Lesson 12

Stereoscopy and Photo Preparation

Steven J. Steinberg

Description: The lessons in this section focus on stereoscopy and photo preparation. We begin with a discussion of the principles of stereoscopy. This is followed by the identification and description of major image points, effective area, and neat model. We then practice stereo viewing and point transfer followed by the delineation of the effective areas of a photo set. Finally we examine this stereo model to locate points in the terrain.

Principles of Stereoscopy

Stereoscopy is the science dealing with the methods by which three-dimensional effects are produced. Using our knowledge of stereoscopy, we are able to create three-dimensional views from two-dimensional (flat) images. When interpreting aerial photography, our ability to include three-dimensional information greatly enhances our ability to gather information from the photos.

The basic requirement for obtaining a three-dimensional perspective is simple; we require two different views, or looks, at the object. Our two eyes provide us with these two different views as we look at the world around us. As we look at any object, our eyes converge so that each eye looks directly toward it. The angle of the convergence is known as the **parallax**. The closer we are to an object, the greater the angle of parallax (figure 12-1).

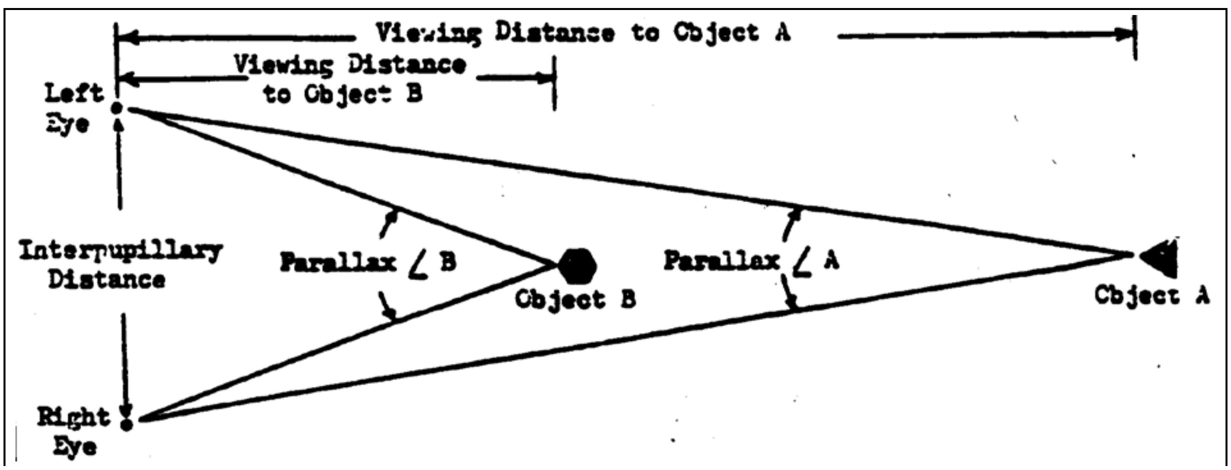

Figure 12-1. Schematic diagram illustrating the role of a parallax angle difference in depth perception. In this case, parallax angle B is greater than parallax angle A and, therefore, object B appears closer to the observer. (Meyer)

The apparent depth of any scene, its relief, is a function of several factors:

1) Distance from the eyes to the nearest point.
2) Distance from nearest to farthest point.
3) Effective distance between the eyes (**interpupillary distance**).

Individuals with sight in only one eye, monoscopic vision, cannot see a true three-dimensional perspective. Similarly, if vision is binocular, but one eye is significantly weaker than the other, stereoscopic vision may be difficult or impossible. Vision correction by glasses or contact lenses will compensate for the latter of these.

The limit of unaided human eye stereoscopic vision is 1,500 to 2,500 feet since beyond that the lines of sight are essentially parallel. To increase the distance at which true three-dimensional effects can be attained, we must somehow increase interpupillary distance. Fortunately, using aerial photography we can accomplish this quite easily by taking vertical overlapping photographs at regular intervals (figure 12-2). By viewing the resulting photographs with an optical instrument that permits viewing the photo pairs stereoscopically, the viewer actually "occupies" the individual aerial camera stations with their eyes. This effectively places each one of their eyes at the position of the airplane at the time of the photograph and achieves an effective interpupillary distance of

hundreds or even thousands of feet.

