Topic Series 05

Aerial Film Cameras, Photo Geometry, Films/Filters, Image Formation

I. Single Lens Reflex Camera

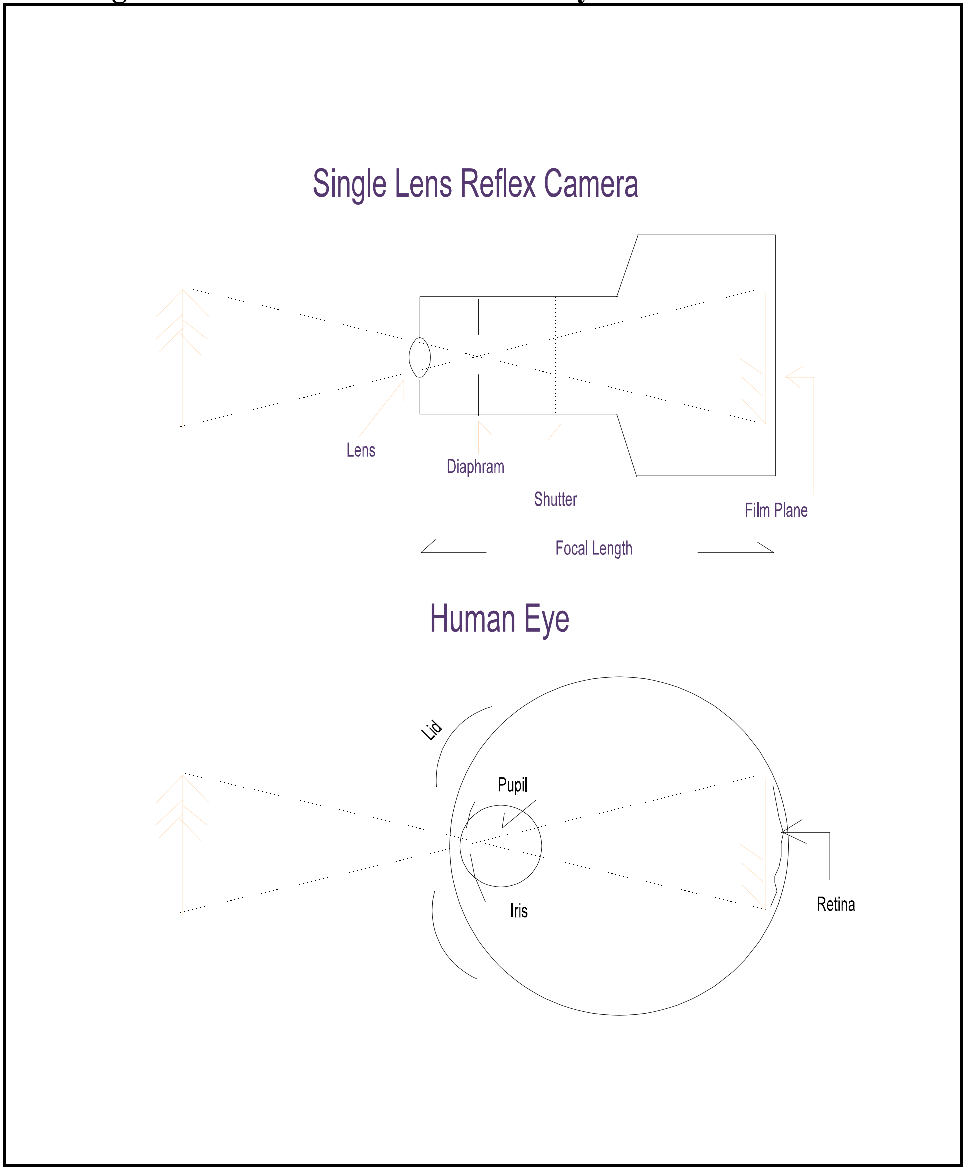
The wondrous thing is ... we have sensors to capture data all the way from the UV to Microwave & Radio. We can capture a certain amount of the energy on film in a CAMERA. What is a camera? A simple S(ingle) L(ens) R(eflex) camera consists of:

1. a LENS
2. an IMAGE SPACE, and
3. an ENERGY-GATHERING PLANE (film).

One of the best remote sensing devices (i.e. camera) that has ever been "invented" is the human eye. The common characteristics of a camera and the human eye are:

Eye	SLR Camera
Pupil	Lens
Iris	diaphram
Lid	shutter
Retina	film plane
eye muscles	screw focusing
rods/cones in retina	crystals in film

Figure 5-1: Single lens reflex camera vs. human eye



The PUPIL acts as the APERTURE, the IMAGE SPACE is between the pupil and the RETINA which records the images passed through the pupil; further, the eye is attached to an analog computer (the mind) that permits virtually real-time analysis of the data gathered on the retina or image plane. Because of your experience, both field and classroom, you have the capacity to analyze patterns and spatial relationships that a computer probably can never be programmed to duplicate.

Incidentally, why do we see "blue" or "green" or whatever color? Spectral variation in the magnitude of reflected energy = color. How many colors can the eye discriminate? (64) How many shades of GRAY (16).

II. Focal Length, Aperture, Shutter Speed, Depth of Field

To "take a picture" which contains the maximum amount of information possible, you need to understand a few simple things about SLR cameras:

Focal Length - distance from the lens to film.

Aperture - full aperture versus relative aperture; when you buy a camera, you usually check the aperture rating, the smaller the better; i.e., an f2.8 is a better camera than an f6.3 - a relative indication of the quality of the lens, measured by the RELATIVE APERTURE - the ratio of the of FOCAL LENGTH to LENS DIAMETER. a 55mm f camera with an aperture of 10mm (fully open) has an F/STOP RATING of 55/10 = 5.5; if the lens aperture was 20mm, the f/stop would be 55/20 = 2.75, a better lens.

Shutter Speed - the speed at which the shutter opens and closes; 1/50 sec, 1/100, 1/500th. You can use this to get equal exposure on the negative under differing sunlight conditions; you can also use this to increase or decrease DEPTH OF FIELD.

> Using the F/Stop & Shutter Speed: the f/stop relationship is important - first, the smaller the number, the larger the relative aperture; moving from an f4 one "stop" to an f5.6 setting decreases the amount of light by 1/2 ... the effective diameter is decreased by half for every f/stop. an f/16 passes only 1/16 the light of f/4 (1/2 reduction f/4 --> f/5.6, 1/4 to an f/8, 1/8 to f/11 and 1/16 to f/16).

Depth of Field - The area between the nearest and farthest point in focus is the Depth of Field. As the f/stop number gets larger (smaller opening) the depth of field increases!

III. Characteristics of Aerial Photographs

Photo Annotations

USDA Photography - usually located on the north end of the photo and contain the following items:

Date (1-31-92)	Roll - Frame Number (3986-100)
Scale (40)	Flight Designation (NHAP, HAP)

Contract Photography - location is dependent upon orientation of flight lines.

Fiducial Marks

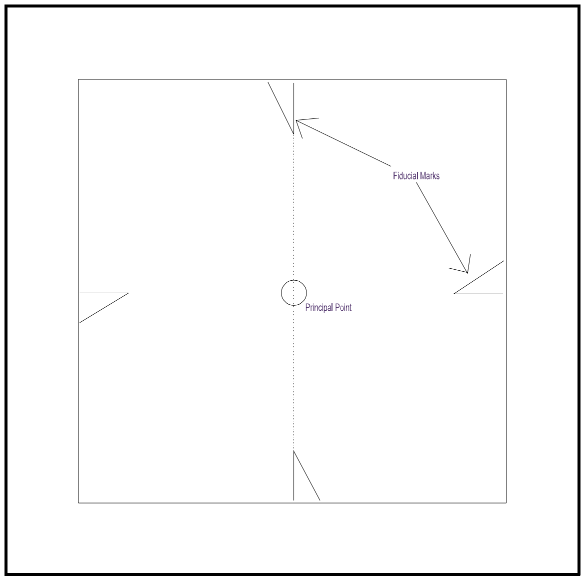
Fiducial Mark - an indicator of the center of the film plane in the aerial camera. The marks appear in the middle of each photograph border.

