **a''_2**, the parallactic angle decreases and the brain receives an impression that the object is farther away at **A''.**

The phenomenon of creating the three dimensional or stereoscopic impressions of objects can be achieved through photographically.

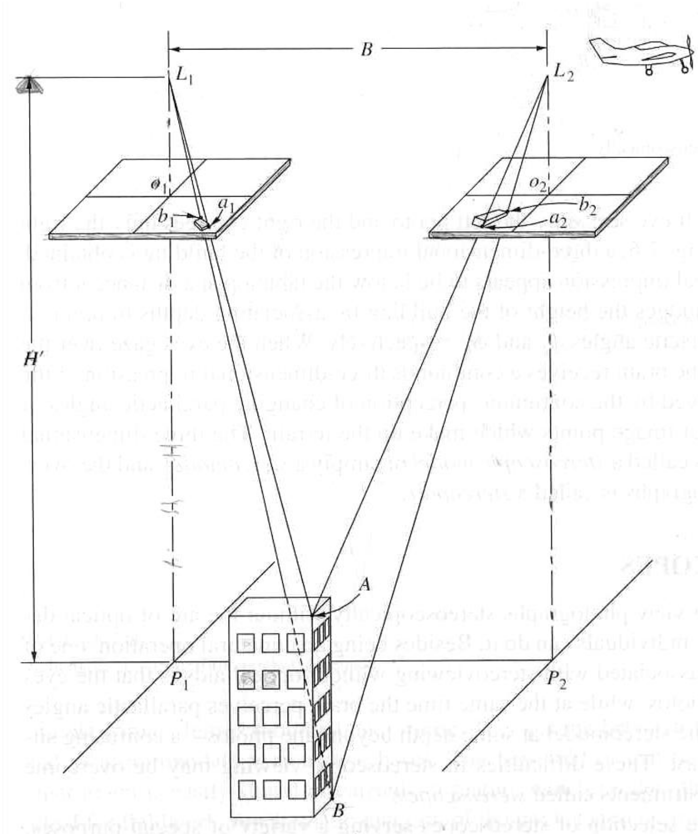


FIGURE 7-5
Photographs from two exposure stations with building in common overlap area.

A pair of aerial photographs is taken from exposure station **L_1** and **L_2** so that the building appears on both photos.

Flying height above ground is **H'** and the distance between the two exposures is **B,** the air base.

Object point A and B at the top and bottom of the building are imaged at a_1 and b_1 on the left photo and at a_2 and b_2 on the right photo.

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

The brain judges the height of the building by associating depths to points A and B with the parallactic angles ϕ_a and ϕ_b respectively.

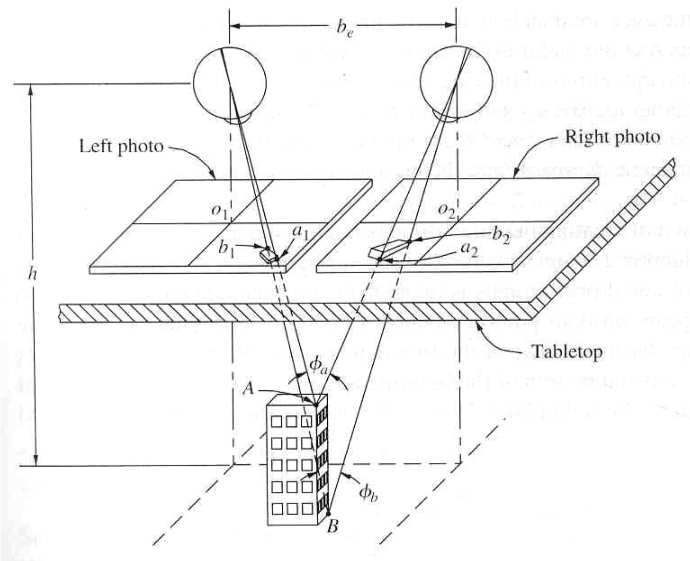


FIGURE 7-6
Viewing the building stereoscopically.

When the eyes gaze over the area entire overlap area, the brain receives a continuous three dimensional impression of the terrain. The three dimensional model thus formed is called a stereoscopic model or simply **stereomodel** and the overlapping pair of photograph is called a **stereopair.**

Eye base : the distance between the optical axes of the two eyes (l&r) is called eye base.

Air base: the distance between two subsequent exposures of aerial photograph is called air base.

Stereo model or stereoscopic model: the three dimensional model formed either using overlapping pair of aerial photographs / terrain photographs / satellite images is called stereo model.

Stereo pair: the overlapping pair of aerial photographs is called a stereopair.

Principal point: the point in the focal plane where a line from the rear nodal point of the camera lens and perpendicular to the focal plane intersects the focal plane = photo centre.

Conjugate principal point : locations of principal points of adjacent overlapping photos.

Photographic flight line: the line connecting principal point and conjugate principal point is called the flight line.

Pseudoscopic vision

If the aerial photos are oriented to the eyes reversely (i.e., left photo viewed by right eye and the right photo viewed by left eye), then a pseudoscopic view results, in which ups and downs are reversed.
E.g. Valleys appear as ridges and hills appear as depressions. This pseudoscopic view can be advantageous for tracing drainage patterns, lineaments, structural trends, etc. But normally correct stereoscopic view is desired.

Base Height Ratio – Vertical Exaggeration

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

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

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

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

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

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

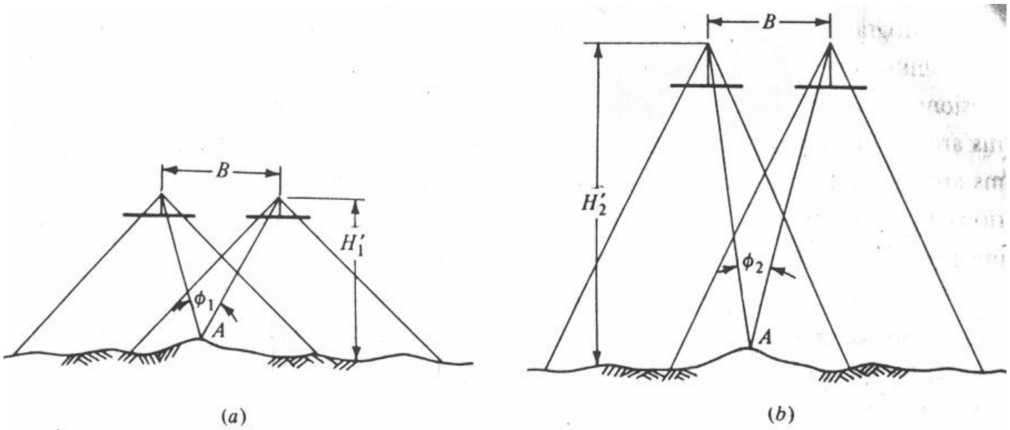


FIGURE 10-6
Parallactic angles increase with increasing B/H' ratios.

The air bases are equal in these two cases. But the focal length and flying height are half those of right side figure

Decreased b/h' ratio can be attained by increasing flying height and now by using a longer focal length camera to compensate the scale reduction, this can be done.

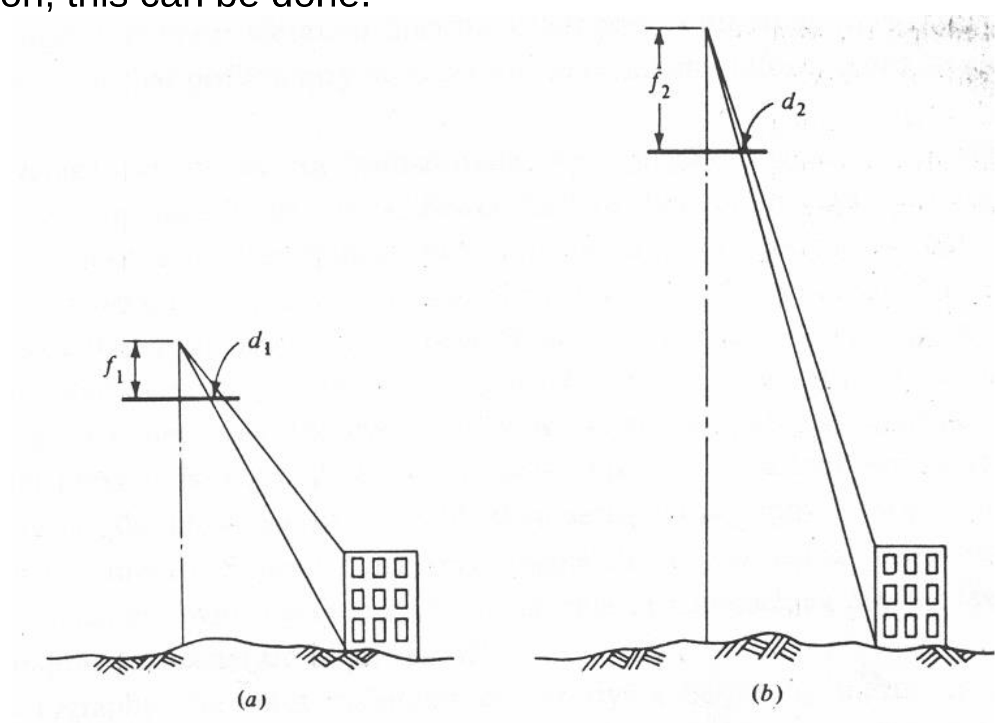


FIGURE 10-7
Reduction in relief displacement is achieved by increasing flying height.

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

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

VERTICAL EXAGGERATION IN STEREOVIEWING

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

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

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

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

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

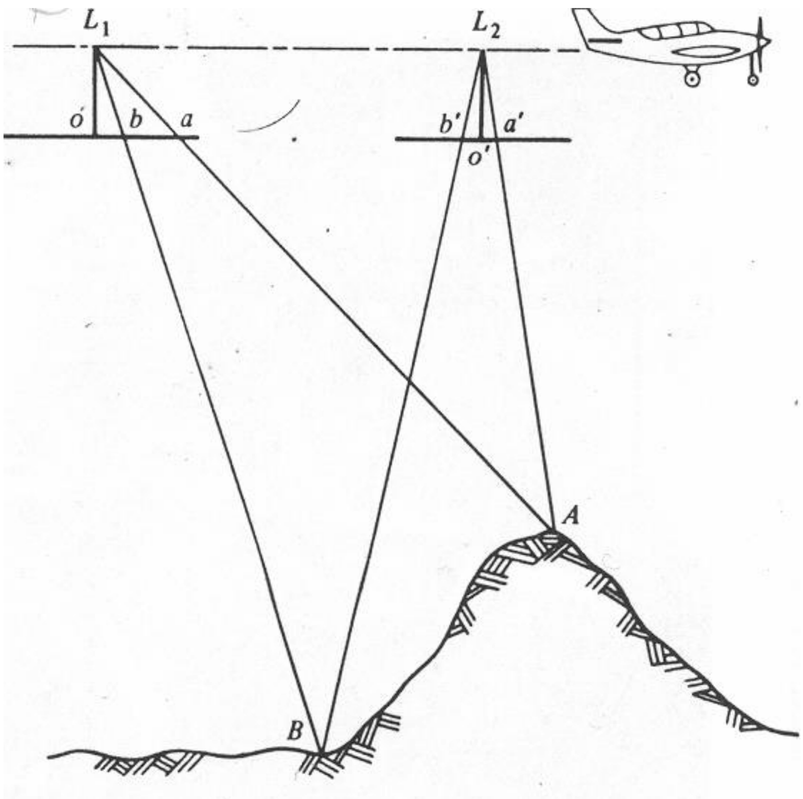
$$V = \frac{B}{H'} * \frac{h}{b_e}$$

STEREOSCOPIC PARALLAX

Stereoscopic parallax or x parallax or parallax is the apparent displacement in the position of an object with respect to a frame of reference caused by a shift in the position of observation.

A simple experiment will serve to illustrate parallax. If a finger is held in front of the eyes and while gazing at the finger the head is quickly shifted from side to side with out moving the finger, the finger will appear to move from side to side with respect to objects beyond the finger. The closer the finger is held to the eyes, the greater will be its apparent shift. This apparent motion of the finger is parallax and it is due to the shift in the position of observation.

An aerial camera exposing overlapping photograph at regular intervals of time obtains a record of positions of images at the instants of exposure. The change in position of an image from one photograph to the next caused by the aircraft's motion is termed **stereoscopic parallax, x parallax or simply parallax**. Parallax exits for all images appearing appearing on successive overlapping photographs.



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

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

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

This lead to two important aspects of stereoscopic parallax such as

1. The parallax of any point is directly related to the elevation of the point
2. Parallax is greater for high points than low points

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

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

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

$$p_a = x_a - x'_a$$

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

Photographic Flight Line Axes for Parallax Measurement

Since parallax occurs parallel to the direction of flight, the photographic x and x' axes for parallax measurement must be parallel with the with the flight line for each of the photographs of a stereopair. The y and y' axes for parallax measurement pass through their respective principal points and are perpendicular to the flight line.

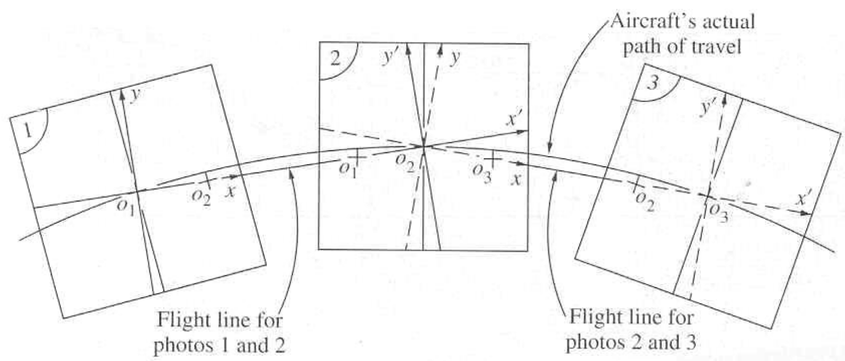


FIGURE 8-4
Flight-line axes for measurement of stereoscopic parallax.

Monoscopic Methods of Parallax Measurement

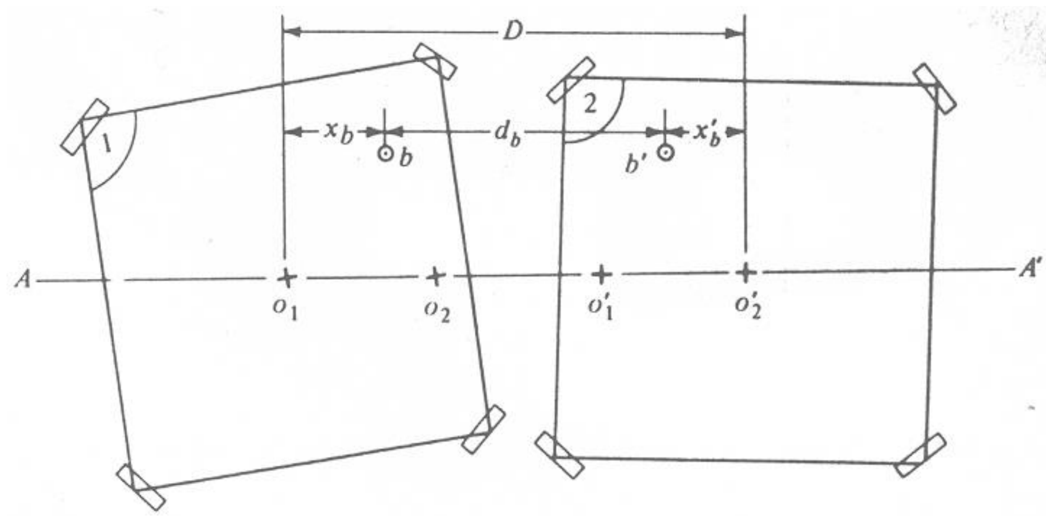
Parallaxes points on a stereopair may be measured either monoscopically or stereoscopically. There are certain advantages and disadvantages associated with each method

In either method, the photographic flight line axes must be carefully located by marking principal points and corresponding principal points.

The simplest method of parallax measurement is the monoscopic approach. By direct measurement of x and x' on the left and right photos respectively.

$$p_a = x_a - x'_a$$

p_a is the stereoscopic parallax of object point A, x_a is the measured photo coordinate of image a on the left photograph of the stereopair and x'a is the photo coordinate of image a' on the right photo. A disadvantage of this method is that two measurements are required for each point.



Another monoscopic approach to parallax measurement is to fasten the photographs on a table. In this method the photographic flight lines o_1 o_2 and o'_1 o'_2 are marked carefully. A long straight line AA' is drawn. D – distance between the two principal points. d is distance between its images on left and right photo. The parallax of point B is

$$p_b = x_b - x'_b$$

or

$$p_b = D_b - d_b$$

Only single measurement required.

Principle of Floating Mark

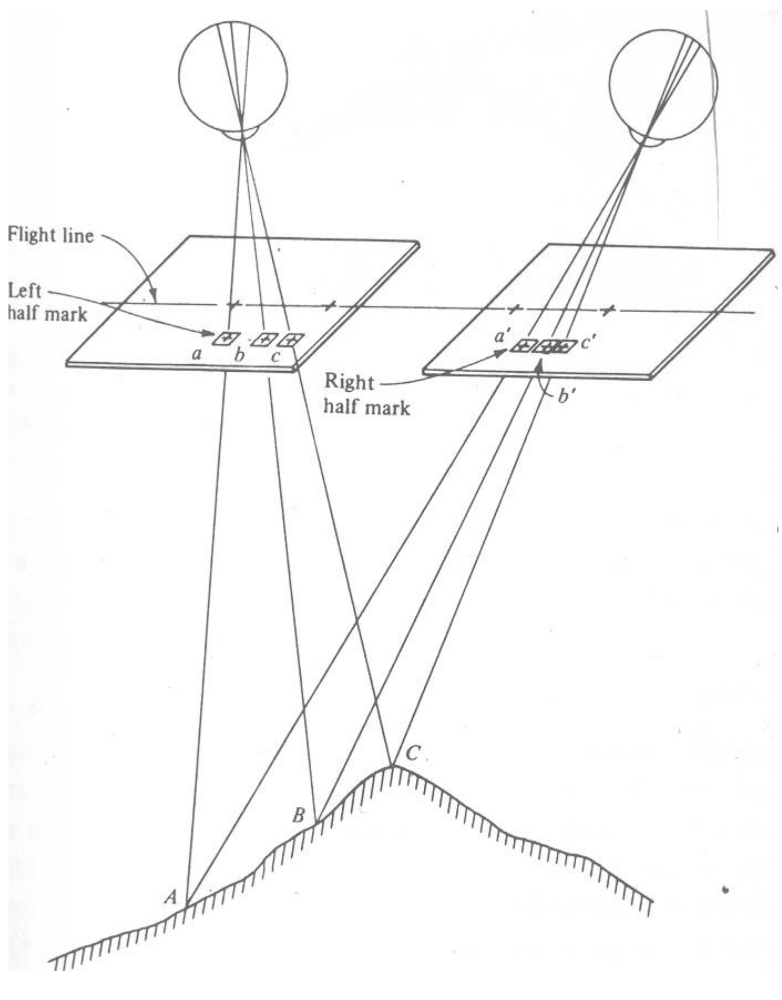
Parallaxes of points can be measured with speed and accuracy through viewing stereoscope.