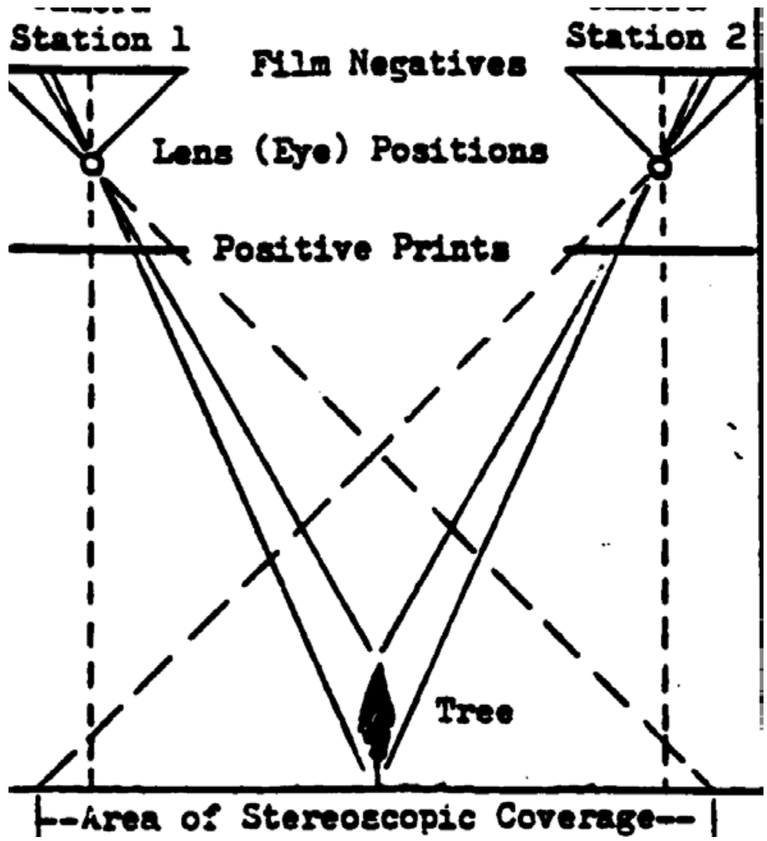

Figure 12-2. Diagram illustrating the taking of a stereoscopic
pair of aerial photographs. When viewing the prints, the interpreter's eyes "occupy" the aerial camera stations, thus achieving a great increase in interpupillary distance in the

Stereoscopes

The tool for viewing stereo pairs of photography is known as a **stereoscope**. Several different types are available, each having particular characteristics that make them more or less desirable for a given application. The major types are described in detail below:

The *pocket stereoscope* is the most inexpensive and portable type. Priced from under $10 to around $100, most have 2× magnification. Some of the better models have higher (up to 4×) magnification settings. Due to their small size, pocket stereoscopes have the disadvantage of requiring the photo edges to be curled back to permit viewing of the larger format photographs. However, their portability make pocket stereoscopes ideal for use in the field when a quick look at the stereo model is needed and your interpretation lab is a clipboard or the hood of your vehicle.

Mirror stereoscopes are the preferred type for in-depth photo interpretation work. These are also available in a field-portable type, though they are not quite as convenient and mobile as the pocket type. Field portable models vary in magnification from 1.5 to 3×, depending upon manufacturer. Costs vary from approximately $100 to $500.

Non-field type mirror stereoscopes are usually equipped with additional, swing-in, magnification lenses with a range of 1 to 1.5× or 1 to 1.8×. Most also have optional 3× binoculars and often stronger binoculars (5×, 6×, 8×) are available. Of these, 3× magnification is typically sufficient for most natural resource interpretation projects. A good quality non-field type mirror stereoscope with 3× binoculars and hard-shell carrying case will cost in the $1,000 to $2,500 price range. A major advantage of mirror stereoscopes is that the photographs do not need to be overlapped for viewing. Several models can be purchased with tracking table that enables the interpreter to move the stereoscope over the photographs.

Prism stereoscopes are at the high-end of the stereoscope world. The Bausch and Lomb type zoom stereoscope is still available in the marketplace. Prices vary, depending upon accessories, but run approximately $8,000 and up. The Old Delft Scanning Stereoscope is no longer produced, but a large number of these units are still in use. Delft stereoscopes are sometimes available for sale in the classified ad sections of the major remote sensing journals. The primary, and very desirable features of prism stereoscopes are high quality optics, variable magnification and means for tracking across the photographs. However, prism stereoscopes are not field portable.

Important Image Points

Figure 12-3 shows several of the important image points of an aerial photograph which are described below.

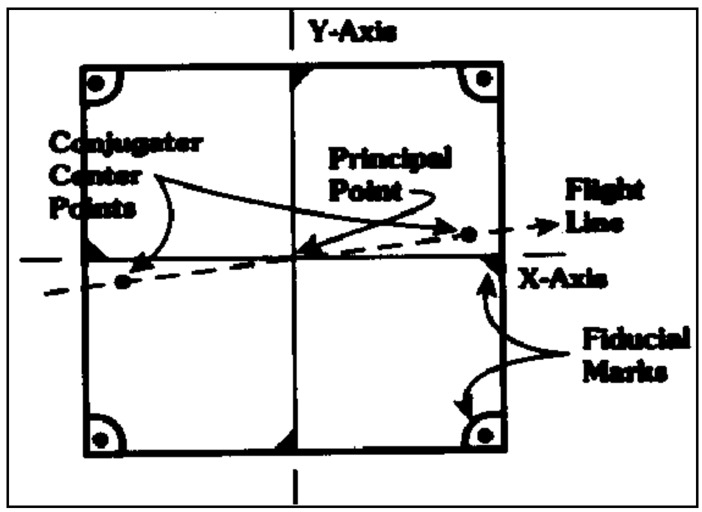

Figure 12-3. Air photo reference. (Rasher, 1990)

Fiducial marks are permanent reference points recorded on a photograph at the time it is taken. These marks are built into the mapping camera body or magazine. Four or eight fiducial marks are present on mapping quality photos. When no fiducial marks are included, a reasonable approximation is to use the corners of the photograph.