Principal Point

Principal Point (PP)- the optical (and geometric) center of the film plane of the photograph.

The principal point of each photograph is located by connecting the fiducial marks, at the center of the photograph. There is only one PP per photo.

Figure 5-2: Fiducial Marks



Marking PP - use small pin prick and draw an ink circle 0.2 inches in diameter.

Conjugate Principal Points

Conjugate principal point (CPP) - the PP of an adjoining photograph for photos with at least 55% end overlap. Each photo of a stereo pair will have at least 2 CPP's. If sidelap is sufficient, there will be 3 CPP's along <u>each side</u> of the photo. Why are there 3 additional CPP's along each side?

To locate CPP's - use ground detail or stereoscopically transfer under the stereoscope. Prick with pin and draw 0.2 inch diameter circle.

NOTE that on a tilted image, there are three (3) possible photo centers:

1. the PRINCIPLE POINT (PP): a geometric or optical center, found by connecting fiducial marks.

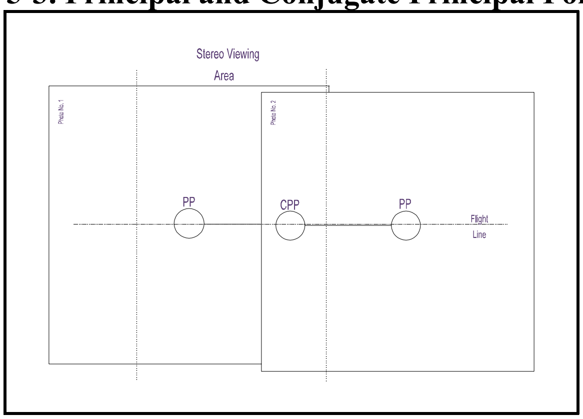
2. the NADIR POINT (NP): a plumb point - a point perpendicular to the 0 datum passing through the lens at the instant of exposure.

3. the ISOCENTER (IC); the intersection of the **axis of tilt** and the line between **NP and PP.**

Overlap, End Lap, or Forward Lap

In order to have stereo coverage, the camera shutter speed is synchronized with the ground speed of the aircraft so that each succeeding photo overlaps the previous photo, along the line of flight, by a stated percentage of coverage. For example, 60% end lap means each photo overlaps the previous photo by 60%.

Figure 5-3. Principal and Conjugate Principal Points



Sidelap

Photos generally have side overlap of 20%-30% (between flight lines) to insure total coverage of the target area.

Overhang

The percentage of an image on the first and last flight lines that falls outside the boundary of the target area; usually 20-25%.

Flight Line

Line of flight is obtaining by connecting the PP's and CPP's.

Air and Stereo Base

Air Base - the line of flight between two exposures (photos) of stereo pair.

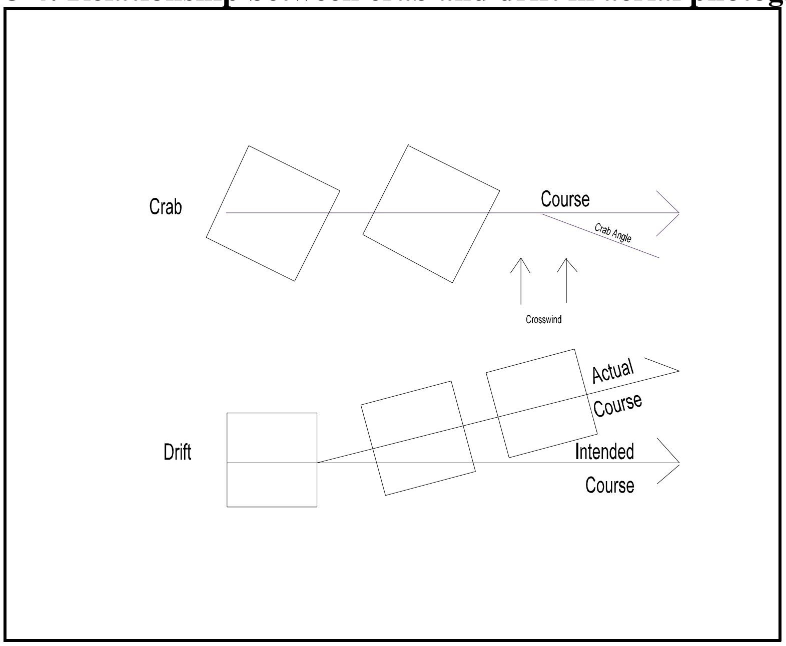
Stereo Base - the length of the line between the PP and CPP.

Crab and/or Drift

Crab - The departure from 90 degree orientation of successive photos from the line of flight caused by the plane crabbing into the wind to avoid drifting off the intended course.

Drift - The departure of the actual flight line from the intended course.

Figure 5-4: Relationship between crab and drift in aerial photography.



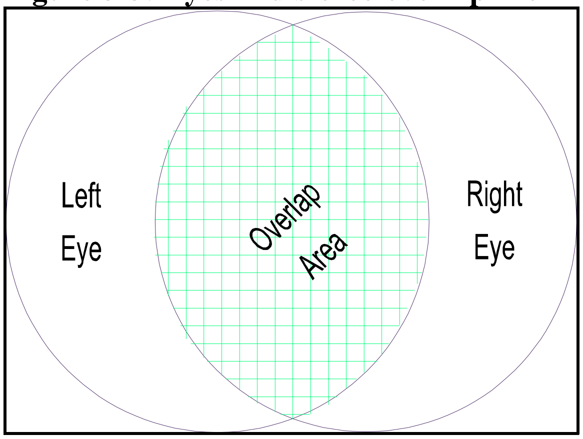
IV. Stereoscopic Vision

Binocular vs. Monocular Vision

Monocular Vision - image viewed from one viewing station; i.e. using one eye only, or taking a single photograph.

Binocular Vision - simultaneous vision with a pair of normal eyes where each eye focuses on the same object from a different position (i.e. viewing station) and transmits a slightly different image to the brain, where the two images are fused into a three dimensional counterpart of the viewed object.