Stereoscopic measurement of parallax makes use of the principal of the floating marks.

Floating marks – two small identical marks etched on clear glass called 'half marks' placed over the photos on a particular point to be measured and moved / shifted in position until they fuse together into a single mark.

If the half marks are moved closer, then the parallax is increased and the fused mark appears to rise.

If the marks are moved apart, parallax is decreased and the mark appears to fall.



The Principle of Floating Mark

Stereoscopic Methods of Parallax Measurement

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

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

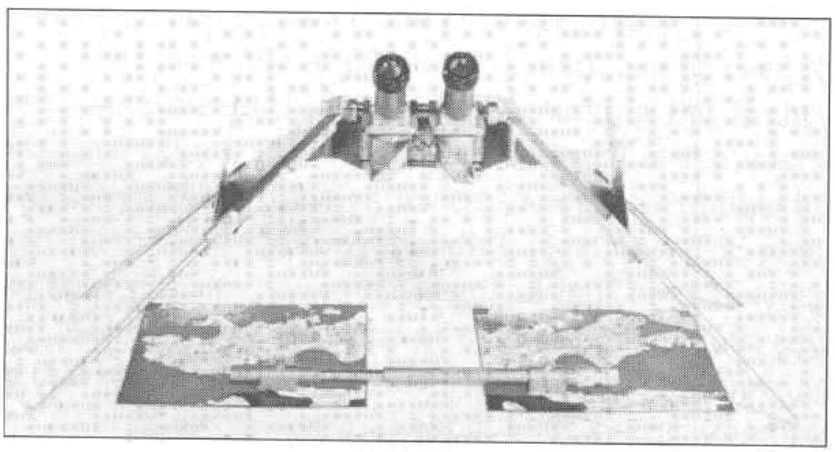


FIGURE 8-9
Wild ST-4 mirror stereoscope with binocular attachment and parallax bar. (*Courtesy LH Systems, LLC.*)

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

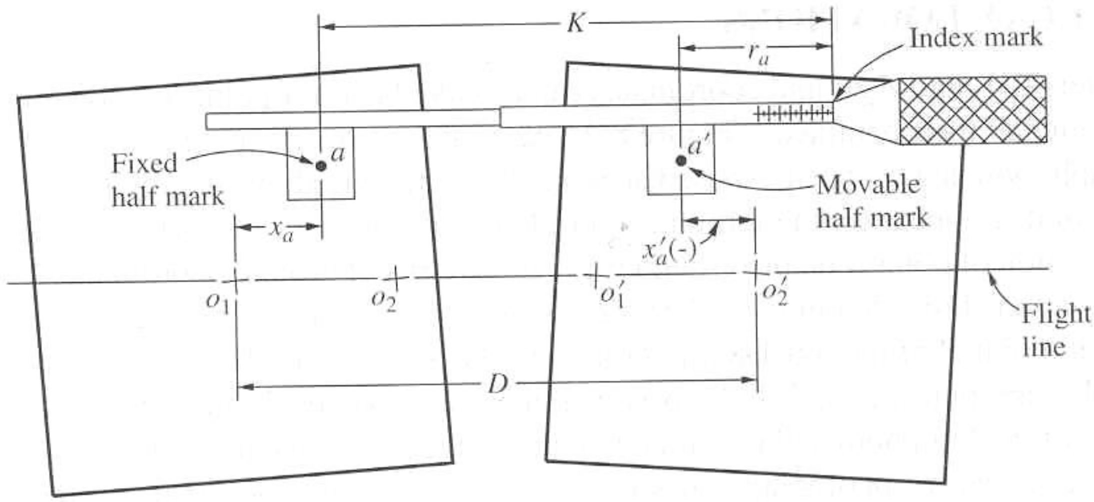


FIGURE 8-10
Schematic diagram of the parallax bar.

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

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

The parallax of point A is

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

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

$$p_a = C + r_a$$

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

$$C = p + r$$

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

Parallax Equation

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

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

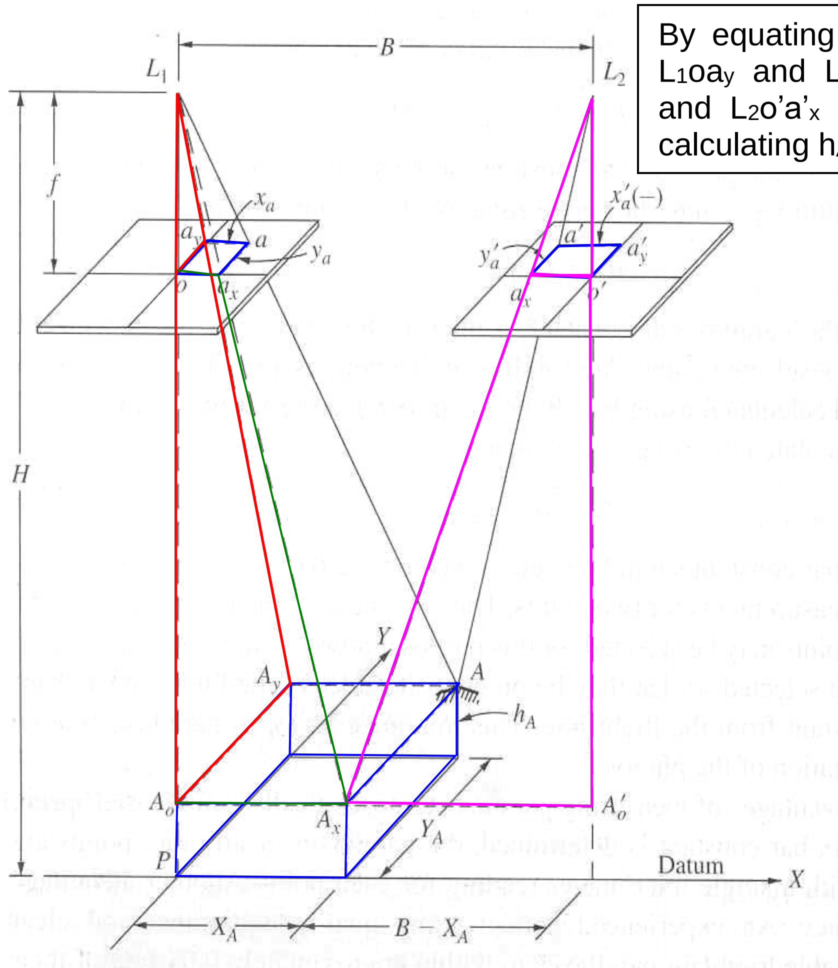


FIGURE 8-11
Geometry of an overlapping pair of vertical photographs.

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

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

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

Images of object point A appear on the left and right photos at a and a' respectively. The ground coordinate of A is X_A and Y_A and its elevation above ground is h_A. The XY ground axis system has its origin at the datum principal point P of the left hand photograph. The X axis is the x and x' fight axes. The Y axis passes through the datum principal point of the left photo and is perpendicular to the X axis.

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

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

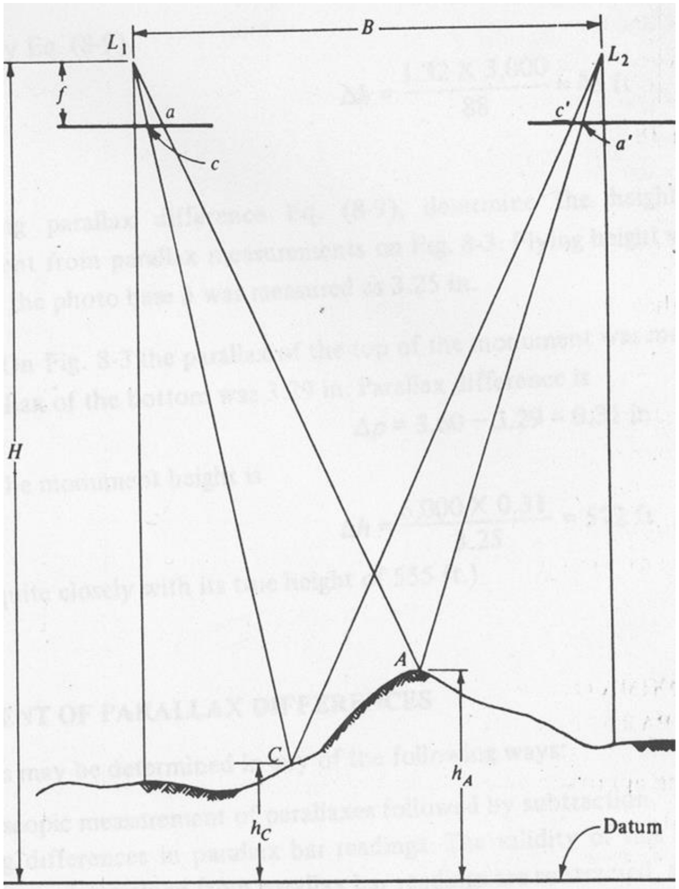
$$X_A = B \frac{x_a}{p_a}$$

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

h_A is the elevation of point A above datum, H is the flying height above datum, B is the air base, f is the focal length of the camera. p_a is the parallax of point A, X_A and Y_A are the ground coordinates of point A, x_a and y_b are the photo coordinates of point 'a' measured with respect to flight line axes on the left photo.

These equations are called **parallax equations**.

Elevations by Parallax Differences



Parallax differences between one point and another are caused by different elevation of two points. While parallax serves to define the relationship of stereoscopic parallax to flying height, elevation, airbase and camera focal length, parallax differences are more convenient for determining elevations.

Object point C is a control point whose elevation h_c above datum is known. The elevation of object point A is desired. Parallaxes of both points can be expressed as

$$p_c = \frac{fB}{H - h_C} \qquad p_a = \frac{fB}{H - h_A}$$

The differences in parallax $p_a - p_c$ obtained by subtracting above two equations and let $p_a - p_c$ equal Δp.

From the above two equation, the following expression for elevation h_A is obtained

$$h_A = h_C + \frac{\Delta p\,(H-h_C)}{p_a}$$

Approximate Equation for Height of Objects from Parallax Differences

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

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

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

h_A**:** Height of the point A above ground
Δp: = pa – pc is the difference in parallax between the top of the feature and the ground
H : is the flying height above ground
b: is the photo base for the stereopair

The parallax difference between the top and bottom of a tree is measured as 1.3mm on a stereopair of photos taken at 915 m above ground. Average photo base is 88.2 mm. How tall is the tree?

$$h_A = \frac{\Delta p H}{b+\Delta p} \qquad h_A \approx \frac{\Delta p H}{b}$$

PHOTO MOSAICS & AERIAL PHOTO RADIAL TRIANGULATION

Mosaics:

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

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

Uses of Mosaics:

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

Disadvantages:

1. Not a true planimetric representation and
2. Scale variations – rectification does not remove the effect of topographic relief.

Types of Mosaics:

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

1. Photo indexing or index mosaics

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

Overlap of photos are not trimmed so that the indexing numbers such as

➔ Flight line
➔ Roll number and
➔ Photo numbers are clearly visible.

The primary use

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

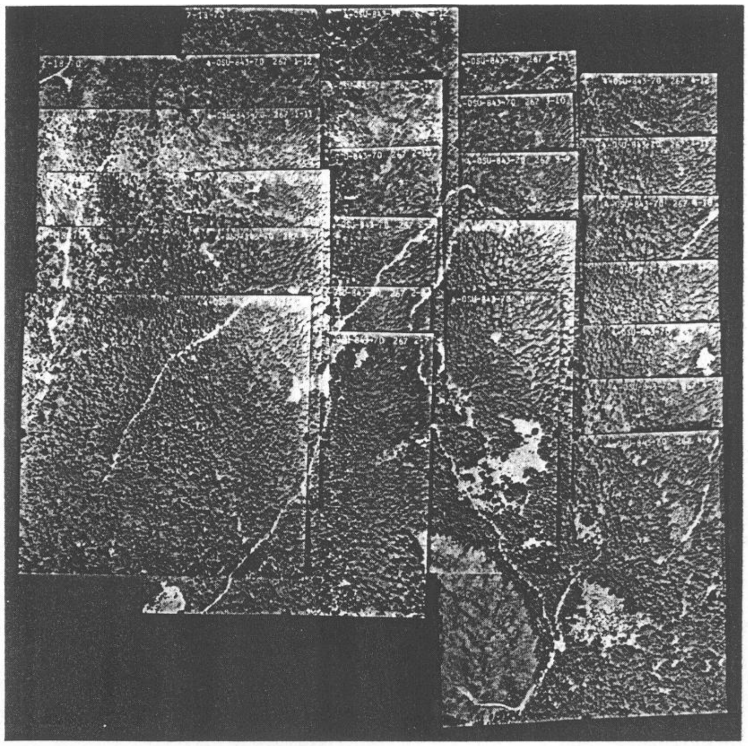


Fig.1 Index Mosaic

2. Strip Mosaic:

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

May be controlled, uncontrolled or semicontrolled.

3. Controlled Mosaic

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

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

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

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

The rectified photo will have

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

4.0 Uncontrolled mosaic

Prepared by simply matching the image details of adjacent photos.

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

5.0 Semicontrolled mosaic:

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

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

6.0 Temporary Mosaic:

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

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

7. Orthophoto Mosaic:

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

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

AERO TRIANGULATION

Aerotriangulation is the term most frequently applied to the process of determining the X, Y and Z ground coordinates of individual points based on photo coordinate measurements

Phototriangulation is a general term as it can be used for terrestrial and aerial photos.

Aerotriangulation is used extensively for many purposes. One of the principal applications lies in extending or densifying ground control through strips or blocks of photos for use in subsequent use in photogrammetric operations is called bridging.

Compilation of topographic maps with stereo plotters is an excellent example to illustrate the value of triangulation

Atleast minimum three horizontal and four vertical ground control points are needed in each stereo model. For larger mapping project, more number of ground control points needed. The cost of establishing the control points is very high if it is done exclusively through field survey.

Much of the more control is now established through aero triangulation with limited network of field surveyed control points and at a substantial cost saving.

Advantages of Aerotriangulation

- ➔ Most of the work is done under laboratory conditions
- ➔ Filed surveys in difficult areas such as marshes, extreme slopes and hazardous rock formations can be minimized
- ➔ Accuracy of field surveyed control is verified during the aerotriangulation

Methods of Aerotriangulation may be classified in to three

- ➔ Analog
- ➔ Semianalytical
- ➔ Analytical

Early analog procedures involved manual interior, relative and absolute orientation of the successive models of long strips of photos using stereoscopic plotting instruments having several projectors

Later, universal stereoplotting instruments were developed which enabled this process to be accomplished with only two projectors.

Semianalytical aerotriangulation involves manual interior and relative orientation of stereomodels within a stereoplotter, followed by measurement of model coordinates. Absolute orientation is performed numerically – hence the term semianalytical aerotriangulation

Pass Points for Aerotriangulation

Pass points for Aerotriangulation are normally selected in the general photographic locations. The points may be images of natural, well defined objects that appear in the required photo areas, but if such points are not available, pass points may be artificially marked by using a special stereoscopic point-marking device.

The points d, e and f appear on three successive photos. Each of these points may be located quite arbitrarily on one photograph, which is usually centre of the photos

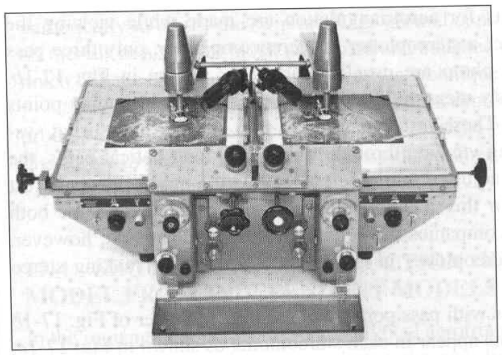


FIGURE 17-2
Wild PUG-4 stereoscopic point-transfer instrument. (*Courtesy LH Systems, LLC.*)

The Wild PUG-4 point transfer instrument is a device specially for marking corresponding pass points. With this instrument, a stereopair of diapositives is placed on illuminated stage plates.

The diapositives are viewed stereoscopically through binocular viewing system which has a reference half marks. By means of slow motion screws, the diapositives can be adjusted slightly in the x and y direction. With the help of the half marks points can be transferred.

As marking of points are generally by a holes or emulsion, it will be the permanent marks. So transfer points must be done with extreme caution.