The point of intersection of lines drawn between oppositely positioned fiducial marks defines the **principal point** (**PP**) of the aerial photograph. This point is the optical and geometric center of the photo.

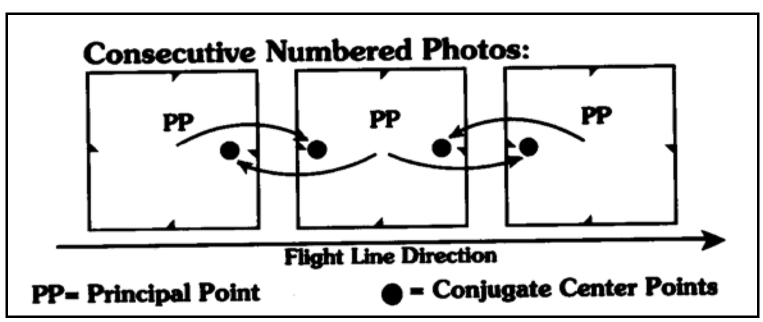

Figure 12-4. Relative locations of PPs and CPPs of air photos. (Rasher, 1990)

The apparent position of a principle point on the adjacent photograph is known as the **conjugate principal point** (**CPP**). Connecting a line through the CPPs and PPs provides a picture of the flight line that shows the path of the aircraft during the photo mission (figure 12-4).

The image of the point directly below the airplane at the instant of exposure is known as the **nadir**. This would be the imaginary point where a plumb-line touches the ground if it were suspended from the center of the lens of the aerial camera system at the time of exposure. The point on a photograph intersected by the bisector of the angle between the nadir and the perpendicular to the photo (at the principle point) is called the **isocenter**. On all but extremely tilted (oblique) photos, the isocenter is about halfway between the nadir and the principal point.

When photos are truly vertical, the principal point, photo nadir, and isocenter are coincident. Photos accepted as fulfilling contract specifications will usually be sufficiently close to vertical (within 3^{o}) so that differences in location of these points are inconsequential for most uses.

Photo Preparation

Proper photo alignment is necessary for precision measurement work and for avoiding eye strain when viewing photographs with a stereoscope for an extended period of time. First the photographs need to be aligned in their same positions as they were taken along a flight line. The principal point of each photo is located by drawing lines between the fiducial marks; the intersection of these lines is the principal point of the photograph. Conjugate principal points are marked by locating the principal point of the adjacent photo on each photograph. Then the flight line is drawn in on each photograph by connecting the principal point and conjugate principal points. Finally the two photos are then aligned so that the principal points and conjugate principal points lie on a straight line. At this point, the photos are properly aligned except for the separation distance. To estimate the separation distance, a reference feature and its conjugate are centered under each of the stereoscope's mirrors. If a stereo view is still not seen, the separation distance is adjusted until it appears.

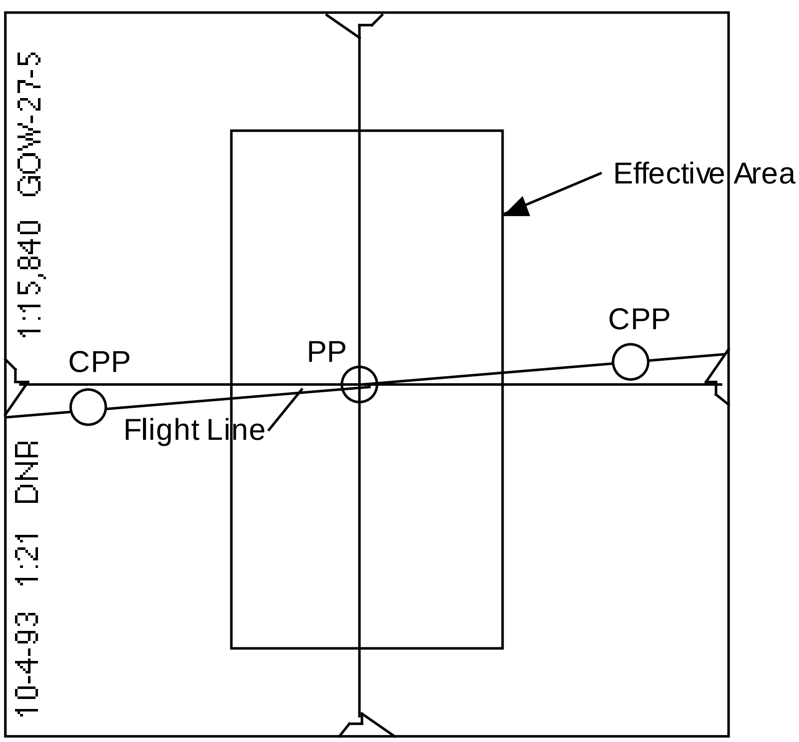

Figure 12-5. The effect area is in the central portion of the photograph. (Ozesmi, 1998)

THE EFFECTIVE AREA

The **effective area** is the central area of a vertical photograph delimited by the bisectors of the overlaps with adjacent photographs (figure 12-5). On a vertical photograph, the features located within the effective area have less **displacement** than their conjugate images on adjacent photographs.