Figure 5-5: Eyes and stereo overlap area



Stereoscopic Vision

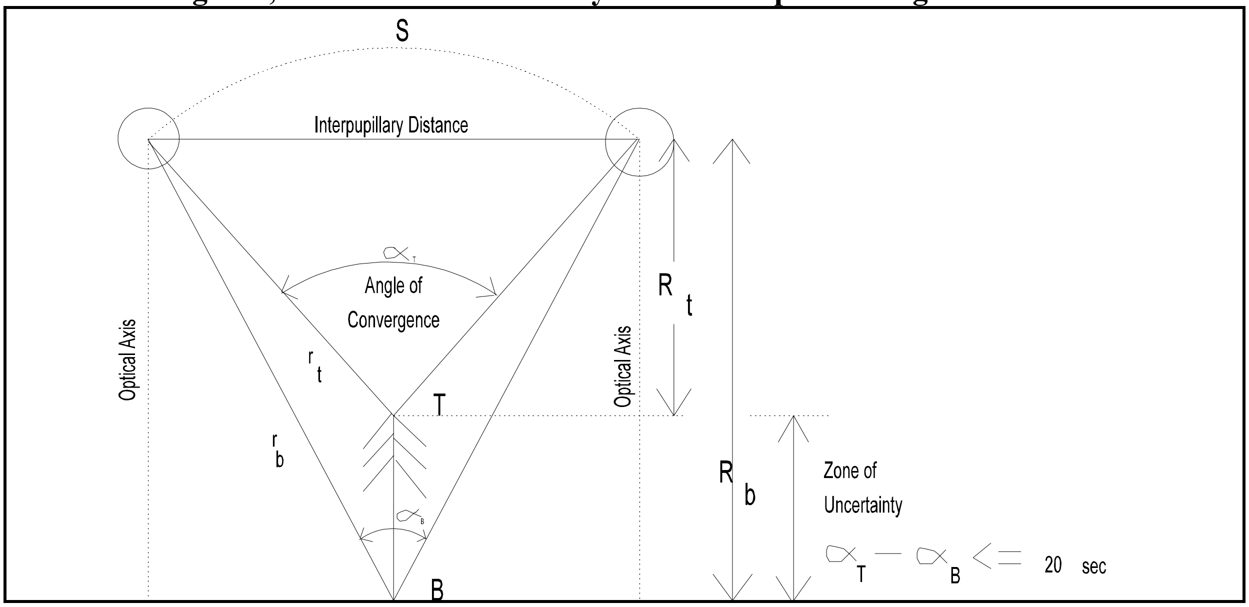
Stereoscopic Vision - the ability to perceive a three-dimensional image from viewing two images of the same object from different angle, and mentally merging them into one image that has length, breadth, and depth; i.e. three dimensions.
Called anaglyph principle.

The third dimension of depth perception is obtained when objects are viewed with two eyes, a process called stereoscopy. When each eye focuses on the same object from a different viewing position and transmits a slightly different image to the brain, the brain fuses the two images into a three-dimensional image of the original object. The result is known as binocular or stereoscopic vision.

Interpupillary or Base Distance - The linear distance between the pupils.

Limit of Depth Perception

Figure 5-6: Relationship between interpupillary distance, optical axis, angle of convergence, and zone of uncertainty in stereoscopic viewing.



Zone of Uncertainty - if angle of convergence is less than 20 seconds, the average person cannot detect range difference.

If eyes are focused on horizon, at infinity, the optical axes are in essence parallel.

$S = r_T \alpha_T$ **where** S = **chord distance**

α = **arc angle (radians)**

r = **radius of arc**

At very small α'**s**

$D = S$

$r_T = R_T$ **thus**

$$D = R_T \alpha_T$$

$$R_T = \frac{D}{\alpha_T}$$

For $D = 2.65''$ **and** α = **20 secs = (0.000097 radians)**

$$R_T = \frac{2.65''}{0.000097} = 2{,}276 \text{ ft., maximum range}$$

Error in Ranging Estimation

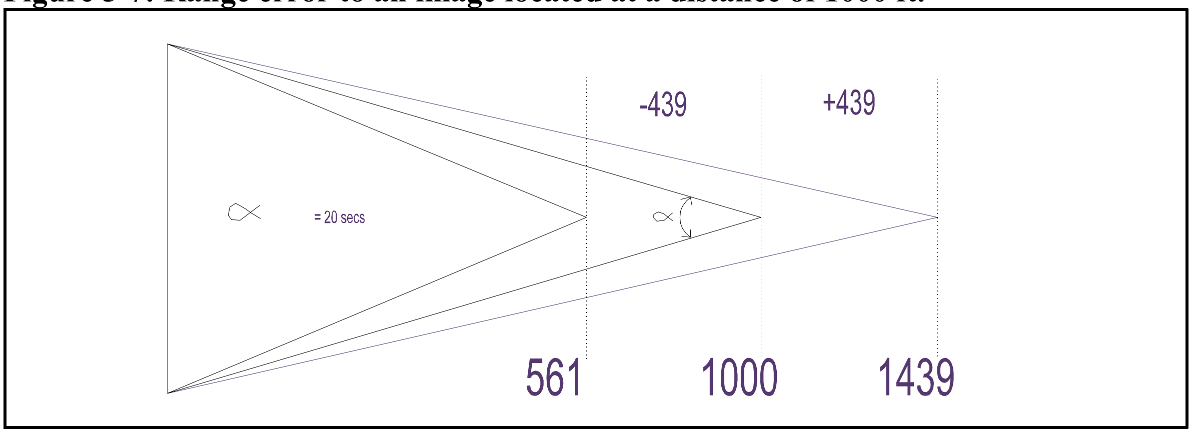
The error in ranging estimation or zone of uncertainty is a function of the range to the object and the limit of depth perception.

$$\mathit{Error} = \frac{(\mathit{Object\ Range})^2}{\mathit{Limit\ of\ Depth\ Perception}}$$

For Range = **1,000** *ft.* *and Limit of DP* = **2,276** *ft.*

Error = +/- **439** *ft.*

Figure 5-7: Range error to an image located at a distance of 1000 ft.



Vertical Exaggeration

Vertical exaggeration - objects seen in stereo have exaggerated vertical distances with respect to horizonal distances; i.e. scale disparity.

$$VE = \left(\frac{AB}{H}\right) \div \left(\frac{EB}{h}\right) = \left(\frac{AB}{H}\right)\left(\frac{h}{EB}\right)$$

where *AB* = *air base, feet*
H = *camera height, feet*
h = *height from stereo image to eyes,* 45*cm*
EB = *eye base disance,* 6.4*cm*

$$\mathit{since}\left(\frac{EB}{h}\right) \mathit{\ is\ a\ constant} = 0.14 = \frac{6.4cm}{45cm}$$

$$VE = \left(\frac{AB}{H}\right) \div c$$

The larger the base-height ratio, the greater the vertical exaggeration factor; e.g. a ratio of .15 produces 1.0 exaggeration, but a ratio of 0.45 produces a 3.0 exaggeration. Also, H is a function of desired scale and focal length: f/H=d/D=1/RF.

V. Stereoscopes

The stereoscope has several important functions:

a. It causes the lines of sight to be parallel.
b. It lengthens the focal point; so you get the perspective of being in the airplane when the photo was taken.
c. It may or may not provide magnification

Types of Stereoscopes:

Pocket - 2.5x magnification; only see portion of overlap
Mirror - uses lenses for magnification; entire overlap

VI. Preparing Photos for Stereo-Viewing

Introduction: In viewing a stereo-pair of photographs, the left eye looks at the left photograph and the right eye at the right photograph. It is essential that the photographs be oriented in the exact relative position as which they were taken. Proper orientation is very important because (1) it insures obtaining the maximum relief effect, (2) it contributes to the accuracy of the work, and (3) above all, it minimizes eye strain, a vital consideration where work is continuous for a period of time.

Two procedures must be accomplished in order to orient a pair of photographs for proper stero-viewing: first, the center or principal point of each print must be located; and second, the line of flight from the center of one photograph to the center of the other must be determined.

Step 1: Locate and Label Principal Point

To facilitate the location of the center, an indicator is accurately adjusted in the aerial camera to record marks on the film from which the center can be determined. These marks are known as fiducial marks. Marks vary with the different types of cameras; note the difference in fiducial marks between ASCS photography and NASA imagery. Lines drawn to connect opposite fiducial marks will intersect at the optical center of the print (i.e. film plane). This point is known as the **principal point (PP)**. Older prints may have brackets in the corners, or in the case of some Canadian photos, a small cross at the principal point.