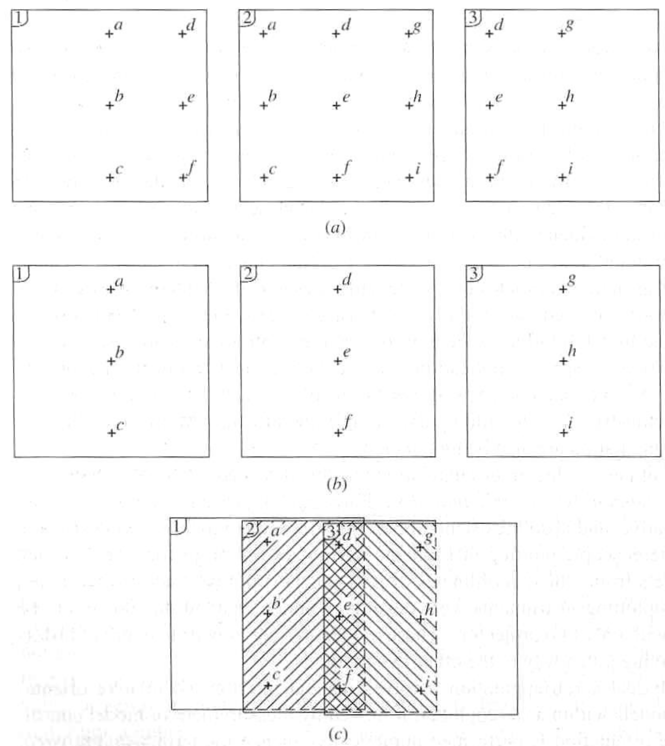


FIGURE 17-1
(*a*) Idealized pass point locations for aerotriangulation. (*b*) Pass point locations for stereoscopic measurement. (*c*) Locations of pass points in two adjacent stereomodels.

When point measurements for aerotriangulation made, only three pass points near the y axis of each photo are usually marked (fig.b). The stereocomparators simultaneously measure photo coordinates of corresponding points on a stereopair of disapositives.

Semianalytical Aerotriangulation

Semianalytical aerotriangulation, often referred to as independent model aerotriangulation, is a partly analog and partly analytical procedures that emerged with the development of computers.

It involves manual relative orientation in a stereoplotter of a each stereomodel of a strip or lock of photos.

After the models have been measured, they are adjusted to sequential or a simultaneous method.

In the sequential approach, contiguous models are joined analytically, one by one to form a continuous strip model and then absolute orientation is performed numerically to adjust the strip model to ground control.

In the simultaneous approach, all models in a strip or block are joined and adjusted to ground control in a single step.

Sequential construction of a strip model from independent models

In the sequential approach, each stereopair of a strip is relatively oriented in a stereoplotter, the coordinate system of each model being independent of the others.

When relative orientation is completed, model coordinates of all control points and pass points are read and recorded. This done for each stereomodel in a strip.

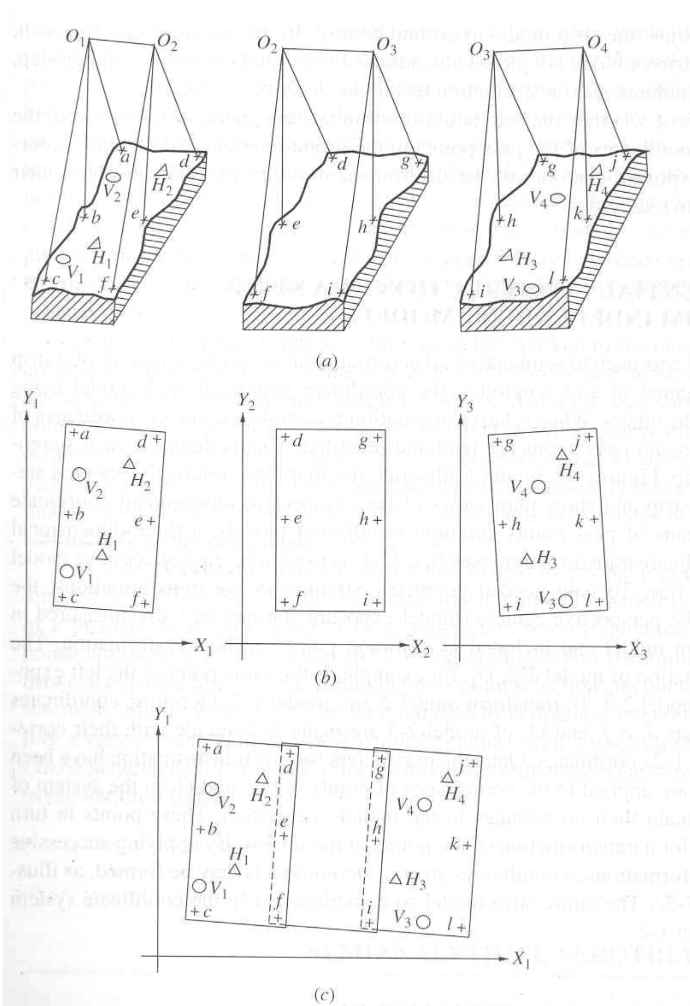
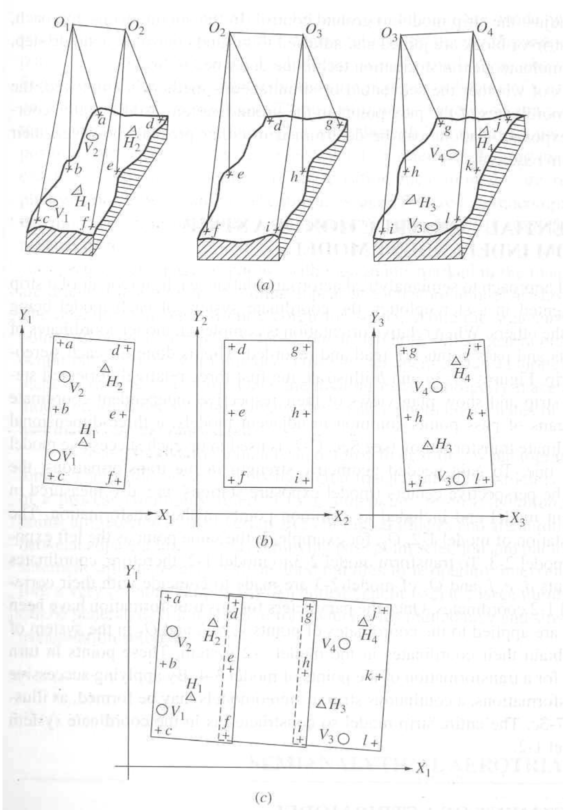


Fig.a&b illustrate the first three relatively oriented stereomodels of a strip and show plan views of their respective independent coordinate systems.

By means of pass points common to adjacent models, a three dimensional conformal coordinate transformation is used to tie each successive model to the previous one.

For geometric strength in the transformation, the coordinates of the perspective centres (model exposure station) are also measured in each model and included as common points in the transformation



The right exposure station of model 1-2, O2, for example, is the same point as the left exposure station of model 2-3.

To transform model 2-3 to model 1-2, therefore coordinates of common points d,e,f and O2 of model 2-3 are made to coincide with their corresponding model 1-2 coordinates.

Once the parameters for this transformation have been computed, they are applied to the coordinates points g,h,I and O3 in the system of model 2-3 to obtain their coordinates in the model 1-2 system.

These points in turn become control for transformation of the points of model 3-4.

By applying successive coordinate transformation, a continuous strip of stereomodels may be formed as shown in fig.c.

The entire strip model so constructed is in the coordinate system defined by model 1-2.

Adjustment of a strip model to ground

After a strip model has been formed, it is numerically adjusted to the ground coordinate system using all available control points.

If the strip is short, i.e., up to about four models, this adjustment may be done using a three dimensional conformal coordinate transformation.

This requires that a minimum of two horizontal control points and three vertical control points be present in the strip

More control than the minimum is desirable.

If the strip is long, a polynomial adjustment is preferred to transform model coordinates to the ground coordinate system.

In the short strip illustrated in Fig.c, horizontal control points H1 to H4 and vertical control points V1 to V4 would be used in three dimensional conformal coordinate transformation to compute the ground coordinates of pass points a through l and exposure stations O1 through O4.

Three dimensional conformal coordinate transformation involves converting from one three dimensional system to another. In the transformation, true shape is retained.

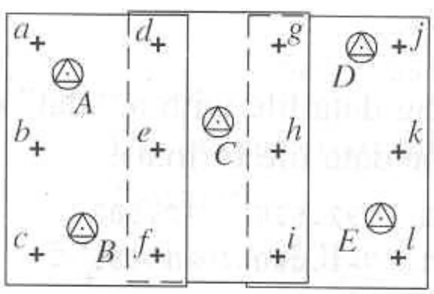


FIGURE 17-4
Configuration of pass points and control for semianalytical aerotriangulation of Example 17-1.

UNIT: 3 & 4 Digital Photogrammetry I: Data sources and input processes (Digital Cameras, Operation principles, Scanners for analog to digital conversion) - Digital Photogrammetric techniques & processes (Digital Photogrammetric equipment, Stereo viewing, image measurements, co-ordinate systems, image transformation, image orientation)

Digital Photogrammetry

Photogrammetry can be regarded as "the science and technology of obtaining spatial measurements and other geometrically reliable derived products from photographs" (Kiefer, Lillesand, 2000).

Photogrammetry is the process of deriving metric information about an object through photo measurements with the advent of computing and imaging technology,

Contemporary definition: The art and science of tool development for automatic generation of spatial and descriptive information from multi-sensory data and/or systems.

Applications:

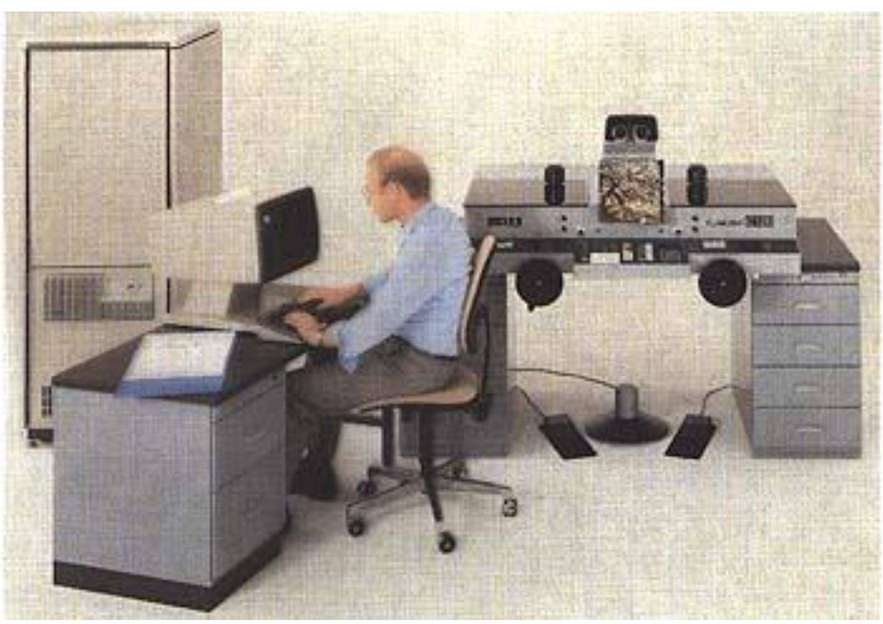
- ➔ Reconnaissance.
- ➔ Production of Topographic Maps.
- ➔ DEM Generation.
- ➔ Close Range Photogrammetry:
    - ❖ Precision survey of buildings and engineering objects.
    - ❖ Documentation of historical buildings.
    - ❖ Medical applications.
    - ❖ Mapping of roads and nearby objects (terrestrial mobile mapping systems).

Analog Photogrammetry

Using optical, mechanical and electronical components, and where the images are hardcopies. Re-creates a 3D model for measurements in 3D space.

Analytical Photogrammetry

The 3D modelling is mathematical (not re-created) and measurements are made in the 2D images.



Digital Photogrammetry or Softcopy Photogrammetry

Analytical solutions applied in digital images. Can also incorporate computer vision and digital image processing techniques.

Digital photogrammetry is applied to digital images that are stored and processed on a computer.

Digital photogrammetry is sometimes called softcopy photogrammetry.

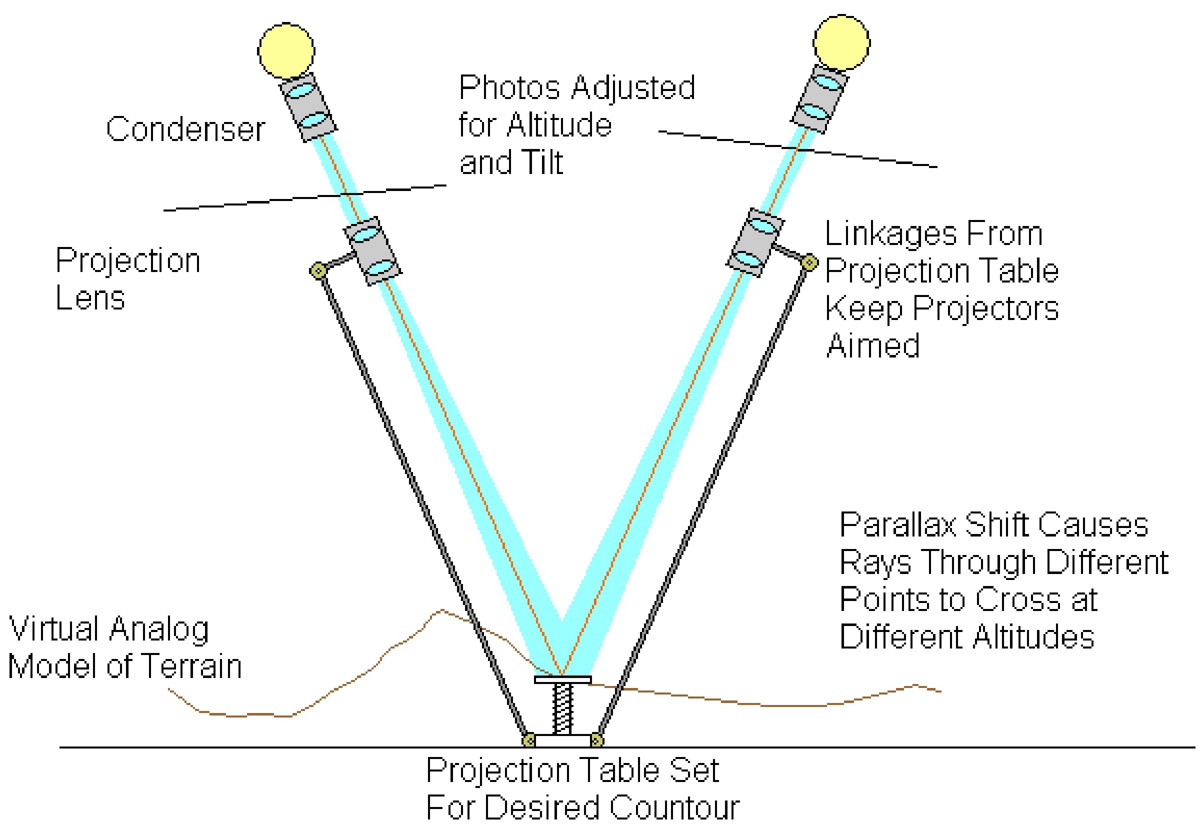
The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media.

ANALOGUE PHOTOGRAMMETRY

Stereoscopic Plotting Instruments

- **Stereoscopic plotting instruments (commonly called stereoplotteres or simply plotters) are designed to provide rigorously accurate solutions for object point position from their corresponding image position on overlapping pairs of photos.**

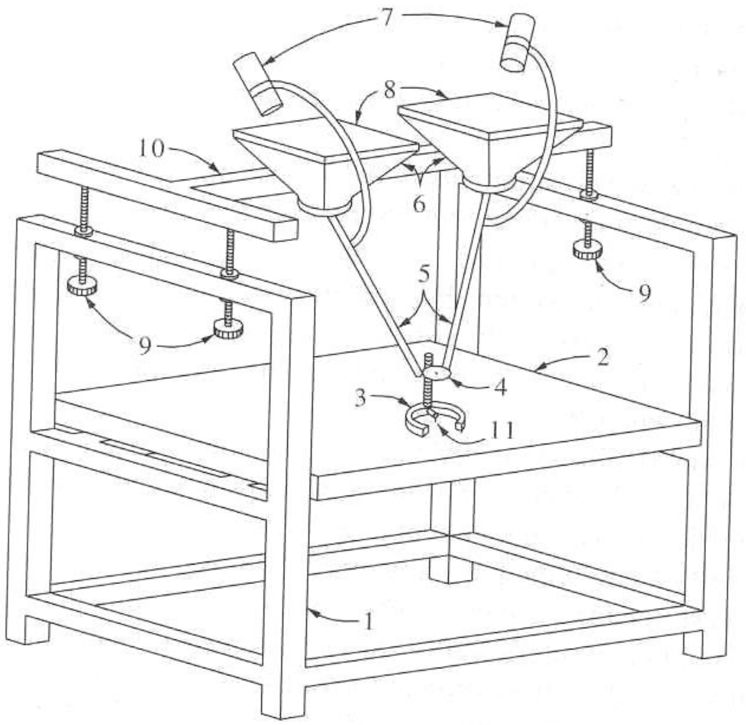
- **A stereoplotters is essentially a three dimensional digitizer, capable of producing accurate X,Y and Z object space coordinates when properly oriented and calibrated.**



DIRECT OPTICAL PROJECTION STEREOPLOTTERS

COMPONENTS

The principal components of a typical direct optical projection stereoplotters are



1) Main frame: This supports the projectors tightly in place, threrby maintaining orientation of a stereomodel over a long period

2) Reference table: A large smooth surface which serves as the vertical datum to which model elevations are referenced and which also provides the surface upon which the manuscript map is compiled.

3) Tracing table: platen and tracing pencil are attached.

4) Platen: the viewing screen which also contain the reference mark.

5) Guide rods: Which drive the illumination lamps causing projected rays to be illuminated on the platen and stereomodel viewed.

6) projectors, 7) illumination lamps, 8) diapositives

9) leveling screws: which may be used to tilt the projectors in absolute orientation, 10) projector bar: to which the projector attached, 11) tracing pencil, which is located vertically beneath the reference mark platen.

PROJECTION SYSTEMS

In the projection system of direct optical projection stereoplotters, dispositives of a stereopair are placed in projectors and illuminated from above. Light rays are projected through the projector objective lenses and captured below on the reflecting surfaces of platen. The projection systems of this type be operated in dark room.

Stereoplotter projector similar to ordinary slide projectors, differing primarily on their optical precision, physical size, etc.

Since projection takes place through an objective lens, it must be satisfied the lens formula in order to obtain the sharply focused stereomodels.