The effective area can be delineated on an aerial photograph after the principal point and conjugate principal points are located and the flight line is drawn. The boundaries are determined by locating the midpoint of the overlap with adjacent photographs.

Reasons for using Effective Area:

Effective area boundaries are important in photo interpretation for two reasons: (1) on photography of mountainous country, the effective area defines the smallest usable area of least displacement on each photograph; and (2) the boundaries provide interpretation match lines between photo pairs which help to avoid duplication or gaps in delineation between photographs in the set. For example, if you were to count the number of old-growth stands in an area that covers several adjacent photographs, you would not duplicate or miss any stands by using only the effective areas on each photograph.

The effective area of the photograph has the least amount of displacement because it is closest to the principal point. Measurements should be made within the effective area. If measurements are needed outside the effective area, they can be made more accurately on an adjacent photograph.

Vertical photographs have a central perspective. Objects at different heights are displaced radially about the principal point. If the top of a feature is higher than average ground level, it will be displaced outward. If the objects are below the average ground level, they will be displaced inward. The greater the height or depth of features relative to the average ground level and the farther features are from the center of the photo, the greater their radial displacement.

A tilted photograph has a slightly oblique view rather than a truly vertical view. Because of the tilt, objects are displaced a small amount from the positions they would occupy on a truly vertical photograph. To deal with small amounts of tilt (less than 3 degrees), only the effective areas of photographs are used. By using only the central portions of photographs for photo interpretation and measurement work and because most photographic tilt is small (less than 3 degrees) on good quality vertical photography the effects of tilt displacement can usually be ignored without serious consequences.

By cutting out the effective areas of a group of adjacent aerial photographs and putting them together, a photo mosaic of an area can be made.

The Stereo Model

When two adjacent overlapping photographs are viewed with a stereoscope, their common areas form a three dimensional image called a **stereo model** or “neat” model (Figure 12-6). Thus the stereo model is the area on a pair of adjacent overlapping photos that is visible in stereo. It is located between the principal points and conjugate principal points. On the sides it extends to approximately the middle of the sidelap with the adjoining line of photographs.

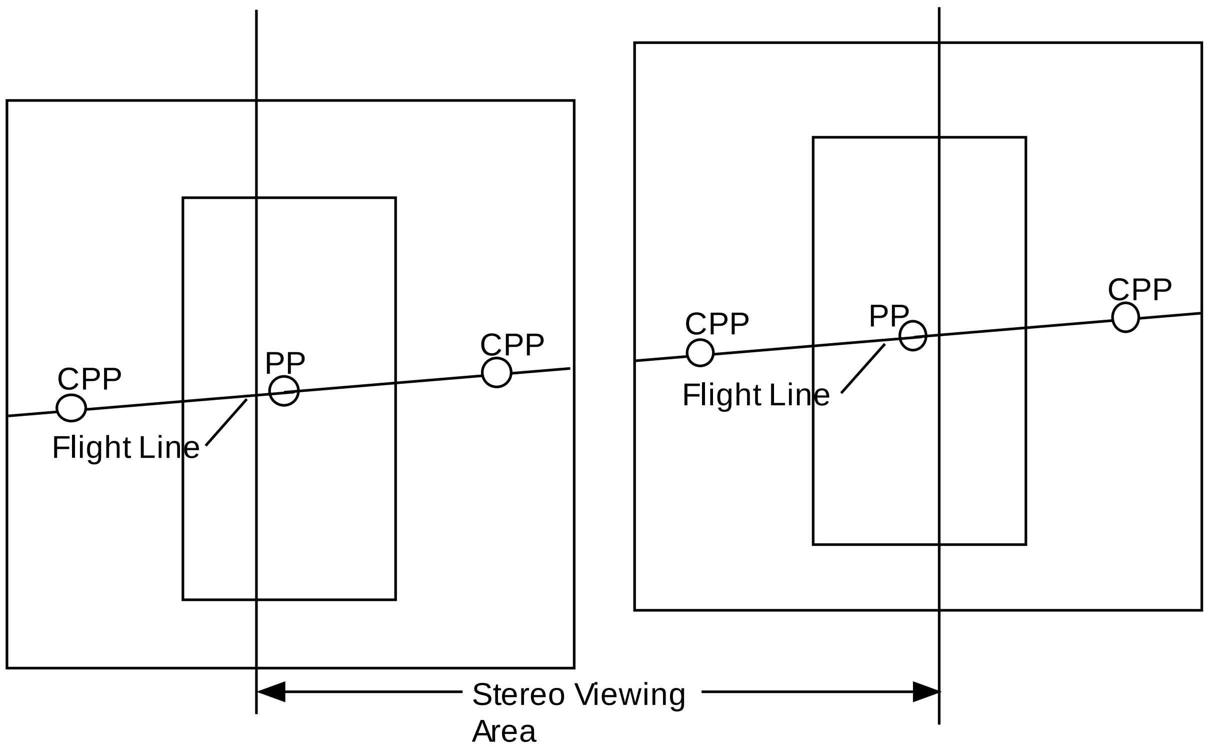

Figure 12-6. When the stereo viewing area is viewed with a stereoscope, a three dimensional image is formed which is called the “neat” model. (Ozesmi, 1998)