Lines projected to obtain the principal point should not be drawn across the full width of the print; extend the lines near the center of the photograph only to form a small cross at the center. This avoids unnecessary defacement of the print and possible later confusion. When the principal point

(PP) is located, a small pin prick is made through the point and a circle drawn around it with compass and red ink to facilitate future recognition. In order to facilitate future mapping operations with the prints, all principal point circles should be drawn the same diameter. Circles should be two-tenths (0.2) of an inch in diameter, with the line as thin as possible.

Step 2: Determine Line of Flight with Conjugate Principal Points

The second step, determining the line of flight, is accomplished by the locating principal point of each photograph on each of the adjacent prints. In order to do this, each exposure must be made with at least 55% overlap. Otherwise, the center of one photograph would not appear clearly on the adjacent ones. The optical center of one print (PP), when transferred to an adjacent one, is called the **conjugate principal point (CPP)**. Conjugate points can be located and pricked by visual inspection of ground detail. If sufficient, identifiable detail around the point is lacking, the prints may be carefully aligned under the stereoscope and the conjugate principal point located by optically superimposing the principal point of one photo onto the adjacent photo of the stereo pair. Align the prints several times to assure that you have obtained the maximum stereo-relief possible, and check the tentative location of the CPP each time (see section below on Obtaining Optimum Stereo).

To optically transfer the PP of the left photo to the right photo, the right photo is overlapped on top. While viewing the "common" area under the stereoscope, move the pencil from right to left on the right photo until the tip appears to be in the pen prick at the center of the PP circle. When the location of the CPP is confirmed, prick the CPP, and draw a circle in black ink; 0.2 inches in diameter.

The Flight Line

The line of flight between the two exposures of a stereo pair is called the air base. The length of a corresponding line drawn between the principal point and the conjugate principal point on a photograph is called the stereo base. Since a plane seldom flies exactly in a straight line, the line passing through one conjugate point and the principal point on a photograph will seldom pass in extension through the other principal point. This variation in the direction of flight, caused by drift and/or crab, is why it is necessary to locate the points on each print and use the line of flight as a basis for orientation rather than just aligning the edges of the prints.

Orientation and Stereo-Viewing of Photographs

Introduction: Although it is convenient, it is not necessary to draw the flight line in ink on the photograph. Location of the principal points and conjugate principal points completes the necessary preliminary preparation of the set of prints for stereoscopy.

Normal eye separation distance: Determining the normal eye separation distance is the next step in orienting photos for stereo viewing and should be accomplished as follows:

Pair off with an adjacent student. Look straight ahead with eyes focused as far in the distance as possible. Have the other student stand in front of and slightly lower than you and hold up a piece of paper just under your eyes. The position (distance separation) of the pupils should be marked on the paper. Measure and make a note of this distance; it is your interpupillary distance that will be used in all subsequent stereo operations.

Orienting stereo-pairs for stereoscopic viewing:

A. The first step in orienting the pair of photographs for stereoscopic examination is to turn them so the shadows fall more toward than away from the observer. The mind is so accustomed to this arrangement that there is a strong tendency to see relief in reverse if the shadows fall away from the point of observation. A few minutes examination of a single print will usually illustrate this phenomenon, known as a pseudoscopic effect.

B. The second step is to superimpose one print on the other so that the recognizable gross features overlap. It is then apparent which is the right hand print and which is left. If the overlap is so great and the field of vision so small that corresponding features cannot be brought into the field of view for the pocket stereoscope, the prints are probably reversed. Reversal of the prints is very possible with the greater separation of a mirror stereoscope. With print reversal, topographic relief will appear in reverse as with incorrect orientation of shadows, only much more strongly. Occasionally a **psuedoscopic** effect is obtained intentionally to facilitate interpretation of detail, or to measure the depth of a well or pit.

C. The third step is to align the photographs along the line of flight (use a straight edge) and to separate the principal point of one photo from the conjugate principal point of the stereo-pair a distance equal to (or slightly less than) the interpupillary distance.

D. The last step is to open the stereoscope to the measured eye separation (interpupillary) distance, and place it up over the stereo-pair so that the long axis of the lenses is parallel to the flight line. Look through the stereoscope. If objects and features are perfectly aligned, instant stereo-vision will result; however, if objects tend to be separated or "drag" together, use the following procedure to obtain optimum stereo-vision.

Obtaining Optimum Stereo-Vision:

A. Optimum Lens Separation: While looking through the stereoscope, observe carefully the relative height of some object. While maintaining your sight on this object, cautiously decrease the lens separation distance by a fraction of an inch. Return to the lens separation to the original position and then pull lenses further apart, all the while watching the selected object. If the original separation distance was correct, movement in either direction will cause an apparent decrease in the height of the object. However, if the separation distance was not initially correct, a point of maximum apparent height will be found at some point during the changes of the separation distance. Record this separation distance and repeat several times to obtain an average. Keep this average for future reference.

B. Optimum Print Separation: After initially determining the best lens separation distance, increase or decrease the print separation distance, holding the lens separation distance constant, to find the distance where the images fuse (i.e. remain "together") and appear to be in the "sharpest" focus.

C. Repeat Steps A and B until the lens and print separation distances remain constant. Record the optimum print and eye separation distances.

Stereo-Viewing of the Effective Area: With a pocket stereoscope, only a small portion of the total stereo area (approximately 14 cm) may be viewed on the end of one photo of the stereo pair. To view the area under the end of photograph, you can reverse the overlap or roll up (i.e. turn up) the end of the photograph between the lenses and slide the stereoscope (parallel to flight line). Use one hand to roll the end up and the other hand to slide the stereoscope. Be careful not to bend the photo and break the emulsion.

VII. Orienting Photos for Stereoscopic Viewing

In viewing a stereo-pair of photographs, the left eye looks at the left photo and the right eye looks at the right photo. It is essential that the photos be oriented in the exact relative position as which they were taken. Proper orientation is important because:

a. It insures obtaining the maximum relief effect.
b. It contributes to the accuracy of measurements.
c. It minimizes eye strain where work is continuous for a long period of time.

1. Measure Interpupillary Distance

Measure distance between pupils to nearest 1 mm.

2. Determine end overlap coverage of photos

Arrange the photos in order by print number. Determine which photo overlaps the other one.

3. Align photos along flight line with straight edge.

4. Orient photos so shadows fall more toward than away from you.
Pseudoscopic illusion - reversal of terrain.

5. Separate the PP on one photo from its CPP on the overlapping photo a distance equal to the interpupillary distance.

6. Place the stereoscope parallel to line of flight.

7. Move the photos closer or further apart until the images fuse.

8. To obtain optimum stereo vision:

Optimum Lens Separation - vary lens separation distance until the maximum apparent height of an object is attained. Measure and record the lens separation distance.

Optimum Print Separation - vary the print separation distance until the images fuse and appear to be in the sharpest focus. Measure and record the print separation distance.

9. View the effective area by sliding the stereoscope parallel to line of flight.

10. Reverse the overlap and view the other portion of the effective area.

11. To view the area under the end of the overlapping photo, roll the edge of the photo up between the lenses of the stereoscope.