The lens formula is

$$\frac{1}{f'} = \frac{1}{p} + \frac{1}{h}$$

f is the focal length, p is the principal distance of the projectors (distance from diapositive image plane to upper nodal point of the projector lens), h is the projection distance (distance from lower nodal point of the lens to the plane of optimum focus)

To create the relative angular relationship of two photographs exactly as they were at the instants of their exposures, it is necessary that the projectors have rotational and translational movement capabilities.

These motions, six in number for each projector

Three of the movements are angular rotations about each of three mutually perpendicular axes. X rotation called omega or tilt, y rotation called phi or tip, z rotation called kappa

The three of the other movements are linear translations along each of the three axes such as X translation, Y translation, Z translation

Projector of this type illuminate only a small area of the diapositive at a time. This type of illumination system consists of a small, narrow angle of light source which illuminates a circular area on the diapositive of only 4 cm. When projected through the objective lens, an area slightly larger than the platen. Using the guide rods, viewing the entire stereo model

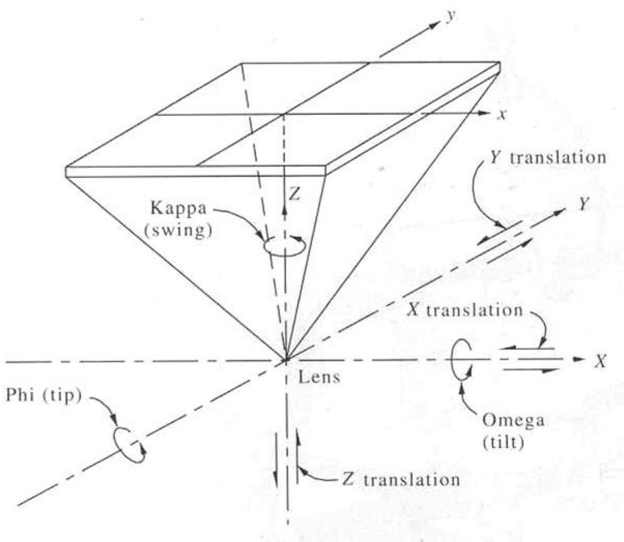


FIGURE 12-3
The six basic projector motions.

The Kelsh plotter utilizes this method of illumination. This instrument combines a nominal principal distance of 152 mm with an optimum projection distance of 760 mm, a combination of which provides a nominal enlargement ratio of 5 from diapositive scale.

Data Capturing

Digital photogrammetry utilizes digital imagery as an input.

The rapid technological advances in computer hardware and software has motivated the shift from analog to digital imagery.

How can we get digital images?

- ❖ Scanning analog images.
- ❖ Using digital camera.

Digital Photogrammetric Equipments and Processes

A DPW combines computer hardware and software to allow photogrammetric operations to be carried out on digital image data.

DPW, DPWS, DPS

Digital Photogrammetric Workstation: "Hardware and software to derive photogrammetric products from digital imagery using manual and automated techniques." (ISPRS)

Typically, a DPW consists of a graphics workstation with, in most but not all cases, a stereo viewing device and a 3-D mouse.

DPWS System Manufacturers

Photogrammetry : Z/I, Leica, ESPA, Geosystems, Inpho…

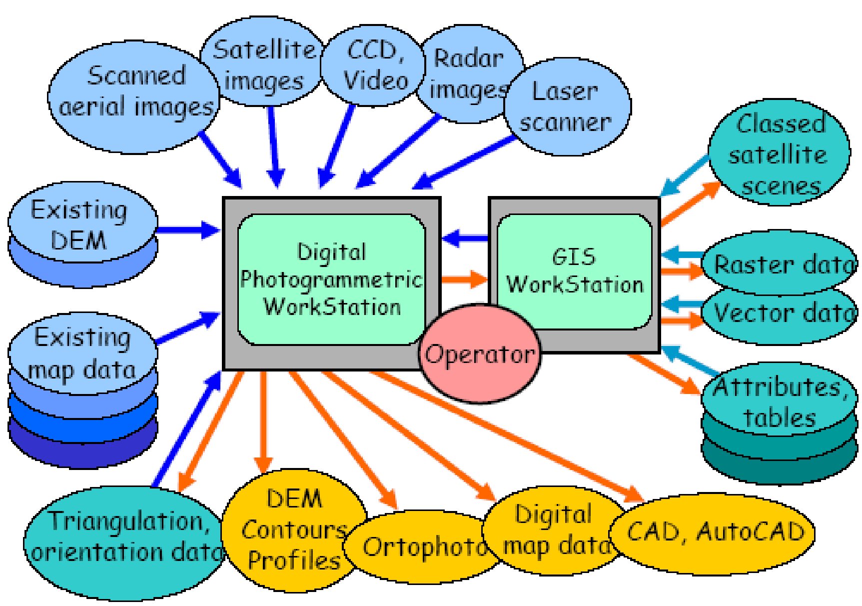
Remote Sensing: I2S, ERDAS, PCI, ERMapper, TNTmips, Vexcel…

Digital Cartography: DAT/EM, ISM…

Military: Helava, Intergraph, Automatrics…

University : DMS, DVP, VirtuoZo...

DPWS "in the center"



COMPUTER SYSTEM REQUIREMENTS:

- ➔ Central Processing Unit (CPU). Should be fast!
- ➔ Operative System (OS). 32-bit real-time processing.
- ➔ Main Memory (RAM). 256 Mb is a minimum.
- ➔ Storage. Hard disc of several Gb
- ➔ Graphics Display System. Graphics card and monitor(s).
- ➔ 3D Viewing System
- ➔ 3D Measuring Device
- ➔ User Interface. GUI, keyboard, mouse, trackball,

Monitor requirements

- 24 bit monitor for viewing colour images.
- 120 Hz for good refresh rate with sequential stereo viewing.
- 1-2 million pixels required (minimum). 1280x1024. The resolution may determine the accuracy.
- One (large) or two monitors. 21"+
- More than two images can be shown simultaneously.
- Overlays of graphic (map data) in 2D or 3D.

Stereo Viewing System

The computer to serve as a stereo workstation, additional hardware is required to enable the operator to see the left image with the left eye and the right image with the right eye.

There are many ways to provide stereo viewing, including

1. Polarizing filters
2. Alternating shutters
3. A split screen with a simple stereoscope,
4. Anaglyph (red/green display),

In the **polarizing filters**, a computer monitor is fitted with an active polarizing screen, while operator wears a simple pair of spectacles consisting of orthogonally polarizing filters.

The active polarizing screen has the capability of alternating the orientation of its polarity between horizontal and vertical (120 times per second).

The computer display has the capability of alternatively displaying the left and right images at same rate.

The spectacles are constructed so that the filter over one eye is oriented vertically and the other filter oriented horizontally.

At the particular instant, the polarity of the left filter of the spectacles has the same orientation as that of the screen, the left image passes through to the operator’s left eye, while right eye see nothing and the same way for the right image.

This alternating display of left and right images with synchronized alteration of the screen, the left image set with left eye and right image set with right eye and thus stereomodel will evolved.

The DPW770 system by LH systems having above setero viewing tools.

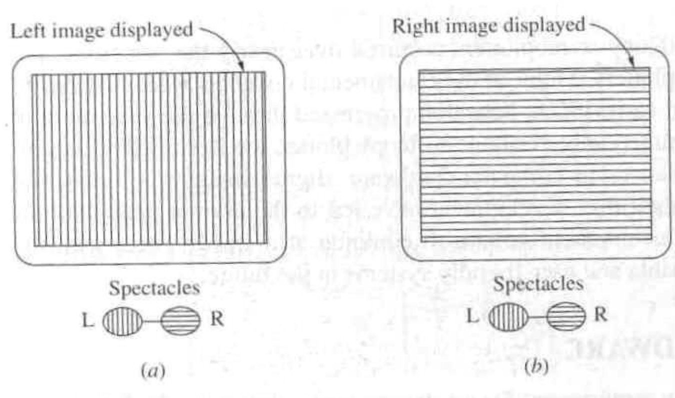


FIGURE 15-1
Stereoviewing principle of the active polarizing screen display.

A second approach of **alternating shutters** is to stereoviewing uses a display monitor which shows alternating left and right images at 120 Hz, along with special viewing glasses that have liquid crystal display (LCD) masks which alternate at the same rate.

The LCD glasses receive signals transmitted from an infrared device, mounted on top of the computer which controls the alternating left and right masking functions.

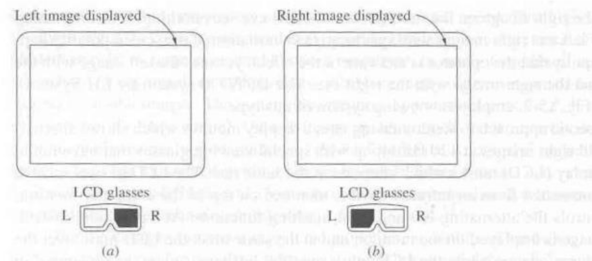


FIGURE 15-3
Stereoviewing principle of the alternating LCD shutter display.

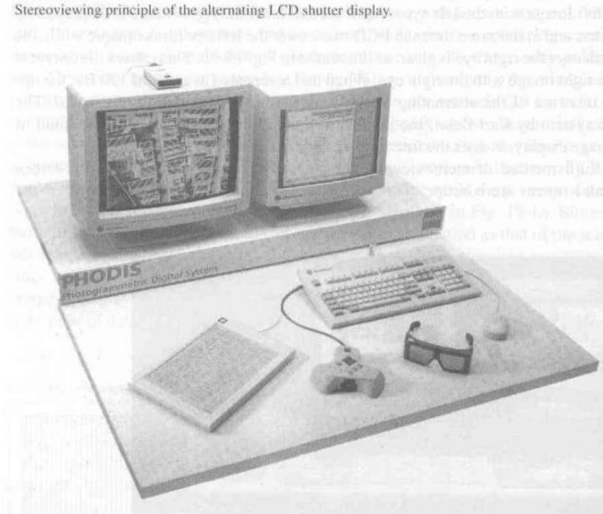


FIGURE 15-4
Zeiss PHODIS ST digital stereo workstation. (*Courtesy Carl Zeiss, Inc.*)

At the particular instant, the left image is displayed on the monitor, and at the same time, the LCD mask over the right eye turns opaque, while LCD mask over the left eye is clear

Since the right eye is blocked and the left eye is unobstructed, the operator sees the left image with left eye.

The same way, while the right image displayed on monitor, the LCD mask over the left eye turns opaque, so right eye sees only right image.

When this is repeated at the rate of 120 Hz, the operator is unaware of the alternating images, and the proper stereoview is crated.

The PHODIS system by Carl Zeiss, Inc., having the above type of stereo viewing method.

A third method of stereoviewing is a **split-screen display and mirror stereoscope**. The mirror stereoscope is mounted in front of the computer monitor and the operator views the monitor through it.

Since the mirror stereoscope diverts the optical paths to the operator eyes, the left eye sees only the left image and the right eyes sees only the right image and thus stereomodel is created.

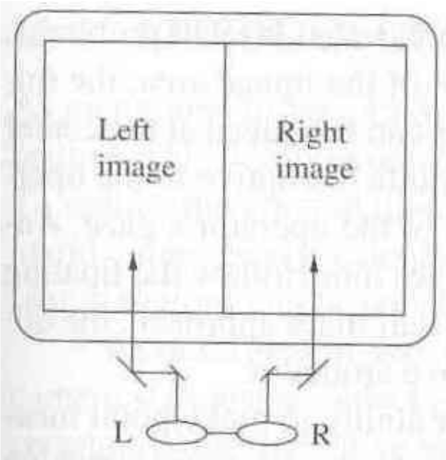


FIGURE 15-5
Stereoviewing principle of the split-screen display.

3D Viewing

The human brain requires separation of stereoimages in order to get a 3D view.

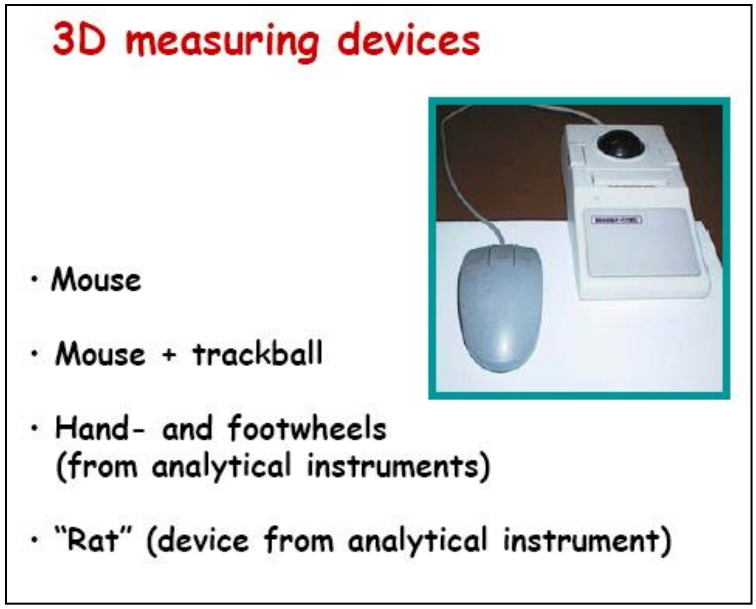
Separation method	Practical implementation
Spatial	2 monitors + stereoscope 1 monitor (split screen) + stereoscope 2 monitors + passive polarisation
Spectral	Anaglyphic Passive polarisation
Sequential	Alternated synchronised display, active polarisation or LCD

3D Viewing – pros and cons

Implementation	Advantage / Disadvantage	
2 monitors	- Bulky - Only one observer	
Split screen + stereoscope	- 50% Field of Vision - Only one observer	
Anaglyphic	- No colour images - Bad transmission	+ Several observers + Very cheap
Passive polarisation	- 50% resolution - High initial cost	+ Several observers + Cheap glasses
LCD and Active polarisation	- 50% resolution - Expensive glasses - Flickering	+ Several observers

Image Measurements

In the stereoplotters, manual image measurements are taken by set the floating mark on the desired features.



On a soft copy stereoplotter, a floating mark consists of left and right half marks which are superimposed on the left and right images respectively.

An individual half mark consists of a single pixel or small pattern of pixels in the shape of a dot, cross or more complex shape.

The pixels of half mark are set to brightness value which give a high contrast with the background image

When the operator moves the X,Y, or Z control, the positions of the individual half marks move with respect to the background image.

Once the floating mark visually coincides with a feature of interest, the operator can press a button or foot pedal to record the features position.

Two approaches are used for half mark movement: a fixed mark with a moving image or a fixed image with a moving mark.

Orientation Procedures

The orientation procedures in DPW are similar fashion to that of analytical plotters. The same three steps of interior, relative and absolute orientation must be performed.

Key difference is the soft copy systems allow for greater automation in processes.

Interior orientation is primarily consists of pointing on the fiducial marks can be done directly under operator control, or by pattern matching methods. In the pattern matching method, attempt to find the position of fiducial marks by matching the standard image fiducial points (template).

Once all the fiducials have been located, a two dimensional transformation can be computed to relate image coordinates (row and column) to the fiducial axis system.

Relative Orientation is done by automatic pattern matching. Small aubarrays from the left image in the standard pass point locations are matched with corresponding subarrays from the right image.

Once sufficient number of pass points have been matched (at least six points), a relative orientation can be computed.

In **Absolute Orientation,** three-dimensional measurements must be made on the positions of ground control points which appear in the model.

Since ground control points can have varying shapes and can appear anywhere in the model, they are more difficult to locate by automatic pattern matching techniques. In these cases, manual pointing on the control points is usually done.

At one situation where absolute orientation can automated when a block aerotriangulation has previously performed in the digital images.

Application

The primary products are

1. digital elevation models (DEMs),
2. ortho-rectified images (or ortho-images) and
3. extracted features (vectors).

The secondary products derived from primary products include

1. contour maps (derived from DEMs),
2. image contour maps (ortho-images with contour overlays),
3. image line maps (ortho-images with vector overlays) and
4. 3-D scene models (DEMs with draped images and 3-D features).

DEM Generation

Digital Elevation Model (DEM)

- ➔ Ground elevation information only; Z as a function of XY.

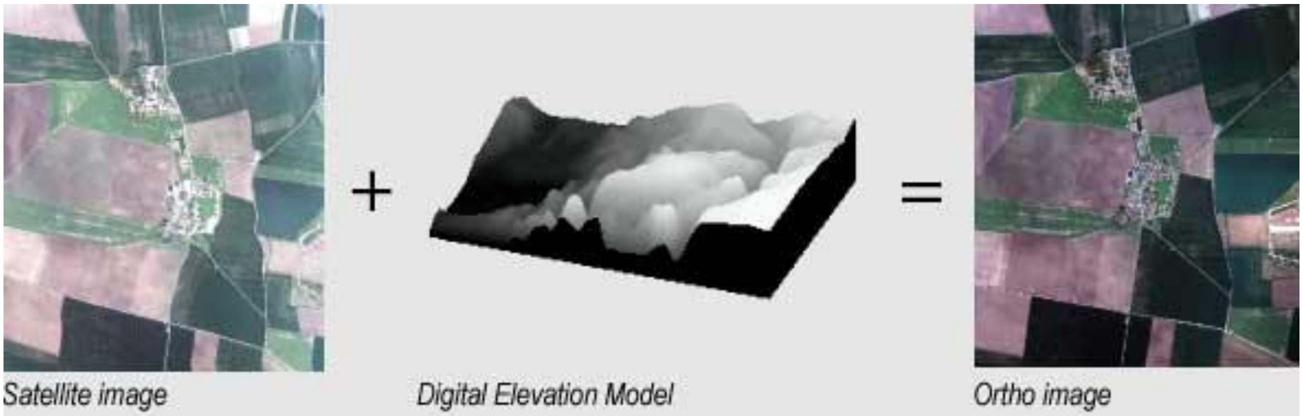
Digital Terrain Model (DTM)

- ➔ Ground elevation + Terrain type information
- ➔ Stores Z (as a function of XY) and terrain type (Geomorphology, lithology, water, forest, etc.) information.