Lesson 12 Exercises

Materials: Point picker (botany teasing needle), regular pencil, fine point permanent pens, ruler, drafting tape, point transfer practice sheet, and six aerial photographs (Utah) consisting of two adjoining lines with a stereo triplicate in each line, pocket stereoscope, mirror stereoscope.

Photo Preparation Exercise:

The objectives of this exercise are to: 1) prepare photographs for stereoscopic viewing, 2) delineate the effective areas, and 3) view the neat model, identifying high and low points on the photographs.

Proper photo preparation minimizes eyestrain in viewing, expedites the arrangement of the photographs for stereoscopic viewing and interpretation, and makes it possible to make height and slope measurements.

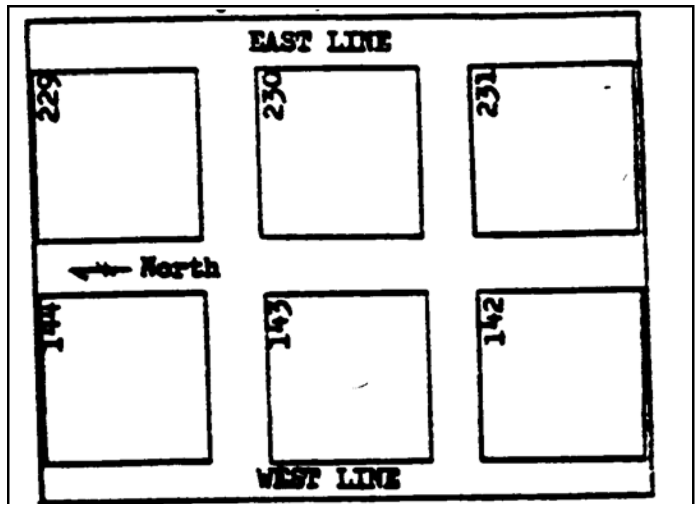

Figure 12-8. In-flight position arrangement photo preparation exercise images. (Meyer)

First, the effective area of each photograph will be determined. Then the principal points and conjugate principal points on each photograph will be located. Then the flight lines will be drawn in. Finally the neat model will be viewed and high and low points on the photographs will be identified.

You have been provided with two adjoining north-south lines of three overlapping photographs of the Wasatch National Forest, Utah. This photography was flown on June 25, 1963, at a nominal scale of 1:15,840 (4 in = 1 mile). Reading from north to south, the west line of photographs is numbered ELK-2-144, 143, 142; and the east line is ELK-2-229, 230, 231 (figure 12-8).

In-line and Between-line Effective Area Boundaries:

1) Remove all six photographs from the packet. Be careful to trim as much of the white border as possible without damaging the image area.

2) Place photo 143 over photo 144 in overlapping position so the flight line segments match up (step 1, figure 12-9). Do not tape down the photos.

3) Measure the **endlap** and mark the midpoint on the west side of both photos. Next, slide photo 143 down slightly across photo 144, perpendicular to the

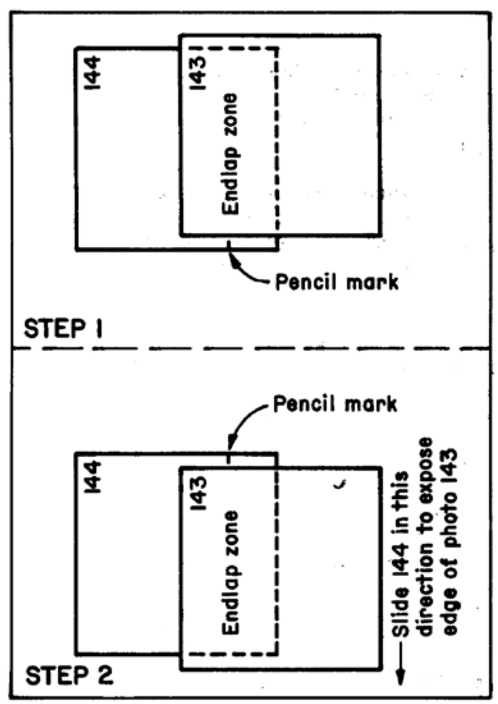

Figure 12-9. Location of endlap midpoints. (Crisco, 1988)