Figure 5-8: Aligning photos for stereo viewing

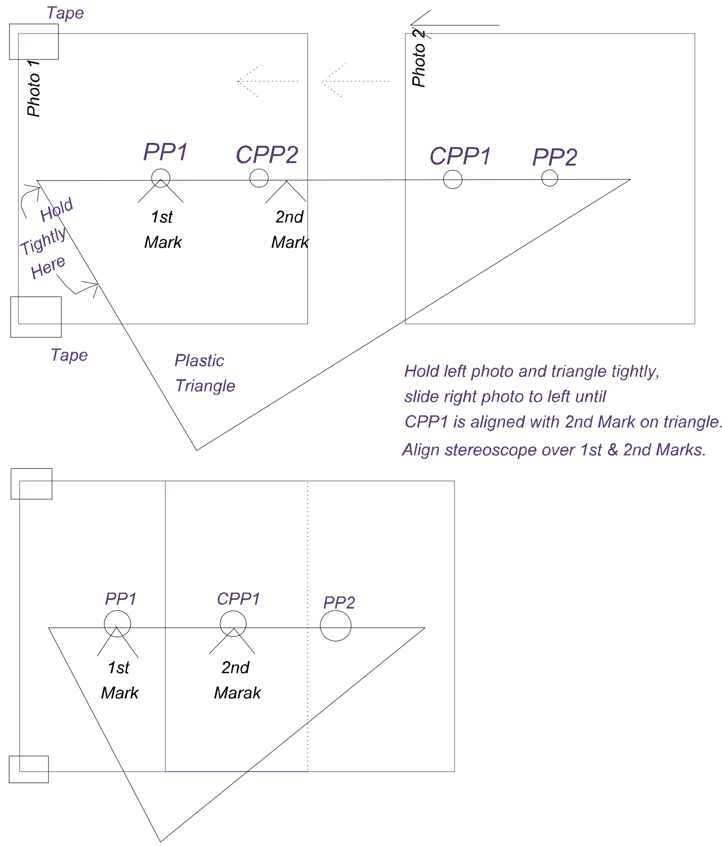
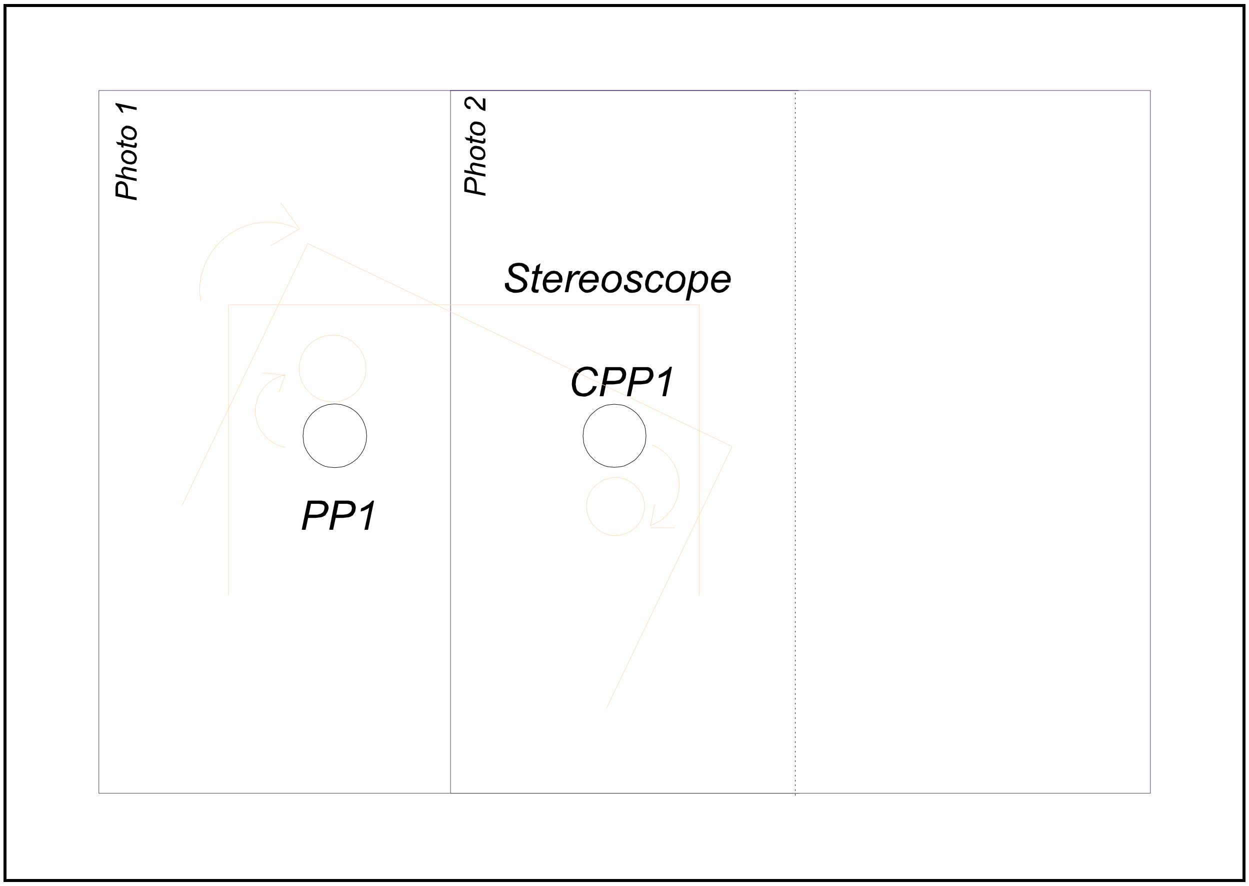


Figure 5-9: Y-Parallax



VIII. Use and Care of Aerial Photographs

Aerial photographs are expensive to purchase and can be damaged with improper handling, storage, marking, and use. New photography is flown every 5-10 years (ASCS=7-10, NAPP=5), so in most forest resource operations you will be using the same photographs for many years.

Marking on Photos: For temporary marks and gross to medium accuracy (i.e line width), use a grease pencil. Grease pencil marks are coarse, but they can be easily removed with benzene or acetone. A cotton swab moistened with an organic solvent should be lightly rubbed over the marks and immediately followed by a dry swab. The cleaning procedure can be repeated as often as necessary.

For more accurate markings, use a soft (H) pencil. Do not apply more than light pressure to the pencil or the emulsion of the print may be depressed and broken.

Permanent marks can be made with India ink or a permanent, thin, felt-tip pen, but remember the ink cannot be removed.

Do not use a ball point pen!

Taping Photos Down: When taping a photo to any surface, use only a small strip of drafting tape in the extreme corners. If you use regular masking tape, the tape should not be left in place more than a few days; it will become brittle over long periods and the adhesive will adhere tenaciously to surfaces. If the tape is extremely sticky, press the tape onto a table surface then remove it and put it on the photo.

When the tape is to be removed, lift the end of the tape attached to the photo and gently peel directly back, from the photo toward the other surface. If care is not taken, the emulsion may pull off with the tape.

Pricking PP and CPP's: Pin pricks should be made as small as possible; a large hole will decrease the accuracy of later work.

Rolling Photo's During Stereo-Viewing: Be careful not to bend the emulsion surface when rolling the photo end.

Storing Photos: Photographs should be stored flat. When photos are bent, the emulsion will crack.

Using Photos in the Field: When photographs are used in the field, they should be protected from rain and dirt with a hard plastic cover or sleeve. Most forestry supply firms sell a field cover for aerial photographs; they are worth the expenditure.

Remember that your lab grade and/or your job depends partially upon the accuracy of your work and that accuracy is partially dependent on the condition of the photos. Treat them properly.

IX. Stereograms

A stereogram consists of two sections from overlapping photos that are properly positioned and mounted for viewing with a lens stereoscope.

X. Image Sharpness and Tonal Contrast

In order to obtain the maximum detail and information from aerial photographs, the photographs must combine the maximum image sharpness with the maximum tonal contrast between dissimilar objects. Among the many variables that influence quality of the photography, the most important are:

a. light source/intensity
b. object reflectance
c. haze
d. filters
e. film emulsion
f. film development

We can't directly control the light source or the reflectance of the object, but we can use our knowledge of these variable influences to obtain the best photographs under the conditions. For example, we can take photographs during the mid portion of the day under a cloudless sky. We can reduce the effects of haze with a filter and by taking photographs after the passage of a cold front when the haze is minimal. We can choose a film that is most sensitive to the reflectance pattern of the object we want to discern and can modify the wavelengths of light reaching the film with a particular filter.