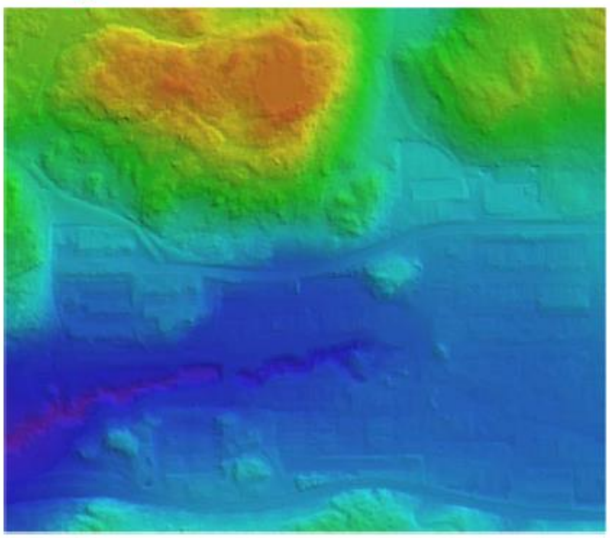
Digital Surface Model (DSM)

- ➔ Stores Z as function of XY, usually the topmost surface.

There is often a lot of confusion between DEM and DTM

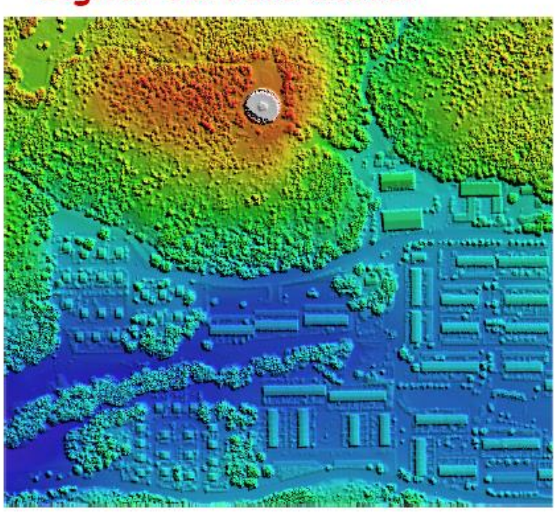


Digital Elevation Model



Digital map with contour lines

Digital Surface Model



Elevation Data Capture

Photogrammetric mapping in Stereo Images

Can produce both DEM, DTM and DSM data

Manual 3D mapping – tedious, but high quality

Automatic matching – fast, but low quality, needs editing.

Laser Scanning (LIDAR)

Faster than photogrammetric mapping - Expensive, but good quality Can produce both DEM, DTM and DSM data Need to reduce data

Ground Survey - Tedious and expensive but high quality. Difficult to get DSM data

Digitize from existing Map data (contours etc.)

Quality depends on original data

In DPWs, users can attempt to do it automatically--a process called image matching that has been one of hottest research topics in the last 10 years. After finding corresponding points by image matching, a DEM can be generated automatically.

Traditionally, with manual DEM generation (measuring elevation point clouds in a stereo viewing mode), the process is extremely labor intensive.

At present, high-end DPWs support automatic or semi-automatic DEM generation functionality.

However, image-matching results still aren't robust in urban core areas (with dense buildings), water bodies, high-relief mountains and areas with poor texture.

Manual editing and quality assurance generally is required after the automated processing.

ORTHOPHOTOGRAPHS AND RECTIFICATION

An orthophoto is a photo reproduction that has been corrected for tilt, topographic displacement and lens distortion

Orthophotos are produced from stereoscopic pairs or triplicates of aerial photographs by a process called differential rectification so that the resulting photographic images are in a correct orthographic position

An orthophoto differs from a standard rectified photograph in that only tilt has been removed from a rectified photo, whereas topographic displacement is also removed in an orthophoto

Ordinary rectification is accomplished by copying the nonrectified print or negative with a camera that is tilted relative to the original negative in such a way that the new photo is free of tilt

Differential rectification as used to produce orthophotos also requires the rephotographing of the original imagery. But, instead of rephotographing the entire image all at once, it is done in very small segments (in thousands for a 9 in x 9 in photo) or by a series of narrow strips.

These segments or strips are all brought to a common scale by keeping the scanning slit continuously in contact with a three dimensional terrain model.

The resulting orthophoto is planimetrically correct which allows one to make accurate measurements of distance, area and direction directly on the orthophoto.

A theoretically perfect orthophoto can be achieved only if each infinitely small point in the stereoscope model is exposed separately.

Orthophotoscopes using scanning slits of about 5mm in size can therefore only approximate a perfect orthophoto.

However, for all practical purposes, this approximation is entirely satisfactory.

Orthophotos are geometrically equivalent to standard line and symbol maps, but instead of lines and symbols they show actual photograph images. Therefore, there is much more detail on an orthophoto.

GENERATION OF ORTHOPHOTOS

The production of an orthophoto involves the conversion of conventional photography by utilizing a double projection orthophotoscope.

The first orthophotoscopes were modified conventional stereoplotting instruments

Today highly specialized equipment such as U.S. Geological survey's model T-64, Gigas-Zeiss Orthoprojector GZ-1, Wild Avioplan OR, Kelch K-320 Orthoscan and other similar models are used.

Photographic Requirements

In some cases existing photography can be used to produce an orthophoto, but a special mission is frequently necessary to produce photography to fulfill all the constrains imposed by equipments and the desired final product.

These constrains include the selection of proper geographical positions for exposure stations, the proper sun angle and film as well as the usual constrains of focal length, flying height, endlap and sidelap.

The Anaglyph Principle

Even though each year brings development if more complicated and sophisticated orthophotoscopes, the basic principle remains the same. Most orthophotos are produced through the use of diapositives and direct opticalnprojection systems that use the analog principle.

The orthophotoscope consists of the two superimposed images of the overlapped portion of a stereoscopic pair of photos.

These superimposed images are produced by double projection optical systems within most orthophotoscopes by placing red and blue filters between the light source and the diapositives – a different coloured filter for each projector. The three dimensional model as viewed through coloured glasses (also red and blue) is projected by the orthophotoscopes on to a film carrier that can be raised and lowered by the operator. The table carries a photographic film (the film plane) that is sensitive only to blue light. When exposed and developed, this film becomes the orthophoto negative.

The scanning Mechanism

Situated directly above the unexposed film is a dark coloured, two-piece, movable curtain with a small slit through which the film is exposed. Surrounding the slit is a small, circular white disc called a platen.

In operation, the operator sees only the portion of the stereo model that is projected onto the platen.

The scanning slit can be moved in both x and y directions to scan entire model

During exposure the film remains stationary with respect with respect to the x and y directions but is raised and lowered along with the curtain by the operator who keep the scanning silt on the ground of the stereo model

When each y scan is complete, the silt us moved its length in the x direction and a new scan line is made. This process is repeated until the entire model is covered.

The y scan is achieved by an electric motor that steadily moves the slit across the film as the operator keeps the scanning slit always on the ground in the model.

A constant scan speed is necessary to ensure uniform exposure of the film. The film being sensitive only to blue light is exposed by the rays from only one of the projectors.

The orthophoto negative is at the same scale as the stereoscopic model. However, enlargement or reductions can be made from the orthophoto negative by conventional photographic mean.

The orthophoto scale will depend on the projected use and desired quality. Orthophotography has its widest acceptance for mapping at scale 1:12,000 and smaller.

Rectification

Rectification is the process of making equivalent vertical photographs from tilted photo negatives.

The resulting equivalent vertical photos are called rectified photographs. The rectified photos theoretically are truly vertical photos and as such they are free from displacement of images due to tilt. However, rectified photograph is still having image displacement and scale variations due to topographic relief.

These relief displacement and scale variation can also removed in a process called differential rectification or orthorectification and resulting products are then called orthophotos. Rectification is generally performed by any of three methods such as analytical, optical-mechanical and digital.

Geometry of Rectification

The fundamental geometry of rectification is illustrated in the figure. The figure shows a side view of the principal plane of a tilted photo.

When the exposure was made, the negative plane made an angle t with the datum plane.

Rays from A and B were imaged at a' and b' on the negative and their corresponding locations on the tilted photo are at a and b.

The plane of an equivalent vertical photo is shown parallel to the datum plane and passing through i, the isocentre of the tilted photo.

The plane of a ratioed rectified photo is parallel to datum plane and vertical photo plane. he projecting points a and b either to a'' and b'' or a''' and b''' is the process of rectification. The above projection is rectifying the tilt displacement only, but displacements due to relief are still present.

Flight Planning

The ultimate success of any photogrammetric project probably depends more upon good-quality photography than on any other aspect.

Planning the aerial photography also called flight planning is of major concern

If the photography is to satisfactorily serve its intended purposes, the photographic mission must be carefully planned and faithfully executed according to the flight plan.

A flight plan generally consists of two items such as flight map which shows where the photos are to be taken and specifications which outline how to take them including specific requirements such as camera and film, scale, flying height, end lap, side lap and tilt and crab tolerance

A flight plan which gives optimum specifications for a project can be prepared only after the careful consideration of all the many variables which influence aerial photography

An aerial photographic mission is an expensive operation involving two or more crewpersons and high priced air craft and equipments

Before planning climate and ground cover related to seasons are also taken to consideration

For these reasons flight planning is one of the most important operations in the overall photogrammetric project.

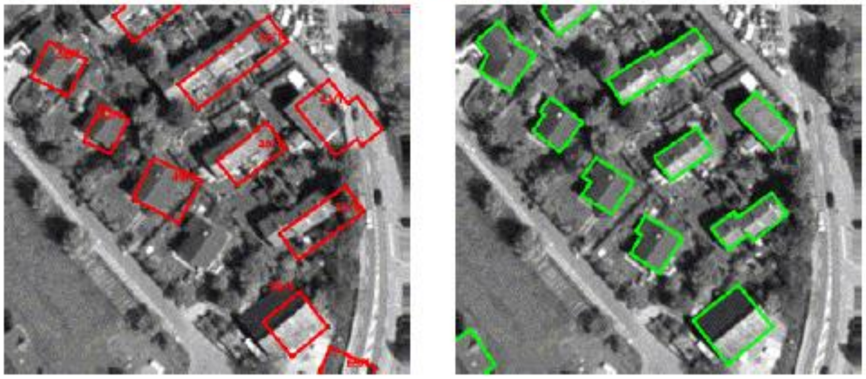
Lambert (Conformal Conic)- Area and shape are distorted away from standard parallels – This is an excellent projection for countries with some what limited extend from north to south. This projection is used by survey of India for all geographical maps in scales 1:1million and smaller

Polyconic Projection

This is a modified conical projection. The scale along each parallel and along the central meridians is correct. The scale along the other meridians increases away from the central meridians. In SOI, it is used for topographic sheets.

Feature Extraction

Automatic Building Extraction



(ETH, Zürich)

Use exisiting 2D building data to find possible locations.

Note that map data is usually not geometrically correct due to cartographic representation!

Automatic Building Extraction

If a DSM should be used for automatic extraction of buildings, it has to be very dense.

Ordinary resolution of maybe 10-50 m grid will not be enough.

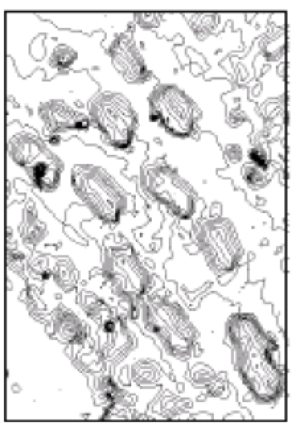
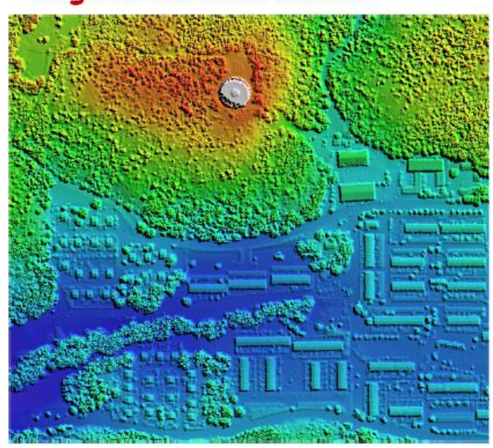


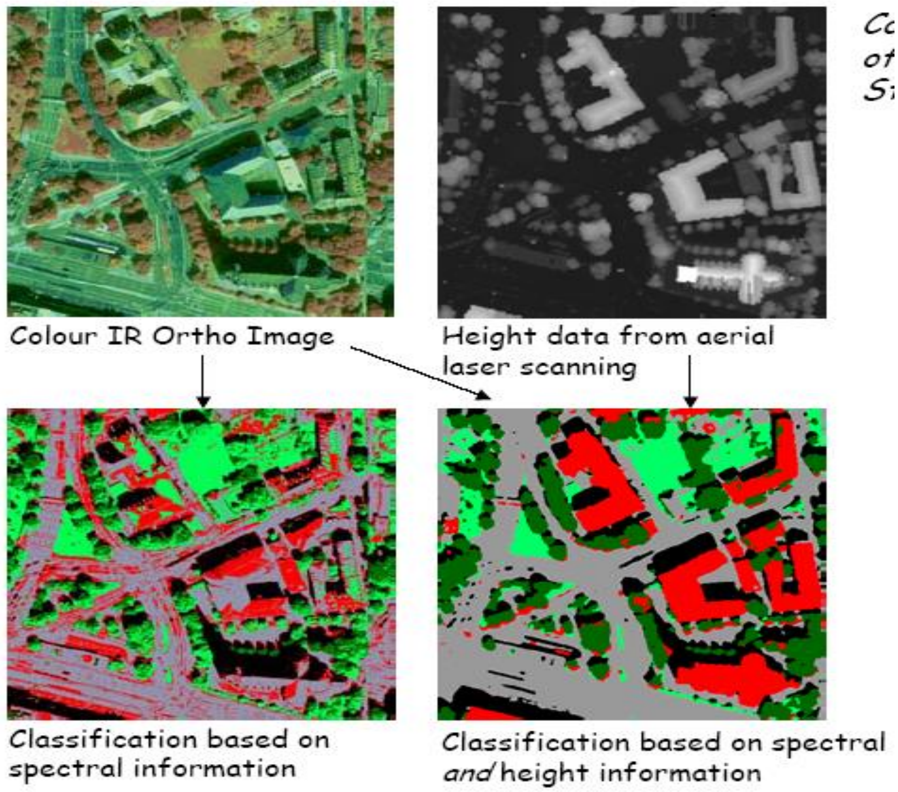
Fig. 1: Part of DSM

Digital Surface Model



Feature extraction from imagery is one of most important tasks to GIS practitioners.

GIS is concerned with the efficiency and accuracy of collecting thematic features or vectors like rivers, forests, lands, road networks, buildings, etc.


Colour IR Ortho Image
Height data from aerial laser scanning
Classification based on spectral information
Classification based on spectral *and* height information

Unit: 5 - Photo Interpretation Keys & Elements: Photo Interpretation Keys (Definition, its parts, Key sets, Types of Study) - Photo Interpretation Elements (Photo elements - Tone, Texture, Color, Shadow) - Geotechnical / Geomorphic elements (Landforms, Drainage, Erosional pattern, vegetative cover, Landuse, Shape & size of objects).

PHOTO INTERPRETATION KEYS & ELEMENTS

Two Steps:

1. **Recording of the Observed Data:**
   Collection of Qualitative and Quantitative Information

Qualitative:

- ➔ Physiographic Forms
- ➔ Geomorphic Units
- ➔ Geological Features
  - ❖ Rock Types
  - ❖ Their Stratigraphic Relationship
  - ❖ Dip
  - ❖ Slopes
  - ❖ Faults, Folds, Joints, Fractures, Etc.

Additional Information Includes

- ➔ Identification and Collection of Data on
  - ❖ Soil
  - ❖ Unconsoidated Surface Deposits
  - ❖ Surface water and Groundwater Conditions
  - ❖ Type and Distribution of Vegetation
  - ❖ Land Use Contrast, etc.

Quantitative:

- ➔ Dip of Beds
- ➔ Thickness of Strata
- ➔ Displacement
- ➔ Direction of Faults
- ➔ Plunge of Fold Axis, etc.

2. <u>Judging the Significance of the data:</u>

The Collected Qualitative and Quantitative Data are to be Processed

To find out the significance of Geology of the Area.

<u>This is Useful</u>

- ➔ To Establish Geological History
- ➔ Its Geomorphic Evolution
- ➔ Tectonic Relationship of Folds, Faults and Intrusive Bodies to Country Rocks and amongst themselves.

The data to be sorted out to suit to the requirements.

<u>A. Empirical Method :</u>

Similar Images of Known areas or keys are compared With Images Under Study.

<u>Interpretation Key</u>

- ➔ Valuable Aid and helps to evaluate the Information in an organized and consistent manner
- ➔ It provides guidance about the correct identification

<u>Two Parts</u>

- ➔ Annotated Stereograms
- ➔ Graphic or Word Descriptions

<u>Key Sets</u>

- ➔ Selective Key -- Photos + Text
- ➔ Elimination Key -- Step By Step (General To Specific)
- ➔ Dichotomous Key -- Two Alternatives

Types of Study

I - Photo Reading

- ➔ Photo Analysis / Convergence of data
- ➔ Photo Interpretation

II – Synthesis of data

Some times these keys may not be useful because

- ➔ Nature is very often complex and non-uniform.
- ➔ Terrain forms polygenetic in origin.

B. Convergence of evidence approach:

- ➔ Inductive (or) deductive approaches

B1. In inductive method – the general condition of an area is inferred from a particular recognized object, for example

- ➔ A volcanic cone – indicate a volcanic area
- ➔ Swarm of sand dunes – desertic / arid region.

B2. In deductive method – a particular object is identified based on the general conditions prevailed there, for example:

- ➔ Glaciated region – identify esters, trumlins, etc.

The ability of photo-interpreter to carry out reliable interpretation depends on several factors, such as

- ➔ The quality of aerial photographs
- ➔ Types of viewing instruments
- ➔ Working conditions and
- ➔ The personal acuity of photo-interpretation.

The last factor is the most important one and it differs from person to person in Photogeologic interpretation and

Knowledge of

- ➔ Geomorphology
- ➔ Stratigraphy
- ➔ Lithology
- ➔ Structural Geology
- ➔ Pedology
- ➔ Vegetation
- ➔ Groundwater Geology

is Essential.