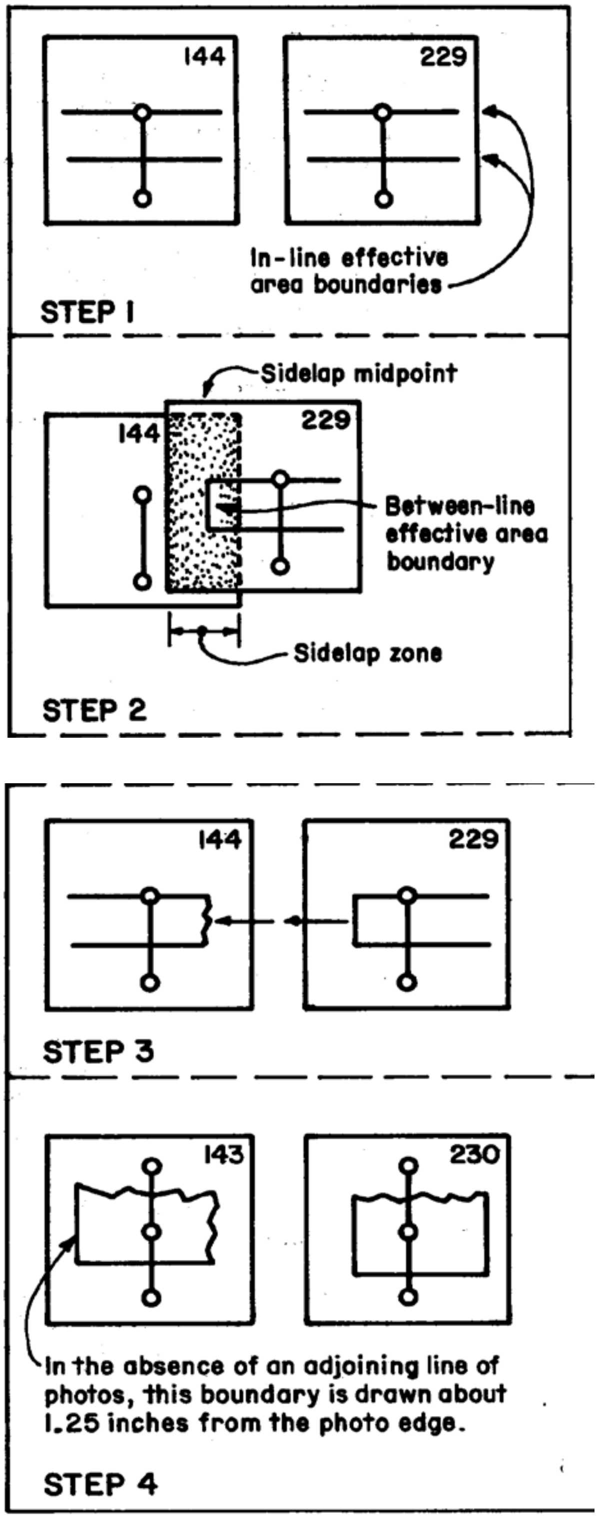

Figure 12-10. Effective area boundaries. (Crisco, 1988)

flight line, until the format margin on the east side of 144 is showing. Mark the endlap midpoint on the side of each photo (steps 1 and 2, figure 12-9).

4) Using a straight edge, connect these overlap midpoints on each photo with a light pencil line. This method is a shortcut and not entirely correct**. See the note at the end of the chapter for the correct technique**.

5) Locate the in-line effective area boundaries between stereo pairs 143-142, 229-230, and 230-231 as in Figure 12-9.

6) On the end photos in the flight lines (142, 144, 229, 231), rule straight pencil lines through the PPs, perpendicular to the edge of the photo (step 1, figure 12-9). This completes end lap.

7) Place the two lines of photography side-by-side in front of you with the titles away from you (step 1, figure 12-10).

8) Overlap photo 229 over 144. Visually aligning matching ground features, determine the **sidelap** zone in the same fashion as you determined endlap.

9) Locate the midpoints of the sidelap and rule straight lines on photos 229 and 144. Do not extend the line beyond the endlap effective area boundaries (step 2, figure 12-10).

10) Repeat the same procedure between the other two photo pairs (143 and 230, 142 and 231).

11) Since we do not have the adjoining photographs on the east of 229-231, or on the west of 142-144, simply draw the missing side of each effective area box approximately 1.25 in from the edge of the photo (step 4, figure 12-10).

Note: It is not unusual for the effective area boundaries to sometimes be located on *alternate* photos—particularly in areas with little, or no steep topography. In such cases, the effective area boundaries are determined in precisely the manner described above—but between every other photo.

Principal Points:

1) Lay out the six photos in flight line position with north (titled photo ends) to your left as in figure 12-8 above.

2) Beginning with photo 144, locate its principal point (PP) by drawing *light* pencil lines from the four fiducial marks (step 1, figure 12-11).

3) Pinprick the line intersection with a small, neat hole. Lightly circumscribe the pinhole in pencil, with a locator circle (steps 2 and 3, figure 12-11). Using the same approach, locate the PPs on the other photos.

