Volume 1 - Module 7
Stereoscopy & Height Measurement

I. Review

II. Stereoscopy

Stereoscopy is the science and art that deals with the use of binocular vision for the observation of overlapping photographs or other perspective views and the method by which such views are produced.

- Essentially most of us with "normal" eyesight have stereoscopic vision (i. e. The ability to see and appreciate depth of field through the perception of parallax.)

Monocular Depth Perception

There are clues to the depth of field of objects which can be perceived/ appreciated monocularily. Monocular or one eye depth perception deals with "in-born" cues that humans instinctively employ when viewing objects. These are things we do we don't normally think about. Such cues or clues to the distance we think an object is at include the fact that close objects typically appear;

1. Larger
2. Brighter;
3. To be seen in more detail
4. To obscure the view of objects that are more distant.

There are limits, however, to monocular depth perception. Put a coin on end on a table and view it with only one eye. You see only the edge of the coin. The same can be said for looking straight on at other objects. A chimney viewed from directly above can appear to be as an: o . Is it a well; or is it a smokestack?

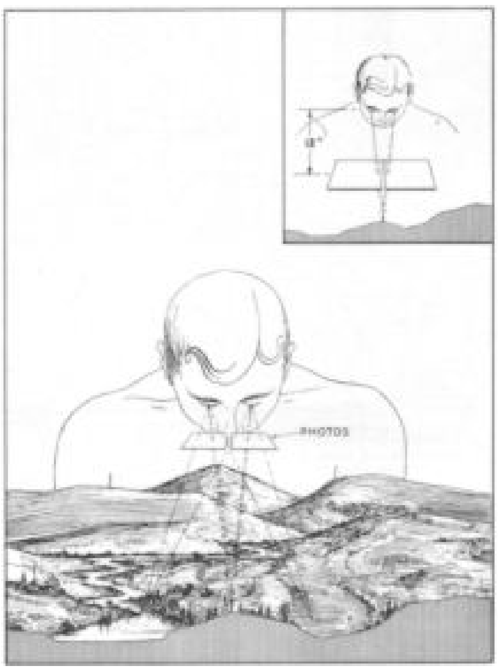
Binocular Vision

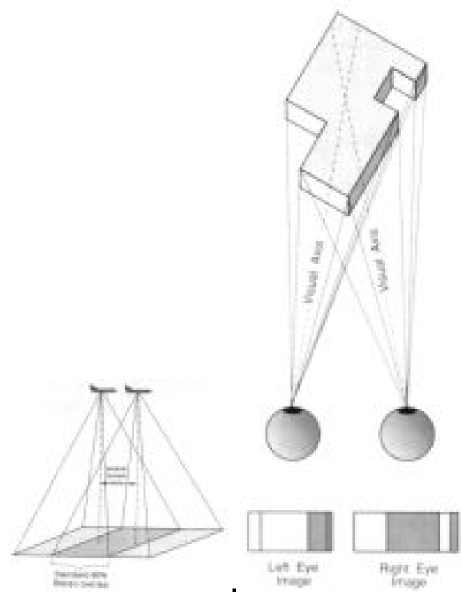
With binocular vision eye sees a different picture and the brain fuses the two images into one. {Talk about the dominant eye, and experiment with glasses that "turned the world up-side-down.} Stereoscopic vision is not an all or nothing affair. Individuals, depending on a number of factors (e.g. interpupillary distance, near or far sightedness, etc.) have stereoscopic vision to varying degrees. It is best if interpreters who do a lot of work with stereo have nearly equal vision in both eyes. Don't worry if you don't have equal eye strength, I don't either and it hasn't stopped me from being an interpreter. Very few interpreters I know work only with stereo, or with stereo all the time. The people who do this type of work are the photogrammetric engineers who work all day on stereo plotting equipment.

Depth Perception

The normal interpupillary distance in humans is 2.5 to 2.6 inches. If we could increase this distance we would increase our perception of depth. Stereo pairs greatly stretch this normal eye base (interpupillary distance) and give up the exaggerated 3-D photographic effect we perceive when viewing the stereo pairs.

Now, Normally when viewing objects greater than 1,500 feet it 2,000 feet away the special ability to perceive depth is essentially lost. Look, say at a far off line of trees on a flat plane. It is very difficult to tell if they are really in a line or staggered. Basically what your eye brain mechanism will do in this case is employ other clues to help determine the depth of the trees (again, these are essentially the monocular cues described above). With normal eyes from an aerial view we would see a tree like this; while with a stereo pair it would appear like this.

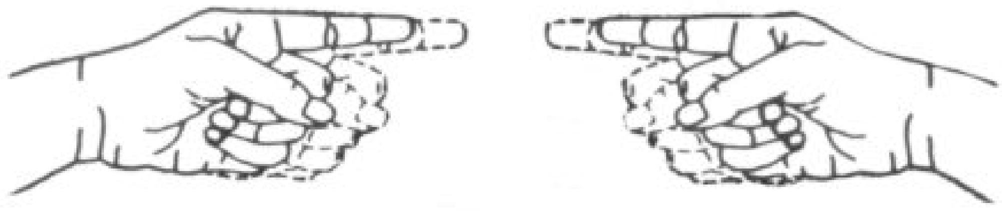




A. Stereo Eyes
B. Stereo Photos

From this you can begin to see the difference between unaided stereo viewing and viewing objects and features in the environment with the aid of stereo pairs.