Further a specialized knowledge in branches of applied geology helps in making interpretation of specific fields such as

- ➔ Morpho-tectonics
- ➔ Engineering geology
- ➔ Ground-water surveys
- ➔ Mineral prospecting
- ➔ Terrain evaluation
- ➔ Landuse planning, etc.

Training in photo interpretation, working experience of a person and higher degree of confidence of the interpreter are the very important factors for accurate and reliable results.

An excellent photo interpreter virtually meditates with the stereoscopic model to the extent that the viewer and the terrain model virtuality become one. The observer not only views the terrain but feels his presence within it.

Deep perception can be achieved by long practice and concentration.

Elements of photo interpretation (photo recognition elements)

- **I. Photo elements**
- **II. Geotechnical / geomorphic elements.**

I. Photo elements (T^2 s^3)

Tone
Texture

Shape
Size
Shadow

Site
Association &
Pattern.

and then

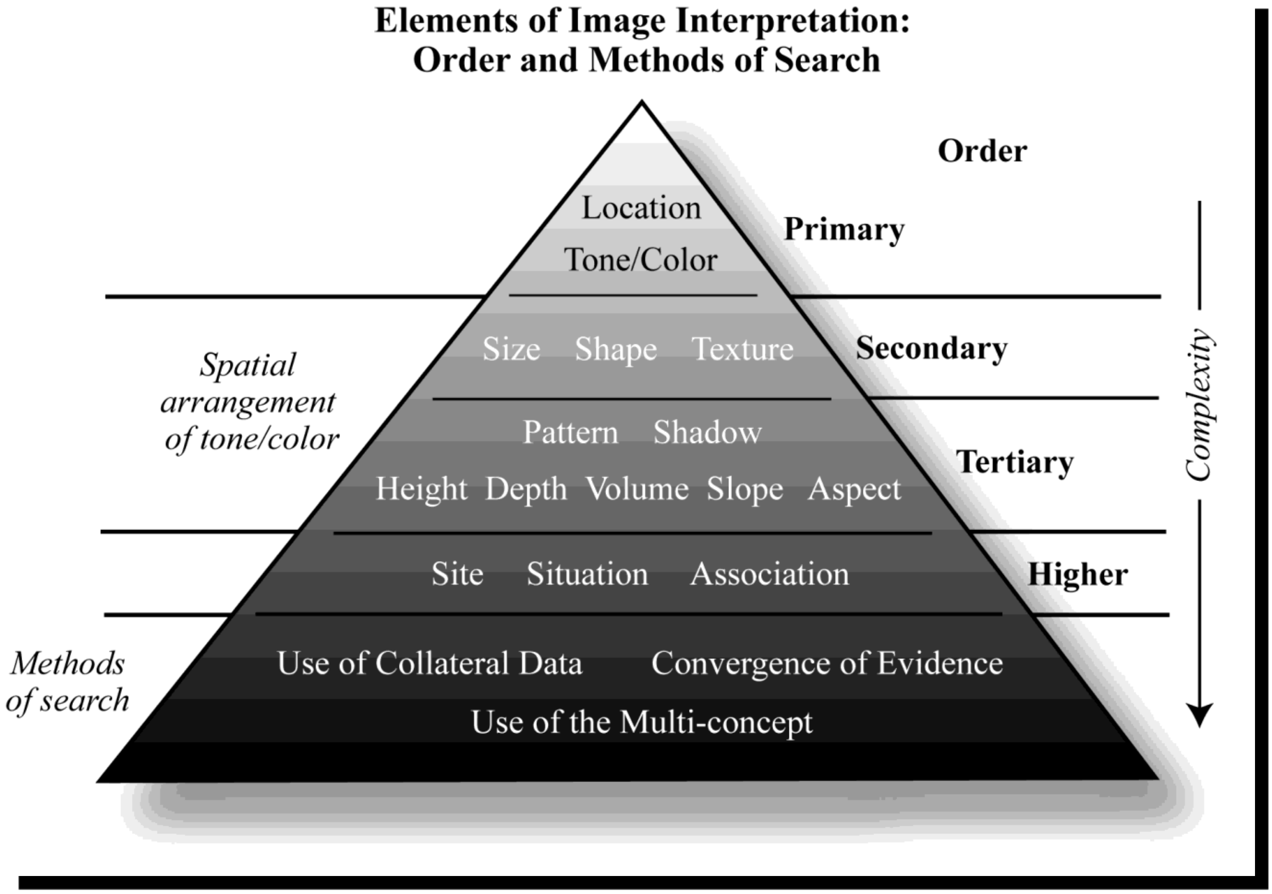
Scale
Ve – vertical exaggeration.

and the other minor factors such as

Man made features
Soil
Water
Vegetation, etc.

Table 5-1. Elements of image interpretation.

Element	Common Adjectives (quantitative and qualitative)
***x,y* location**	• *x,y* image coordinates: column (*x*) and row (*y*) coordinates in an unrectified image • *x,y* image map coordinates: silver halide crystals or pixels in photograph or image are rectified to a map projection (e.g., UTM)
Tone/Color	• gray tone: light (bright), intermediate (gray), dark (black) • color: IHS = intensity, hue (color), saturation; RGB = red, green, and blue; Munsell
Size	• length, width, perimeter, area (m^2) • small, medium (intermediate), large
Shape	• an object's geometric characteristics: linear, curvilinear, circular, elliptical, radial, square, rectangular, triangular, hexagonal, pentagonal, star, amorphous, etc.
Texture	• characteristic placement and arrangement of repetitions of tone or color • smooth, intermediate (medium), rough (coarse), mottled, stippled
Pattern	• spatial arrangement of objects on the ground: systematic, unsystematic or random, linear, curvilinear, rectangular, circular, elliptical, parallel, centripetal, serrated, striated, braided
Shadow	• a silhouette caused by solar illumination from the side
Height/Depth Volume/Slope/ Aspect	• *z*-elevation (height), *z*-bathymetry (depth), volume (m^3), slope °, aspect °
Site Situation Association	• *Site*: elevation, slope, aspect, exposure, adjacency to water, transportation, utilities • *Situation*: objects are placed in a particular order or orientation relative to one another • *Association*: related phenomena are usually present



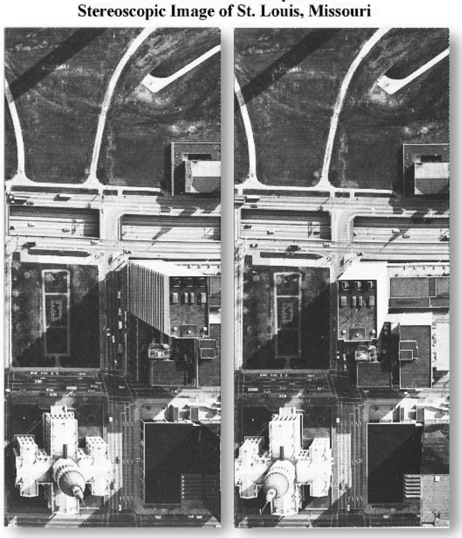
Reasons why photo/image interpretation are powerful scientific tools:

- ➔ **aerial/regional perspective;**
- ➔ **three-dimensional depth perception;**
- ➔ **ability to obtain knowledge beyond our human visual perception;**
- ➔ **ability to obtain a historical image record to document change.**

Earth as Seen from Apollo 17

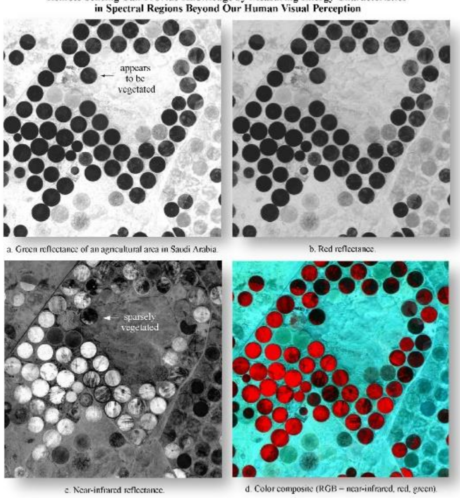
The Aerial/Regional Perspective

Three-dimensional Perspective:
Stereoscopic Image of St. Louis, Missouri



Three-dimensional Depth Perception

Remote Sensing Can Provide Knowledge by Measuring Energy Characteristics in Spectral Regions Beyond Our Human Visual Perception



Obtaining Knowledge Beyond our Human Visual Perception

Historical Image Record and Change Detection Documentation

Remote Sensing Imagery as A Historical Record:
Informal City Demolition in Harare, Zimbabwe in 2005

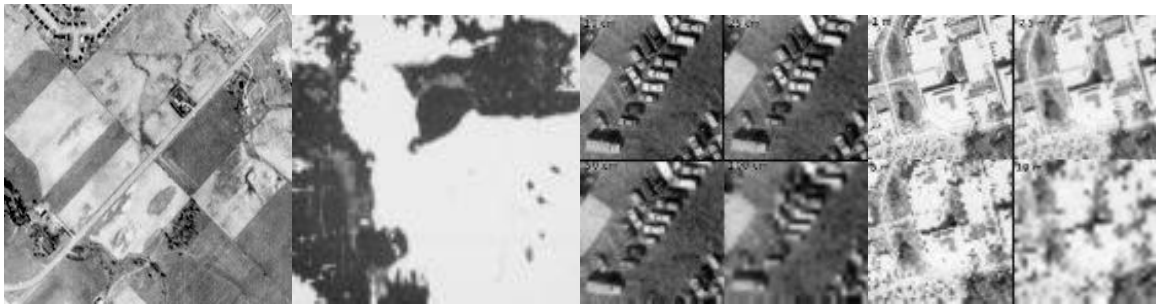
a. QuickBird 61-cm image obtained on April 16, 2005. b. QuickBird 61-cm image obtained on June 4, 2005.

Photographic tone:

It is a measure of the relative amount of light reflected by an object and recorded in the photograph.

The tonality of aerial photograph is influenced by the following factors:

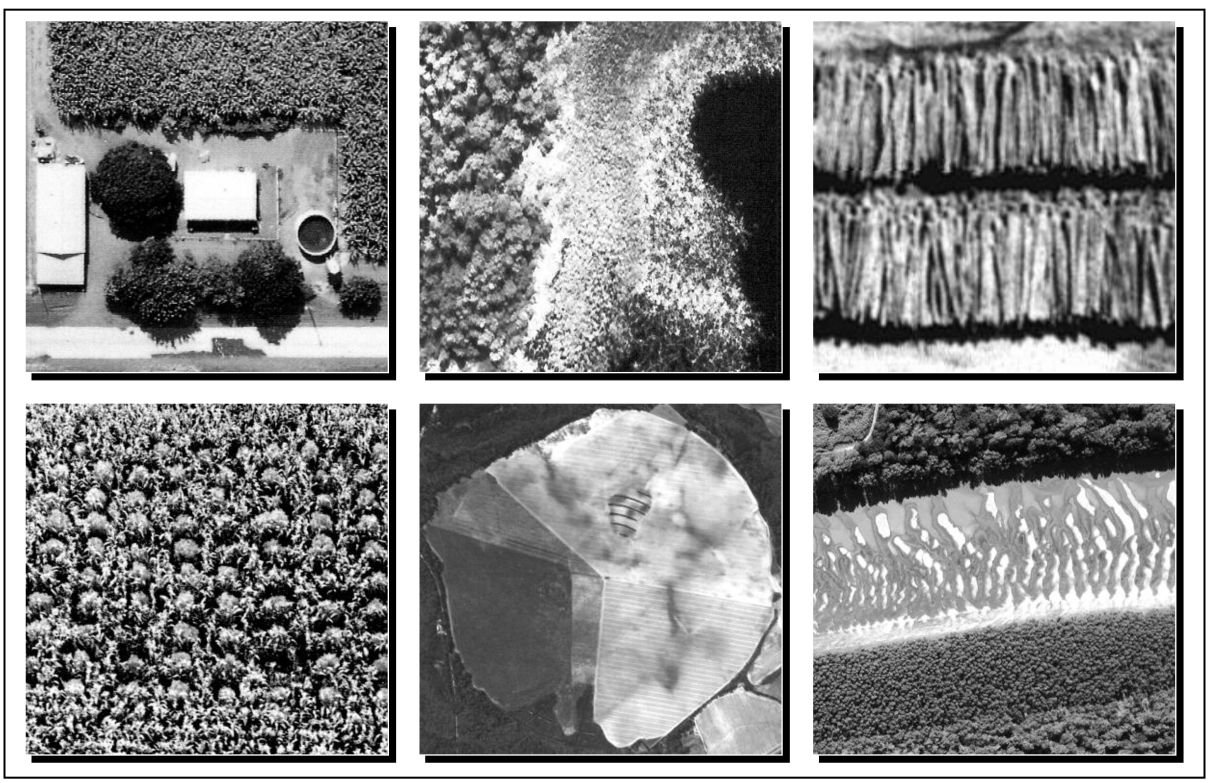
i. The light reflectivity of the object
ii. Angle of reflected light
iii. The geographic latitude
iv. Type of photography and films sensitivity
v. Light transmission of filters
vi. Photographic processing
vii. Densitometers.

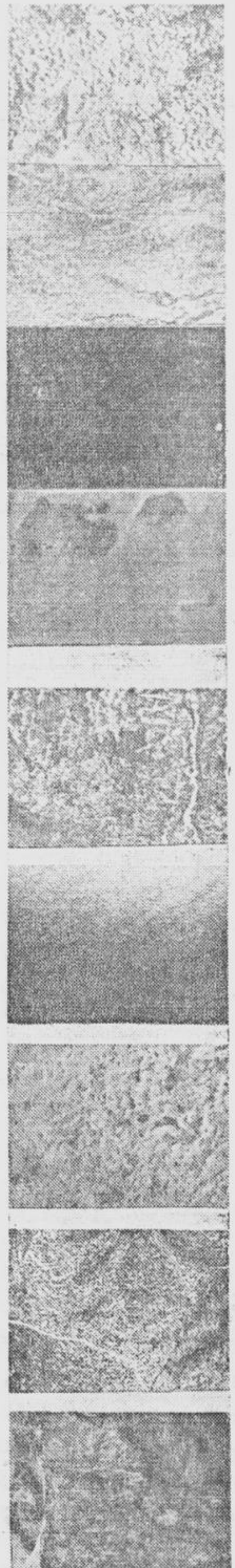


Examples of Tone

Photographic Texture

The frequency of change and arrangement of tones in a photographic image and it is produced by an aggregate of unit features too small to be clearly recognised individually on an aerial photograph. And can be classified as 1) Coarse, 2) Medium, 3) Fine, 4) Smooth, 5) Rough, 6) Rippled, 7)Mottled, 8) Speckled, Criss-Cross, Etc.





Coarse texture: Developed due to clustering of trees with rounded crowns in a large scale photograph.

Medium texture: Developed due to bushy vegetation and scattered trees in a medium scale photograph.

Fine texture: Developed due to thick forest with small crown trees in a small scale photograph.

Smooth texture: Developed due to alluvial deposits in descrtic region in a medium scale photograph.

Rough texture: Developed due to irregularly vegetated rough glacial terrain in a small scale photograph.

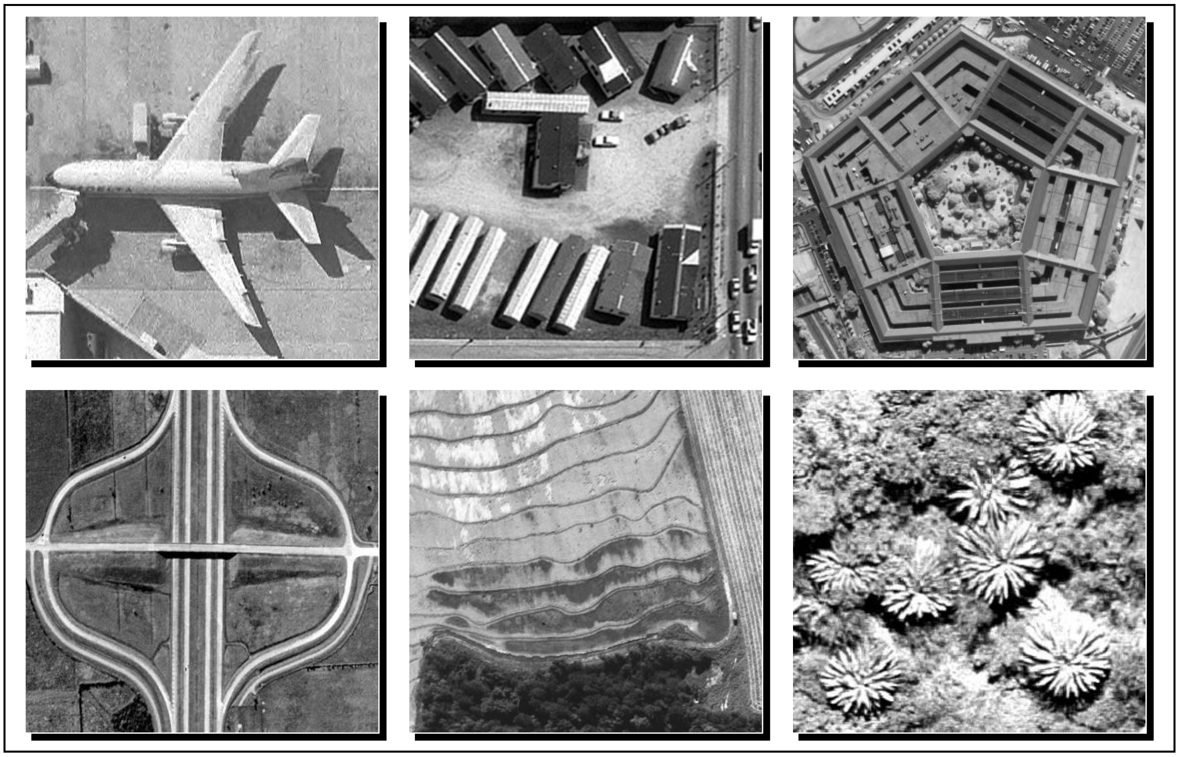
Rippled texture: Developed due to water waves over shallow water surface in a small scale photograph.

Mottled texture: Developed due to pitted outwash plain in fluvio-glacial region in a medium scale photograph.