Image Sharpness

Sharpness is a subjective value that refers to the fineness of detail that is recorded and can be detected. It depends upon (1) the lens quality and focus, (2) lens setting, (3) camera motion, and (4) the film emulsion.

Scale affects resolution of detail. The smallest image that is recorded on film and recognized by the human eye under slight magnification is about 0.0005 inch in diameter. So at an RF of 1:40,000, the smallest recognizable object would have to be 20 inches (1.67 ft). in size or larger. Very distinct objects of small size may be see if they are linear in form (railroad tracks, roads, etc.) or if they are oriented parallel to line of flight.

Tonal Contrast

Contrast is the actual difference in density between the high lights and shadows on a negative or print.

High light - place where direct light is concentrated.
Shadow - place where direct light has been excluded.

Tonal contrast between objects and their background or between two similar but different objects is highly desirable. The tone recorded on a photographic image is determined by (1) the quality and amount of light reaching the object, (2) reflectance of light by the object, (3) screening of reflected light by the filter, (4) sensitivity of the film emulsion, and (5) conditions of exposure, development and printing.

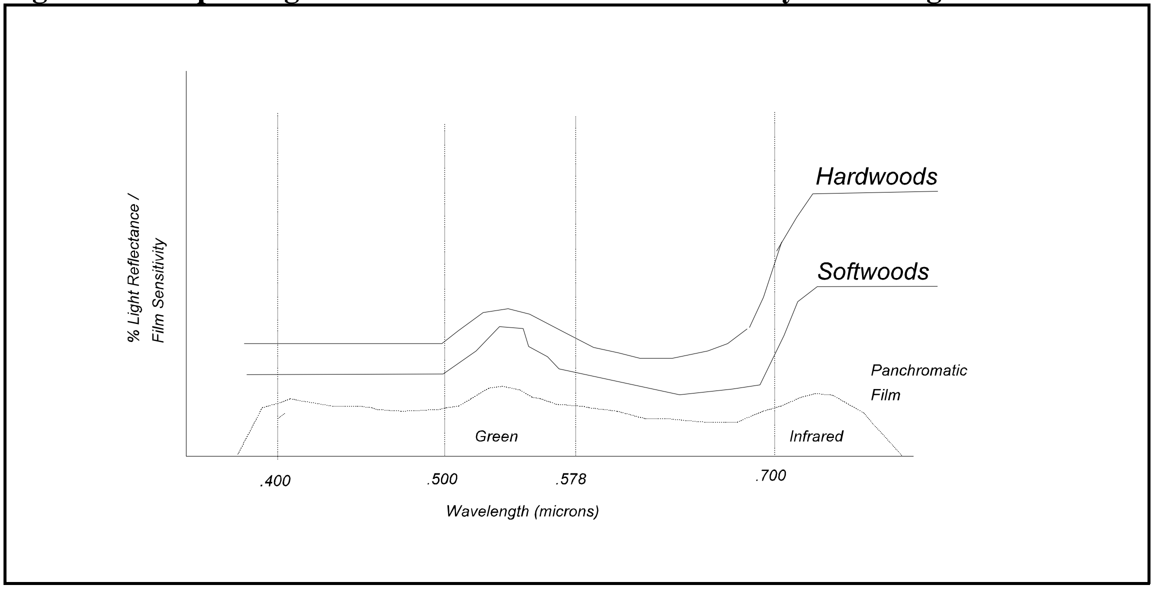
Detail in black-and-white photographs is provided by contrasts in tones. Detail is lost (i.e. "washed out") in very dark and (i.e. "submerged") in very light tones.

XI. Aerial Films

Panchromatic

Still probably the most widely used aerial film. It has about the same spectral sensitivity as the human eye. It provides "reasonably good" tonal contrast, wide latitude of exposure, satisfactory resolution, and low graininess (why is this important with enlargements?). The contrast can be appreciably sharpened by using the appropriate FILTER - see below! Wavelengths are rendered in shades of gray - i.e., white to black - the tone is comparable to the density of an object's color as seen by the eye; however, it is more sensitive in the red, thus, it is weak in the green and not so good for separation of <u>vegetative types</u> - trees species for example. As an aside, faster PAN is used under lower light conditions, but it is GRAINIER. (TRI-X Pan)

Figure 5-10: Spectrogram of Panchromatic film sensitivity and foliage reflectance

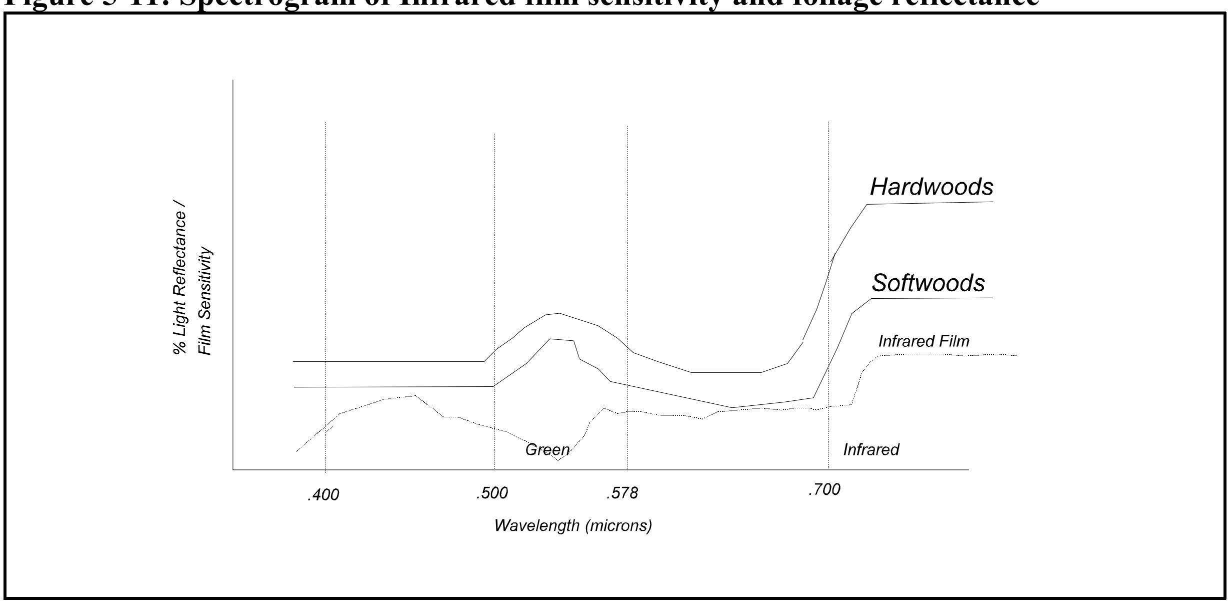


Black and White Infrared

Another type of black and white film, but sensitized to the spectral range 0.4 - 0.9 microns. (near IR 0.7 - 0.9 microns). It is most sensitive to blue and indigo in visible spectrum and extreme red. Not much sensitivity in the green wavelengths but high sensitivity in the infrared wavelengths.

Modified IR includes a portion of the visible spectrum and the Near IR whereas TRUE IR includes only the Near IR. Either way, this film opens up a new vista for us - beyond human vision.

Figure 5-11: Spectrogram of Infrared film sensitivity and foliage reflectance



Note: In Figure 5-11, there is not much distinction of hardwoods vs. softwoods in the visible spectrum, but look at the infrared end of the spectrum where there is good film sensitivity.