Conjugate Principal Points:

1) Set up photos 144 and 143 for stereo viewing using the *mirror stereoscope* (titles to left, photo 143 right of photo 144). Arrange for stereo viewing so that details in the vicinity of PP144 and their conjugate images on photo 143 are in optimal viewing position. Locate, pinprick, CPP144.

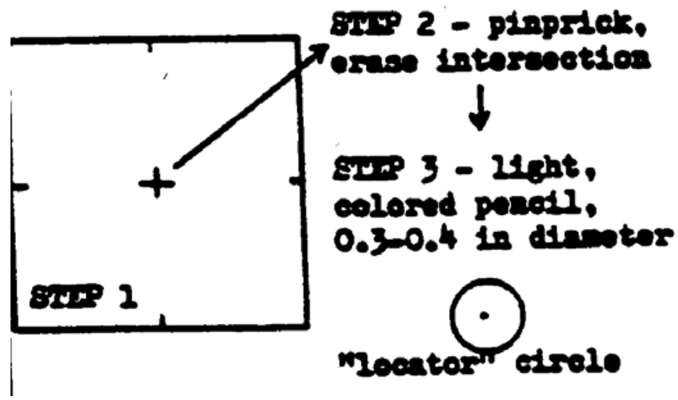

Figure 12-11. Location and identification of principal points. (Meyer)

2) Once you have located the CPP, circumscribe the point with pencil and inspect stereoscopically. If the point is properly located, circumscribe both the PP and CPP with 1 cm ink circles and erase the locator circles.

3) Repeat this process for all photos in the set. Remember that the center photos will have a CPP from each adjacent photo (figure 12-12).

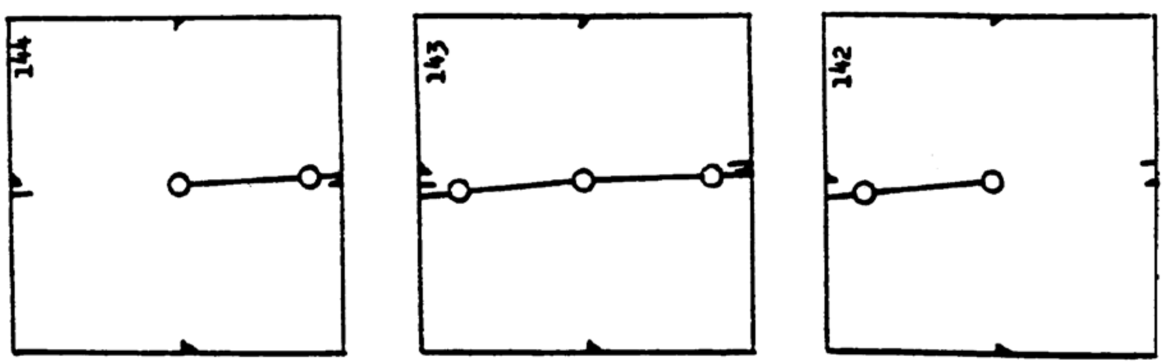

Figure 12-12. Diagrammatic portrayal of appearance of photos 142, 143, and 144.after location of principal points, conjugate principal points and flight lines. (Meyer)

Flight Lines:

1) Use a ruler and pen to draw the flight lines and extensions on both lines of photography (figure 12-12). *Do not* extend the lines through the circles. Also, be aware that the flight lines do not always line up with the fiducial marks due to aircraft flight path variations.

Helpful tips for mastering the skills presented in this lab

Stereoscopic Viewing:

When viewing in stereo for long periods of time, precise alignment of the stereo pairs will help to reduce eyestrain. The photos can be taped in place or held by magnets on a metal surface.

1) Position photos 144 and 143 (titling to your left) so that the flight lines are properly aligned. Tape the left corners of photo 144 in place using drafting tape.

2) Slide photo 143 directly to the right, being careful to keep the flight lines properly aligned. When photo 143 is close to the proper photo viewing distance for use with your mirror stereoscope, you may find it helpful to position it while looking into the scope.

3) Tape photo 143 when it is properly positioned and practice stereo viewing.

4) Practice scanning the **neat model**, the area between the PPs and CPPs of a stereo pair extending approximately to the middle of the sidelap with adjoining lines of photographs.

5) On the *east half* of the photo (143) pair neat model, locate and circle what appears to be the *highest point* of elevation and *label it H-1* with your pencil.

6) Within the same portion of the effective area, locate the *lowest* point of elevation and *label it L-1* with your pencil.

7) Have your partner repeat this procedure for the west half of the neat model and label the *highest* and *lowest* points of elevation as *H-2* and *L-2*, respectively.

8) Check each other's opinions regarding these points and when ready compare your photo set to the example provided by the instructor. Check the PPS, CPPs, effective areas and high and low points. <u>*Be sure to save these photos for a future lesson*</u>.

Point Transfer: (Optional only if you have time)

This exercise has two objectives: 1) To provide you the skill to pick, and accurately transfer points from photo-to-photo. Such features as principal points, plot centers, transect terminals, benchmarks, and legal description corners must often be accurately marked onto adjacent photos in a stereo pair; and 2) to provide you with practice in stereoscopic perception of small objects and features.