Speckeled or Granular texture: Developed due to scattered vegetation over poorly bedded loosely cemented sandstone in a small scale photograph.

Cris-cross texture: Developed due to closely spaced intersecting joints in basic igneous rocks in a small scale photograph.

Shape of Objects: The shape of objects/features can provide diagnostic clues that aid identification. The Pentagon building in Washington is a diagnostic shape. Man-made features have straight edges that natural features tend not to. Roads can have right angle turns, railroads do not.



The following Geological features can be identified with the help of their shapes

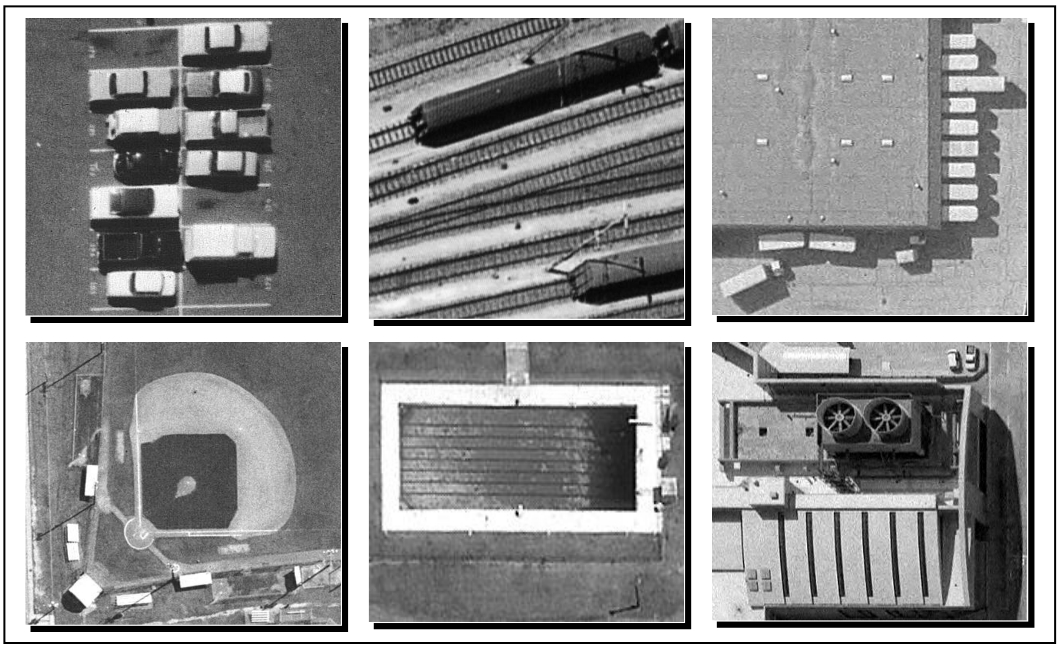
Circular – Craters, Ring Dykes
Oblong / Elongated – Doubly Plunging Syncline / Anticlind
Linear – Dyke, Sill
Ovular – Aureole, Doubly Plunging Folds
Rectangle / Diamond – Fracture Swarms
Crescent - Dunes
Cone – Volcano, Alluvial
Fan - Alluvial
Zig-Zag (Ridge And Valleys) – Plunging Folds
Annular – Domes
Concentric- Basins
Irregular – Igneous Body.

Size of Objects: The size of objects can be important in discrimination of objects and features (cars vs. trucks or buses; single family vs. multi-family residences, brush vs. trees, etc.).

Consider with shape of objects and scale of photo.

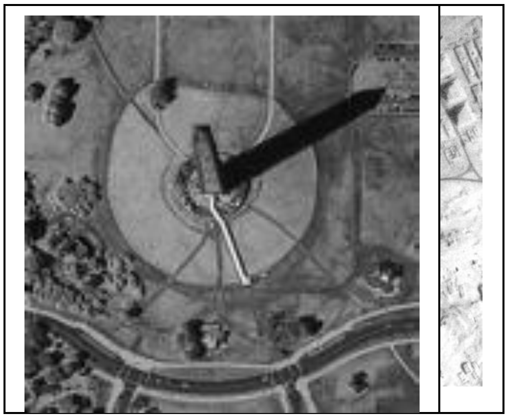
➔ Geomorphic features with certain defined sizes could be used for relative size of objects

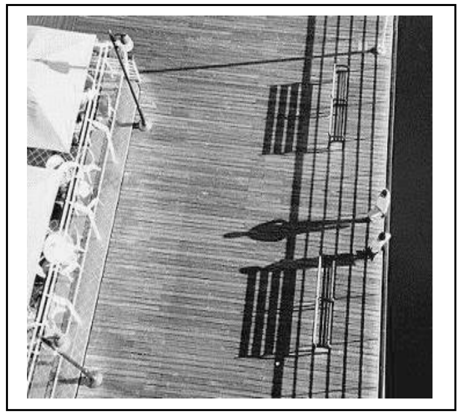
➔ Relative size from known objects at the side.



Shadow of Objects: Geologists like low sun angle photography because shadow patterns can help identify objects. Steeples and smoke stacks can cast shadows that can facilitate interpretations. Tree identification can be aided by an examination of the shadows thrown. Extra depth – due to shadow – not only in stereo model but also over a single photo

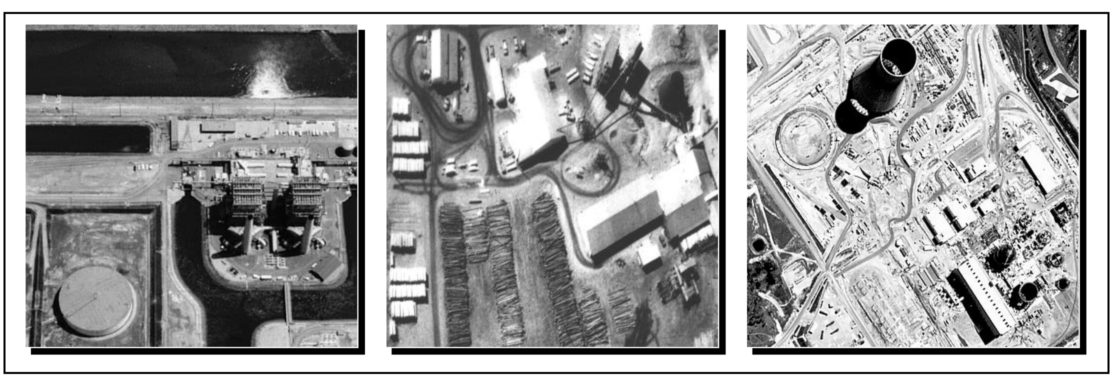
➔ Shadow helps in defining sizes of the objects.





Site: How objects are arranged with respect to one another; or with respect to various terrain features, can be an aid in interpretation. Aspect, topography, geology, soil, vegetation and cultural features on the landscape are distinctive factors that the interpreter should use when examining a site. The relative importance of each of these factors will vary with local conditions, but all are important. Just as some vegetation grows in swamps others grow on sandy ridges

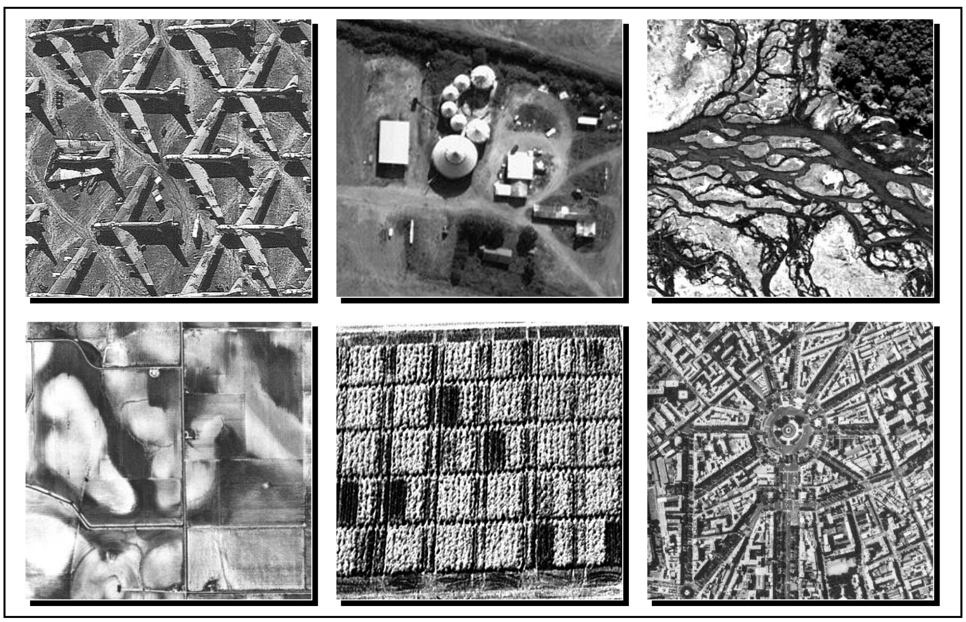
Association:_Association - Some objects are so commonly associated with one another that identification of one tends to indicate or confirm the existence of another. Smoke stacks, step buildings, cooling ponds, transformer yards, coal piles, railroad tracks = coal fired power plant. Arid terrain, basin bottom location, highly reflective surface, sparse vegetation = playa.



- ➔ Hills and their drinage patterns, Rivers and meanders, floodplains, oxbow lakes, Volcanoes – crater, ash bed, lava flow, etc.

Pattern: Pattern is the spatial arrangement of objects. Pattern can be either man-made or natural. Pattern is a macro image characteristic. It is the regular arrangement of objects that can be diagnostic of features on the landscape. An orchard has a particular pattern. Likewise, the network or grid of streets in a subdivision or urban area can aid identification and aid in problem solving such as the growth patterns of a city.

Pattern can also be very important in geologic or geomorphologic analysis. Drainage pattern can tell the trained observer a great deal about the lithology and structural patterns in an area. Dendritic drainage patterns develop on flat bedded sediments; radial on/over domes; linear or trellis in areas with faults or other structural controls.



- ➔ Outcrop pattern – lithological assemblage and geological structure
- ➔ Drainage pattern – underlying lithology, structure, soil texture and hydrological characteristics of ground
- ➔ Landform patterns – ridge and valley pattern
- ➔ Fracture Patterns
- ➔ Joint Patterns
- ➔ Soil Patterns
- ➔ Vegetation Patterns, Etc.

Geotechnical / Geomorphic Elements:

Landforms

The landforms can have a variety of meanings, depending on the specific discipline involved.

- ➔ The geologist may describe landforms in terms of surface characteristics that yield evidence as to the geologic structures such as faults, joints, domes, basins, etc.
- ➔ The soil scientists is more interested in studying landforms for the purpose of identifying the parent soil material, soil texture potential fertility, soil moisture, soil drainage, erotability, etc.
- ➔ The civil engineer interested in studying landforms to gain information about soil or rock bearing strength, drainage pattern, sites for major engineering construction, etc.
- ➔ The hydrologist analyse the landforms for surface and groundwater prospecting

Way (1973) defined the term landform as terrain features formed by natural processes.

Recognition of Landforms

There are seven basic pattern elements that the photo interpreter can use to identify and categorize landforms and landscapes such as

1. Topography
2. Drainage Pattern
3. Drainage texture
4. Gully types
5. Photo tone and photo texture
6. Vergetational patterns
7. Land use pattern

Topography: Using stereoscopic model, the interpreter can quickly identified the hills or plain, steep slope, valleys, ridges, valleys, domes, etc.

Drainage Pattern: Drainage pattern which are closely related to topography and rainfall are the most important characteristics for the classification of landforms

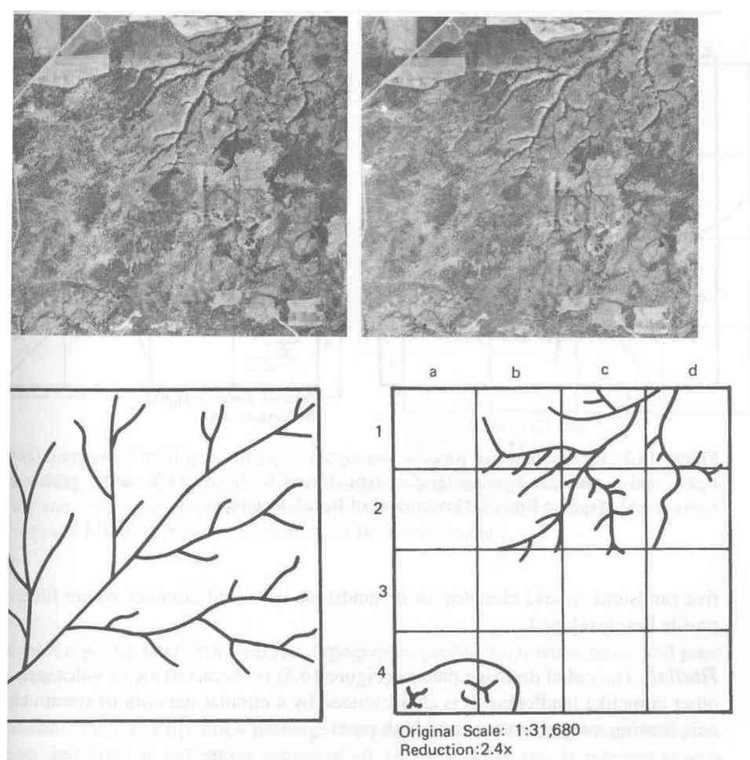
An analysis of topography and drainage patterns gives the much information about the underlying geologic structures, parent soil materials and erodability of a particular area. There are seven basic drainage patterns such as

1. Dendritic,
2. Parallel
3. Trellis
4. Rectangular
5. Radial
6. Deranged
7. Internal

Dendritic: The dendritic pattern is the most common and is characterized by a treelike branching system where the branches (tributaries) join the stem (main stream) at acute angles.

This drainage system indicates homogeneous rock and soil materials with little or no structural control.

Soft sedimentary rocks, volcanic tuff and dissected deposits of thick glacial generally indicate the dendritic pattern



ure 16.1. Dendritic drainage patterns: stereogram (*top*) drawing from stereogram (*bottom* ht), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from veys and Mapping Branch, Government of British Columbia.)

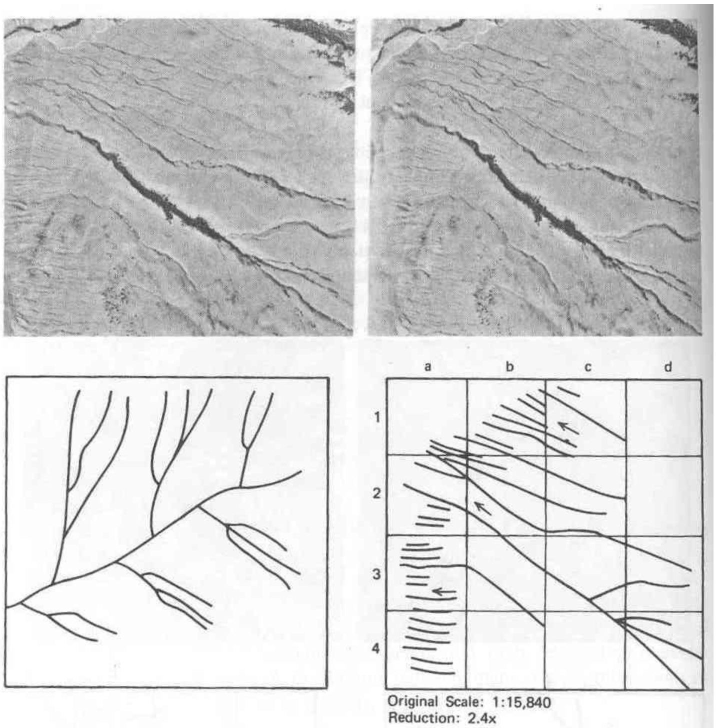


Figure 16.2. Parallel drainage patterns: stereogram (*top*), drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

Parallel: Parallel drainage systems generally develop on gentle to moderate, uniform slopes whose main collector streams may indicate a fault or fracture.

The tributaries characteristically join the main streams at about the same angle

There are many transitions possible between this pattern and the dendritic and trellis types

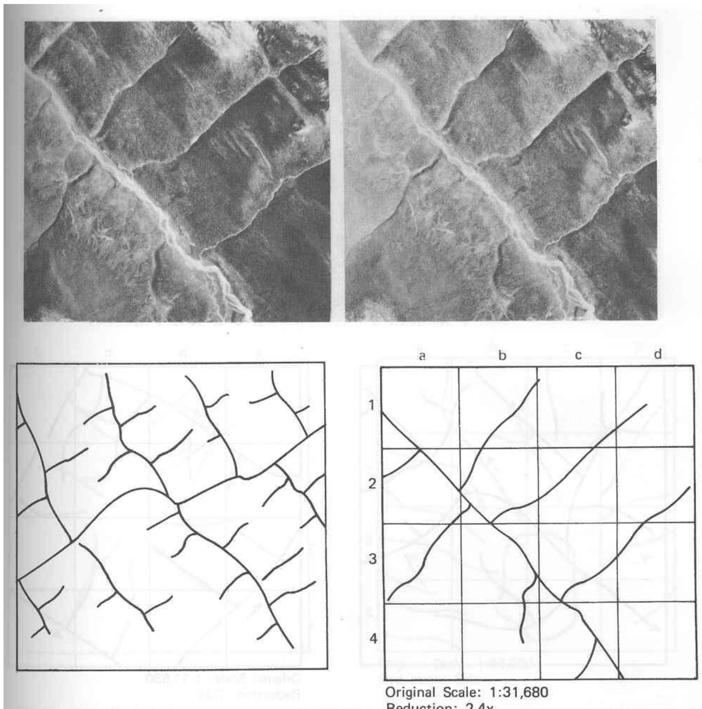


Figure 16.3. Trellis drainage patterns: stereogram (*top*), drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

Trellis: Trellis drainage pattern are modified dendritic forms where secondary streams occur at right angles to the main stream with the tertiary streams at right angles to the secondary streams.