Healthy vegetation reflects IR strongly! Thus the high reflectance creates a dark negative and light positive print. Water ABSORBS strongly (unless they are highly turbid); thus water is light on negative and dark on positive. Soil moisture also registers in dark tones; the wetter the soil, the darker the tone.

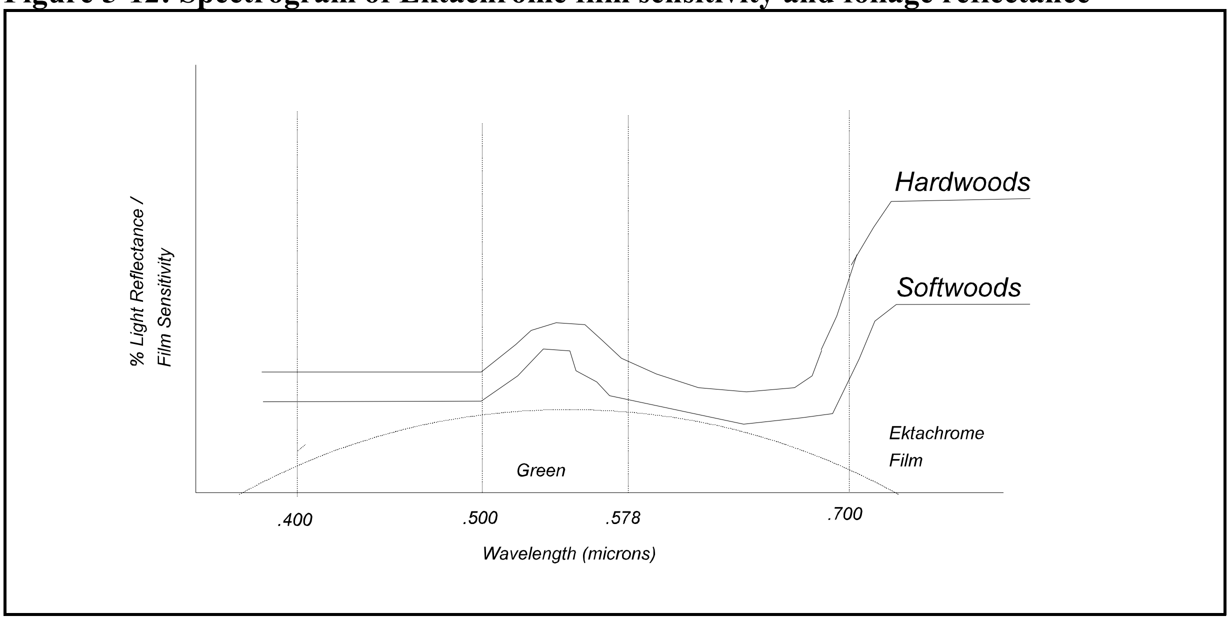
When you are operating in True IR, you can fly on hazy days when Color or Pan is not practical! Drawbacks - shadows are registered in true black and contain no information on True IR.

Two different types of filters are used with this film to regulate the wavelengths of radiation reaching the film. A No. 12 (minus blue) filter is used to produce modified infrared which is intermediate between panchromatic and normal infrared. Filters such as a No. 25 (medium red), and No. 89 (deep red; removes light below .680 microns) are used to produce normal infrared photographs.

Normal (Ektachrome) Color

Normal or Ektachrome color is very close in sensitivity to that of the human eye; thus natural color distinction between vegetation is limited to hues of green.

Figure 5-12: Spectrogram of Ektachrome film sensitivity and foliage reflectance



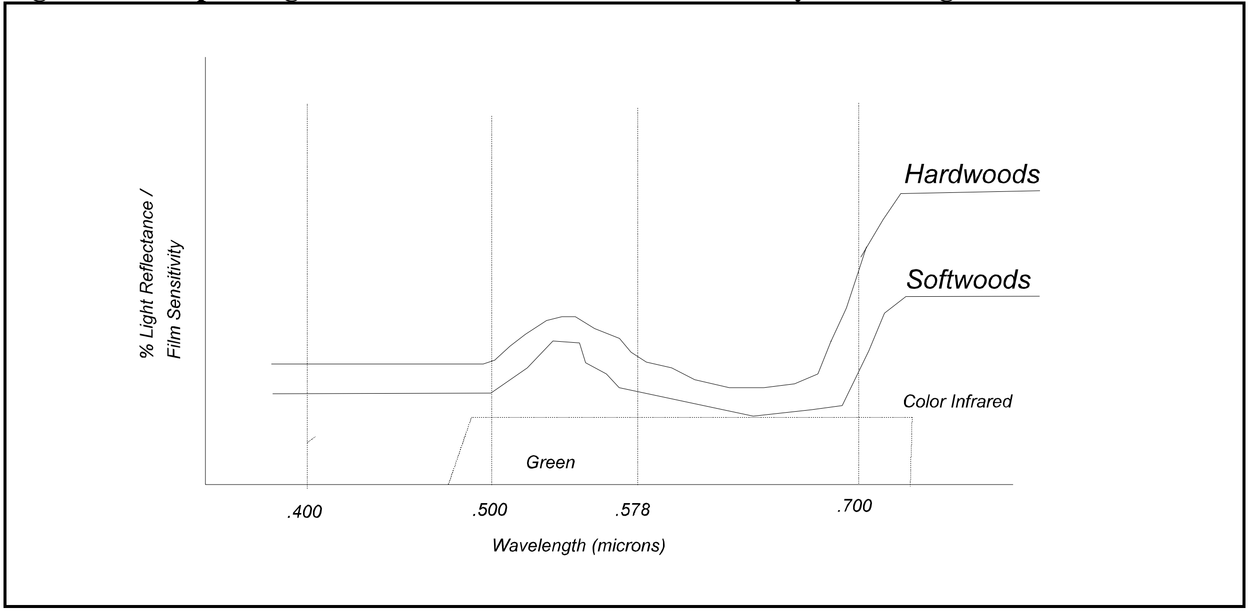
Color reversal vs color negative

Color reversal processes to a Positive Transparency film for use on light table - color negative processes to a negative ---> prints! Color negative film is good because you can derive a number of different products - color prints, B & W prints, and color or B & W transparencies.

Color Infrared or Camouflage Detection

Developed during WWII as camouflage detection. It is a three-emulsion color reversal film - near infrared energy is sensitive to differences in plant chlorophyll, and vegetation under stress show up very nicely. Beetle infestation, disease, water stress (either too much or too little water will cause stress) can all be detected at various stages of stress. Because a yellow filter is commonly used, this film type also has good haze penetration abilities. In addition, it has been used frequently as a means of species discrimination because it responds well to relatively small differences in chlorophyll between species, both within the hardwoods and the pines.