Procedure:

1) Tape the practice sheet flat to the working surface. If the surface is very hard, slide extra sheets of paper beneath them to permit making small, neat holes.

2) Use the lower half of the images for practice. Locate a feature easily seen on both photographs such as an isolated tree.

3) Select a tree (preferably on the photo under your weakest eye) and neatly pinprick it. The pinprick should be a small, neat, round hole made with the point picker in a vertical position.

4) Make a light, freehand, circle around the pinhole with a lead pencil. This **locator circle** will help you relocate the pinhole—particularly when it occurs in dark portions of a photograph.

5) Pinprick the same point on the adjoining photo and circumscribe it with a locator circle.

6) Compare the points stereoscopically by centering the lenses directly over the pinholes. If accurately picked, the two holes will appear to fuse and lie at the same level as the feature picked. If the holes are slightly *too close together*, they will appear to fuse and appear to *float*. If picked slightly *too far apart*, they will fuse and appear to *sink* (not as easy to visualize as those that float). If picked considerably too close together or too far apart, they will not fuse, but appear as two separate holes.

7) If the point transfer is satisfactory, circumscribe each pinhole with a neat, inked circle approximately 1 cm in diameter and erase the locator circles.

8) Pick, transfer, and circumscribe several well-distributed practice points on the *lower half of the stereogram*, so as to include a variety of conditions (e.g., open grassland, individual trees, forest canopy, valley bottom, hillsides, and heights of land).

9) Continue practice points until you feel comfortable with your ability to reliably mark them.

10) Pick and transfer several well-distributed points on all types of surface conditions in the *upper half of the stereogram*. If you create any obvious floaters or sinkers, label them as such. Have your partner inspect your points for accuracy before proceeding with the next

Note about effective area boundaries:

The method outlined in the lab manual for determining the effective area is not correct, according to additional sources (Caylor of USFS, Paine, etc.) . The correct method was not used in lab due to time constraints. You are free to use either the shortcut or the correct method in lab.

The problem occurs when drawing the lines around the effective area. The first line drawn on the endlap of one photo should be straight, It can be the mid-point between the PP and CPP or the mid-point of the overlap; these points are about the same. The second line, which is drawn on the overlapping photo should **not** be straight (figure 12-13). Points from the first photo's straight line should be transferred to the second photo and connected, dot to dot. This second line will only be straight if the terrain is level. In rough terrain, a straight line on the second photo will appear to hang above the ground over valleys and intersect hilltops. A straight line may be acceptable under certain circumstances: if only general measurements are needed, if measurements are not taken near the effective area boundary, or if the terrain is relatively level.

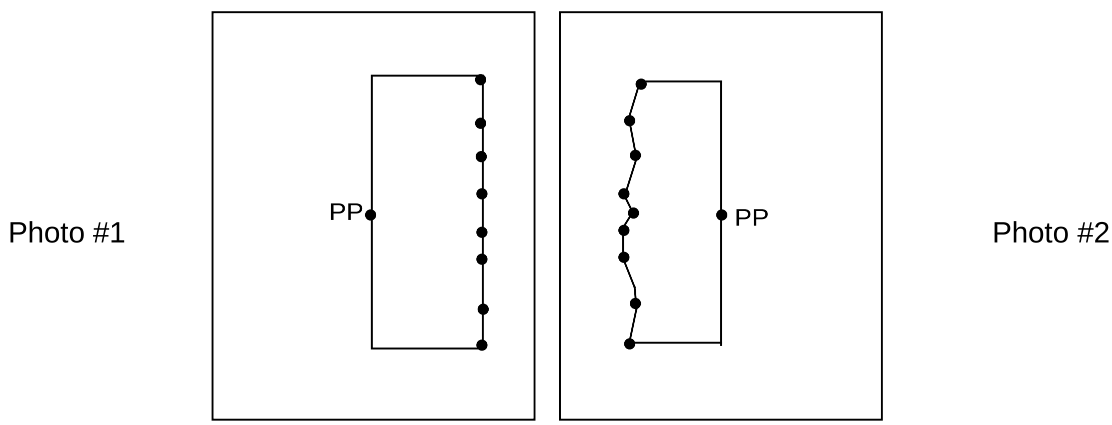

Figure 12-13. Corresponding lines on adjacent photographs. (Doyle, 2000)

Lesson 12 Outcomes

At this point you should:

1) Understand the basis for stereoscopy and parallax.

2) Know about the different types of stereoscopes.

3) Be familiar with the important image points and their definitions.

4) Know how to locate and transfer points from photo-to-photo using stereo viewing (point transfer).

5) Understand the importance of the effective area of a photograph.

6) Be able to prepare a stereo pair of photographs, including location of important photo points, flight lines and effective areas and how to set up photographs under a mirror stereoscope.

7) Begin to feel comfortable distinguishing points of different elevations in the terrain by viewing a three-dimensional neat model under the stereoscope.