This type of pattern is typical in belts of tightly folded sedimentary rock

Rectangular: Rectangular drainage patterns are also modification of dendritic form, but the secondary streams joining the main streams are more at right angle

Rectangular patterns frequently reflect the regional pattern of intersecting joint systems. This pattern are often formed in slate, schist or in resistive sandstone in arid climates or in sandstone in humid climates where little soil profile has developed

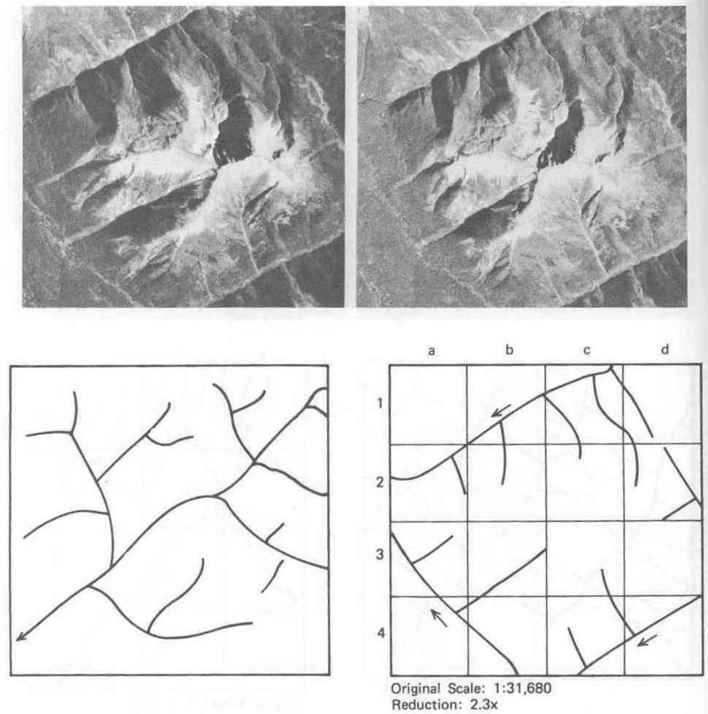


Figure 16.4. Rectangular drainage patterns: stereogram (*top*) drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

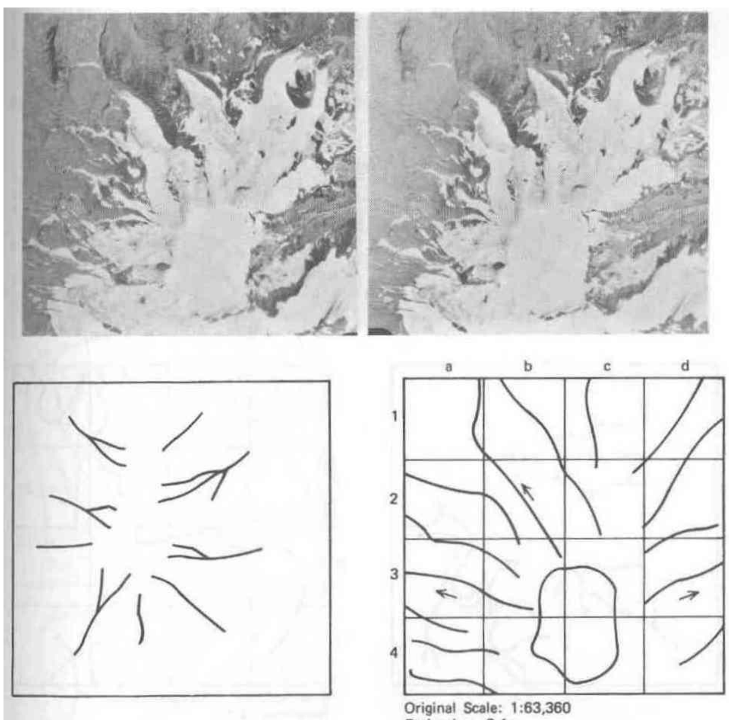


Figure 16.5. Radial drainage patterns: stereogram (*top*), drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

Radial: The radial drainage pattern is characteristic of volcanoes and other dome like landforms. It characterized by a circular network of stream channels flowing away from a central high point.

Deranged: The deranged pattern is nonintegrated and is characterized by swamps, bogs, small ponds or lakes and meandering streams. This usually indicates a young landforms with low topographic profile, high water table and poor drainage

Internal: Internal drainage doesn't have any pattern at all.

In some areas, this is referred to as a braided stream system.

It is the result of highly permeable material with under ground drainage system and is sometimes characterized by sinkholes

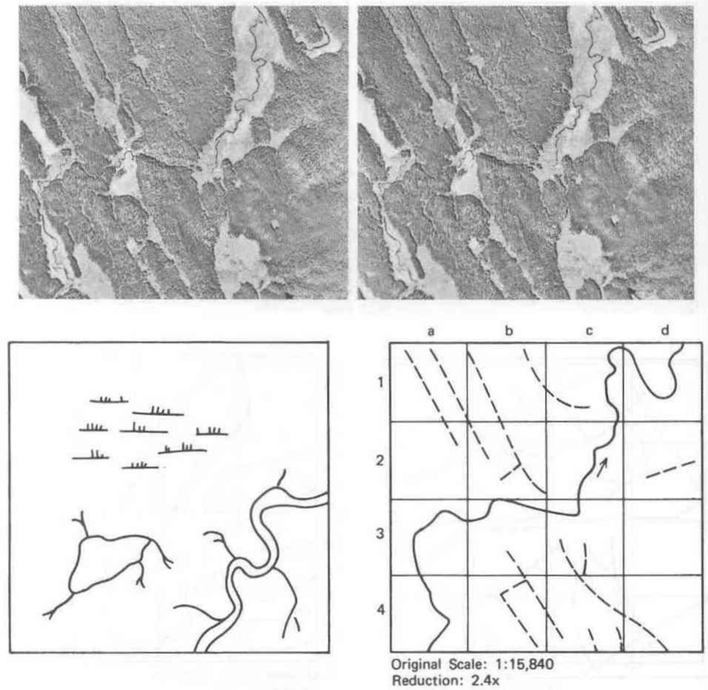


Figure 16.6. Deranged drainage patterns: stereogram (*top*), drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

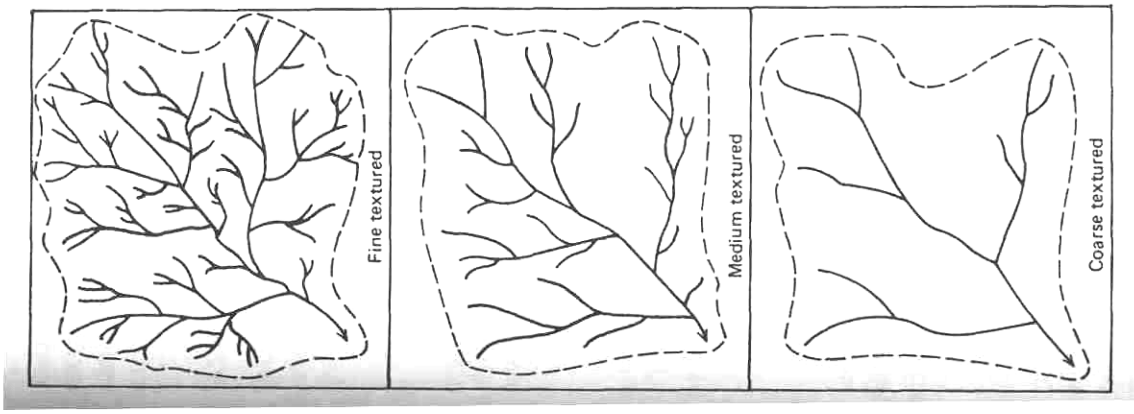
Drainage Texture

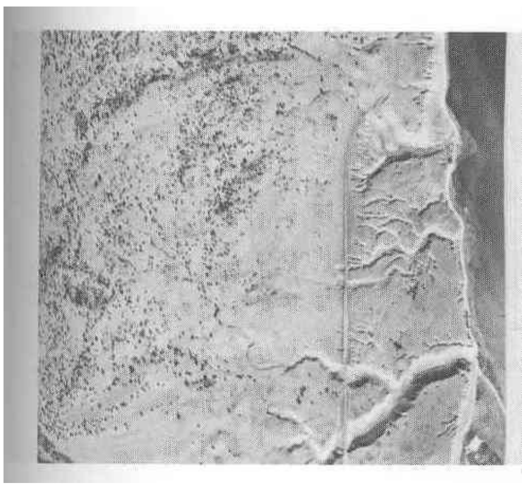
Drainage texture refers to the number and spacing of drainages. Drainage texture can be classified as fine, medium or coarse.

Way (1973) defined fine textured drainage patterns as those with average spacing between the main streams and the first order tributaries as averaging 400 feet or less. Fine textured patterns usually indicate high levels of surface run off, impervious bedrock and soils of low permeability.

Medium textured drainage patterns have average first order tributary spacing of from about 400 to 3200 feet. These are associated with medium levels of runoff and soils with mixtures of fine and coarse textures.

Coarse textured pattern have spacing greater than 3200 feet indicate more resistant bedrock that weathers to form coarse, permeable soils with relatively little runoff.





Gully types:

Gullies are small drainage feature that may be as small as a meter wide and hundreds of meters long. Gullies result from the erosion of unconsolidated material by runoff and develop where rainfall cannot adequately percolate into the ground.

Short gullies with V-shaped cross sections tend to develop in sand and gravel, gullies with U-shaped cross section tend to develop in silty soils and long gullies with gently rounded cross sections tend to develop in silty clay and clay soils.

Image tone: The term image tone refers to the brightness at any point on an aerial or space image.

The absolute value of the image tone depends not only on certain terrain characteristics but also on image acquisition factors such as film-filter combination, exposure and photographic / data processing.

Image tone also depends on meteorological and climatological factors such as atmospheric haze, sun angle and cloud shadows.

Because of the effect of these non-terrain-related factors, image interpretation for terrain evaluation must rely on an analysis of relative tone values, rather than absolute tone values.

Vegetation Pattern

Vegetation frequently prohibits the photo interpreter from viewing the ground, but its mere presence or absence provides a useful clue as to the soil conditions below as to texture, permeability and moisture availability.

Because of different vegetative cover associated with different geographic regions, local experience is absolutely necessary for an accurate assessment of what different vegetational pattern indicate.

Land-Use Pattern

Landuse patterns are man-made alterations of the landscape and are valuable clues as to soil conditions. Man-made patterns are conspicuous because they usually consist of straight lines or other regular configurations.

Winding roads indicate steep or hilly topography. Railroads must be located where slope are gradual.

Farm locations avoid poorly drained areas as well as rocky or other locations of poor soils or shallow soils.

Cities and industrial areas are often located in certain areas because of transportation routes

Geology Application

Sedimentary Landscape

Sedimentary rocks were formed by the deposition of sediments by water, wind or ice.

When the transporting agent slows, sediments are deposited with the larger particle settling first followed by the small particles. This results in sedimentary layers that are stratified by particle size. Though layers were laid down in roughly horizontal planes, many were later deformed, eroded, folded, faulted and uplifted to form various landscapes.

Sedimentary rock characteristics (Way 1973)

TABLE 17.1 Sedimentary Rock Charecteristics

	From Aerial Photos and Geologic Maps				Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristics
Shale								
Humid	Rounded hills	Dendritic Medium-fine	Light (mottled)		Fine Silt-clay	Poor	Agriculture Forestry	Excellent base Poor septic system
Arid	Rough-steep	Dendritic Fine	Light (banded)		Medium Silty	Very poor	Barren	Excavation difficult. Poc aggregate
Sandstone								
Humid	Massive and steep	Dendritic Coarse	Light		Sandy	Excellent	Forestry	Excellent base Shallow to bedrock
Arid	Flat table	Dendritic Medium-coarse	Light (banded)	None	Fine	Poor	Barren	Poor septic systems
Limestone								
Humid	Flat or rough sink holes	Internal	Mottled		Silt-clay	Poor to good	Agriculture	Shallow soil Poor septic systems
Arid	Flat table	Dendritic	Light	None	Fine	Poor	Barren	Poor septic systems
Interbedded								
Flat (humid)	Terraced	Dendritic Medium-coarse	Medium (banded)	Variable	Variable	Variable	Some agriculture Some forest	Good base Variable to bedrock
Tilted (humid)	Parallel ridges	Trellis Medium	Medium (banded)		Fine	Fair	Agriculture Forestry	Good base Excavation difficult

Source: Adapted by permission from Way (1973).

Igneous Landscape

Igneous rocks are formed by the solidification of molten rock either within or on the surface of the Earth. They are classified as intrusive if they were formed beneath the surface of the Earth and extrusive if they were formed on the Earth's surface.

Rock types are classified as granitic or basaltic and are generally hard, durable and associated with poor surface drainage. Igneous rock landscapes make up about 18% of the earth.

Igneous rock characteristics (Way 1973)

TABLE 17.2 Igneous Rock Characteristics

	From Aerial Photos and Geologic Maps				Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristic
Granite								
Humid and intrusive	Bold and domelike	Dendritic Medium	Light (uniform)	Variable	Silty sand	Poor	Agriculture Forestry	Excavation diffic Poor aggregate Good base
Arid and intrusive	*A*-shaped hills	Dendritic Fine or internal	Light (banded)	None	Fine	Poor	Barren (rangeland)	
Basalt								
Extrusive flows	Flat to hilly	Parallel or internal	Dark (spotted)	None	Clay to rock	Good	Agriculture to barren	Blasting not diffic Landslides comm Soil is unstable w disturbed.
Volcanic extrusive	Cinder cone	Radial C to F	Dark	Variable	Silty clay	Poor (surface) Good (subsurface)	Barren	
Fragmented tuff	Sharp-ridged hills (variable height)	Dendritic Fine	Light		Noncohesive sand to dust	Excellent	Forestry or grassland	Blasting not requi Unstable soil. Septic systems ea contaminated.
Embedded flows	Terraced hills	Parallel dendritic	Light and dark (banded)	Variable	Variable	Variable	Agriculture to barren	Unstable soil

Source: Adapted by permission from Way (1973).

Metamorphic Landscape

Metamorphic rocks are formed beneath the surface of the earth by heat and pressure working on sedimentary or igneous rock. The more important rock types include slate, phylite, schist, gneiss and marble.

The photo interpretation of metamorphic landscape is difficult because of intermingling with sedimentary and igneous types and the relatively small size of single deposits

Metamorphic rock characteristics (Way 1973)

TABLE 17.3 Metamorphic Rock Characteristics

	From Aerial Photos and Geologic Maps				Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristics
Slate								
Humid and arid	Many small, sharp ridges of same height	Rectangular Fine	Light		Cohesive fine	thin soil	Unproductive natural vegetation	Excavation difficul Rockslides
Schist								
Humid	Steep, rounded hills	Rectangular Medium-fine	Light (uniform)		Moderately cohesive sand-clay	Good to poor	Cultivated Forested	Seepage problems Poor septic system
Arid	Rugged	Rectangular Fine	Light (banded)		Moderately cohesive sand-clay	Good	Thin soil (grass and scrub)	Little excavation needed
Gneiss								
Humid and arid	Parallel, steep, sharp ridges	Angular dendritic Medium-fine	Light (uniform)		Moderately cohesive sand-silt	Fair	Natural (forested, grass or scrub)	Much blasting Fair aggregate

Source: Adapted by permission of Way (1973).

Fluvial Landscapes

Fluvial landscapes are a result of water erosion where large quantities of soil material have been transported from higher to lower elevations and deposited.

Fluvial landscapes can be classified into three categories such as 1) river associated forms (flood plains, delta, etc.), 2) alluvial forms (alluvial fans, valley fills, etc.) and 3) freshwater forms (Playas, organic deposits, etc.)

TABLE 17.6 Characteristics of Fluvial Deposits

	From Aerial Photos and Geologic Maps				Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristic
Flood plains	Flat	Meanders	Variable	Few	Variable	Poor (variable)	Agriculture	Gravel—poor Minor slumping
Deltas	Level with stream channels	Dendritic (fine)	Medium		Silt to gravel	Very poor	Variable (marshy)	Poor for construction
Alluvial fans	Convex, fan-shaped	Radial	Light (gray)	None	Coarse	Good	Barren to natural cover	Poor support Excavation easy
Valley fills	Gradual slopes	Parallel to dendritic	Light (uniform)	Variable	Coarse (variable)	Variable	Agriculture or natural	Fair support Excavation easy
Continental alluvium	Flat	Dendritic to internal	Light (gray)		Silty-loam	Poor	Agriculture or natural	Poor for septic tanks. Fair supp
Plyas (arid lakebeds)	Flat basin	None (evaporative)	Light	None	Silty-clay	None	Barren	High water tabl (flooding) Poor for sewage
Organic deposits	Flat (depressions)	Dendritic (variable)	Very dark	None	Organic (silt-clay)	None	Agriculture if drained	Not suited for construction

Source: Adapted by permission from Way (1973).

Glacial Drift Landscapes

Landforms composed of glacial deposits were created by the melting of glaciers and the retreat of the ice front. The material left behind created distinct landforms that are easily identified on aerial photographs

TABLE 17.4 Glacial Drift Characteristics

From Aerial Photos and Geologic Maps					Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristics
Till plains								
Old	Broad, level, dissected	Dendritic Variable	Light (mottled)	Variable	Variable	Poor	Agriculture Forestry	Poor subgrade High water table
Young	Broad, gently rolling	Deranged Variable	Light (mottled)	Variable	Variable	Poor	Agriculture Forestry	Poor subgrade High water table
Ground moraine	Between till plaine and moraine	Deranged-dendritic Medium	Light-medium (mottled)	Variable	Variable	Poor	Forestry Range (swamps)	Boulders Coarse textured—good fill
End moraine	Broad belts of hills under 500 feet	Deranged-dendritic Medium	Light-medium (mottled)		Noncohesive sand	Poor to well	Forestry Range (swamps)	Variable
Drumlin	Parallel-oval swarms in one direction	Internal	Light	Variable	Coarse or fine	Good	Agriculture Forestry	Construction difficult. Excellent fill
Esker	Long, narrow winding ridges ½ to 2 miles long	Internal	Light		Noncohesive sand	Very well	Forestry or none	Excavation easy. Excellent sand and gravel
Kame	Conical to irregularly shaped mounds under 50 feet high	Internal	Light		Noncohesive sand	Very well	Forestry (humid climates)	Excellent sand and gravel

Source: Adapted by permission from Way (1973).