Figure 5-13: Spectrogram of Color Infrared film sensitivity and foliage reflectance



Multicamera Photography

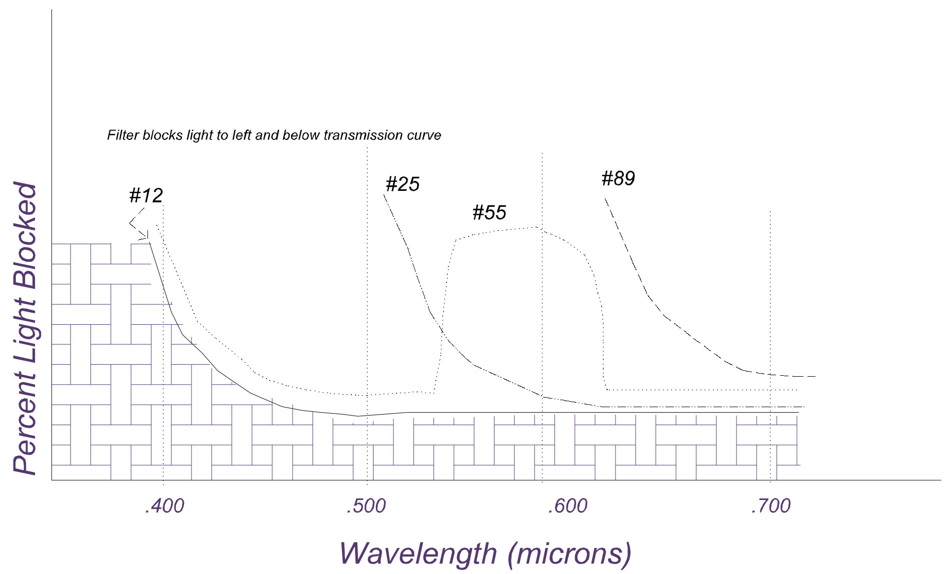
Use of two or more camera with different film/filter combinations; NO ONE film will solve all your problems - some can accomplish more for specific objectives.
NOTE - FILM EMULSIONS BECOME UNSTABLE ABOVE 0.9 MICRONS! beyond 0.9 MICRONS, WE MUST RECORD AND REPRODUCE ELECTRICAL SIGNALS.

XII. Filters

Filters remove undesirable random light from the spectrum of the film sensitivity. We use filters to reduce the effects of haze (skylighting), to improve contrast, to sense only certain wavelengths, or to provide uniform illumination of mapping camera formats.

A transmission curve shows the percent of light blocked in each wavelength.

Figure 5-14: Transmission curves for #12, #25, #55, #89 filters.



Examples of filters:

1. Yellow filter (wratten #12) blocks out mostly blue light; hence the name "minus blue" filter.

2. Green filter (wratten #55) blocks out blue and yellow light.

3. Dark red filter (Wratten #89) blocks all wavelengths except extreme red and infrared.

Light (energy) scattered by the atmosphere contains no useful information about earth features, and it also reduces CONTRAST RATIO of the scene, thus reducing the spatial resolution of the features, and reducing interpretability.

We can overcome much of the skylight (haze) by using an ABSORPTION FILTER - Haze Filters; absorb certain wavelengths.

MINUS BLUE - they reduce the effects of haze on both B&W and Color films; generally improve contrast - the tonal differences between earth features such as trees and pasture, or land and water. Specific filters are used with specific films to improve CONTRAST. For example:

Color film - Skylight or Wratten 2A

Color infrared - Wratten 12 or 15; a yellow filter than permits the passage of red and infrared wavelengths;

B & W IR - WR 89B (black) for maximum IR or WR 25 for modified IR.

Another type of filters are Polarizing filters - used for haze reduction. And yet another that is almost mandatory with large format cameras (9") is an **ANTIVIGNETTING FILTER** - constructed so that it creates a more uniform illumination across the face of the film. Used in conjunction with an absorption filter.

One other filter type that is sometimes important is the **Color Compensating Filters!** - this is actually a set of absorbing filters that are used during duplication of film to enhance certain contrasts - for example, we got several rolls of positive transparencies from NASA for the purpose of hardwood/pine discrimination - but for whatever reason, there was a greenish hue and the film was unusable! However, by duping through a green filter, the contrast was greatly improved and the film was acceptable.

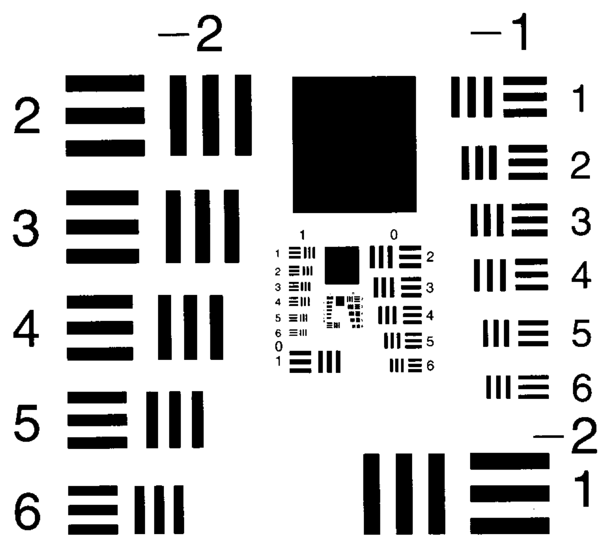
XIII. Resolution

There are two types of resolution; spatial and spectral. we'll deal with SPATIAL now. Spatial resolution is the capability of a film and/or lens to image spatial detail.

CONTRAST IS A FUNCTION OF TONE, BUT SPATIAL RESOLUTION IS A FUNCTION OF THE SYSTEM - both camera lens and film quality. Defined as the ability to "see" or distinguish LINE-PAIRS/MM. SYSTEM RESOLUTION CAN BE MEASURED BY FLYING A GIVEN CAMERA AND FILM OVER A LARGE BAR ARRAY TARGET ON THE GROUND and determining how many line pairs can be seen without magnification.

Figure 5-15: Typical tri-bar resolution chart of high contrast.

The actual chart is a reversal of this illustration (i.e., white bars on a black background).



The effects of the SCALE and RESOLUTION can be expressed as follows:

$$\textbf{Ground Resol(m)} = \frac{\textbf{recip of RF scale}}{\textbf{system resol(line prs/mm)} * \textbf{1,000mm/m}}$$

For example, if scale is 1:20,000 (from f=300mm and H=6,000m) and system resolution is 40 line pairs per mm then,

Ground Resolution(m)= 20,000/(40 pairs/mm x 1,000mm/m)
= 20,000/40,000
= 0.5 meters

The width of a bar or space would be 0.25 meters; i.e. bar width is equal to bar space.

The width of a bar or space can be used to infer minimum ground separation, which is the minimum distance between objects on the ground that enables them to be resolved as individual objects. This value can also be used to indicate the size of the smallest object that could be detected on the film.

Resolution is determined by:

1. Camera system resolution; minimum of film and lens resolution.
2. Desired scale; 1:31,680 = 8 ft. minimum object, 1:15,840 = 4 ft. minimum object size.
3. Sharpness of edge definition; tonal contrast
4. Image blur limitations

D = 1.466667(S/F)(12/denominator of RF scale)

where D = inches of photo blur
S = aircraft speed in miles per hour
F = denominator of shutter speed (i.e. 1,000)
RF = denominator of RF (i.e. 20,000)

As scale gets larger, the blur gets larger. Can only vary aircraft speed for a fixed scale.

XIV. Season Considerations

The 4 seasons (spring, summer, fall, winter) represent 2 vegetative seasons (growing vegetation in summer and dormant vegetation in winter) and 2 transition periods (spring and fall).

Winter
- a stable period of vegetative and climatic conditions.
- evergreen species retain leaves.
- deciduous species have no foliage.
- snow gives good shadows, if not too deep.
- no ground detail if snow exists.

Summer
- conditions are stable also.
- both species groups have vegetation.
- shadows are scarce.
- good time for B&W IR with #12 filter for species differentiation.

Fall - distinction between species during fall coloration changes.

Spring - "hot spots" (where ray of sun goes through the photographic point and falls within the area resulting in over exposure.

XV. Economic Considerations

The economic considerations of aerial photography are related to film, season, scale, resolution.

Film Cost

Panchromatic is cheapest, but modified infrared is only slightly higher. Color is about 4-5 times higher than B&W film.

Season

Season cost is related to weather and number of photographic days. Winter has more available days than summer with no clouds or haze.

Scale

Scale is the result of desired resolution and format size. If you double the scale, you increase the number of photos by a factor of four. The number of photos = $(\text{old rf}/\text{new rf})^2$.