In normal unaided stereo the lines of sight converge, and it is this convergence that gives us depth perception. Basically, then when our eyes focus on a near by object they also converge so that the lines of sight from each eye intersect at the object. However, in stereo photo vision our lines of sight are essentially parallel or focused at infinity. Now, because of a process called accommodation we have a problem. Accommodation relates to the change in focus of the eye with distance. Basically, convergence and accommodation go together. As the eye focuses on an object they also turn (or move) so that the lines of sight intersect at the object. The issue (or problem if you will) with stereo vision is that to “get stereo” we must maintain parallel lines of sight while focusing our eyes at close range. This is not a normal situation and may cause strain on the eyes.



The “Sausage Exercise” can be helpful in developing the ability to see stereo. Essentially in this exercise you focus your eyes on a distant object and then slowly bring your forefingers into the line of vision. The farther apart your fingers and the larger the sausage when it forms the more nearly parallel are your lines of sight.

Proper Use of Stereoscopes

The following are some guidelines that will help you use your stereoscopes properly. They are important and should be kept in mind when performing stereo based interpretations:

1. Be sure that the photos are properly aligned, preferably with the shadows toward the viewer. (Having the shadows away from the viewer can cause terrain reversal or “false stereo”.)

2. Be sure to keep the eye base and the long axis of the stereoscope parallel to the flight line.

3. Try to maintain an even glare free illumination of the images and make yourself comfortable.

4. Keep the lenses of your stereoscope clean.

5. Do Not Attempt Stereoviewing For Long Periods in the Beginning.

Problems/Issues Involved in Viewing Stereo

1. People with eyes of unequal strength may have difficulty seeing stereo. If you wear glasses it is best that they be worn when stereo viewing.

2. Poor photographic illumination, misalaigned prints or uncomfortable viewing positions may result in eye fatigue.

3. Illness or severe emotional distress may create sensations of dizziness when using strereoscopes.

4. Pseudo stereo can be caused by:
 A. Erroneous reversal of prints;
 B. Viewing photos with shadows falling away rather than towards the interpreter.

5. Objects which change position from one photo to another cannot be viewed in stereo.

6. In areas of high vertical relief, scale differences in adjacent photos may make it difficult to obtain a 3-D effect.

7. Dark shadows or clouds may prohibit stereoscopic study by obscuring details of the scene on one

print or the other.

8. Individuals who have difficulty with stereoscopic viewing, should not attempt unaided eye stereo viewing.

Height Measurement

There are a number of methods for measuring the heights of objects using aerial photography. I will briefly discuss three that I feel are important for photo interpreters to be familiar with. Two deal with the measurement of height from a single photo; while the third deals with the determination of height by measuring parallax differences. The types of parallax being measured here are:

1. Absolute Parallax; and,
2. Differential Parallax.

Remember that according to the American Society of Photogrammetry and Remote Sensing's: Manual of Photogrammetry, 3rd.ed.: Parallax= The apparent displacement of the position of a body, with respect to a reference point or system, caused by a shift in the point of observation.

Absolute Parallax= Considering a pair of aerial photographs of equal principle distance, the absolute parallax is the difference of a point is the algebraic difference of the distances of the two images from their respective photo nadirs measured in a horizontal plane and parallel to the air base.

Differential Parallax= The difference in the absolute stereoscopic parallaxes of two points imaged on a pair of photographs. This is usually employed in the determination of the differences in the elevation of objects.

Lets look at the single photo methods of height determination first:

Shadow Height Method:

Basically, if the shadow cast by an object can be measured and the sun angle causing the shadow is known or can be derived (from latitude, date and time) then the height of the object can be calculated using simple trigonometry, as follows:

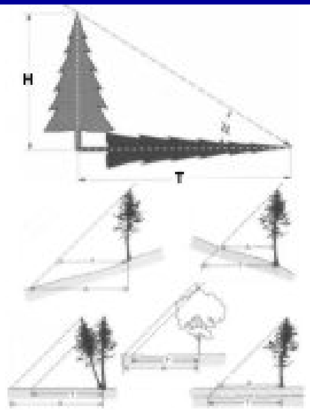
$h = Ls \times \tan a$

Where $\tan a$ = the tangent of the sun angle from the ground surface.

and Ls = Length of the shadow.

Here we assume that the shadow on which the ground falls is level and that the object is vertical. The objects top must be sharply defined so that it creates a distinct image.

There are many sources of error here.



Displacement Method:

In this method of height determination from a single aerial photo we:

1. accept the principle point as the photo nadir (were assuming a “true” vertical photo);

2. Must precisely know or be able to determine the altitude from which the photo was acquired.

3. Both the top and the bottom of the object to be measured should be clearly visible.

4. The degree of image displacement must be great enough to be accurately measured with available equipment.

If the above conditions are met the formula for the displacement method of height determination from a single aerial aerial photo can be written as:

$$Ho = \frac{Ha \times D}{R}$$

Where: Ho = Height of the object;
Ha = Altitude above the surface where the photo is taken;
D = Length of the displaced image;
R = Radial distance from the photo nadir to the top of the object.

Parallax Height Measurement

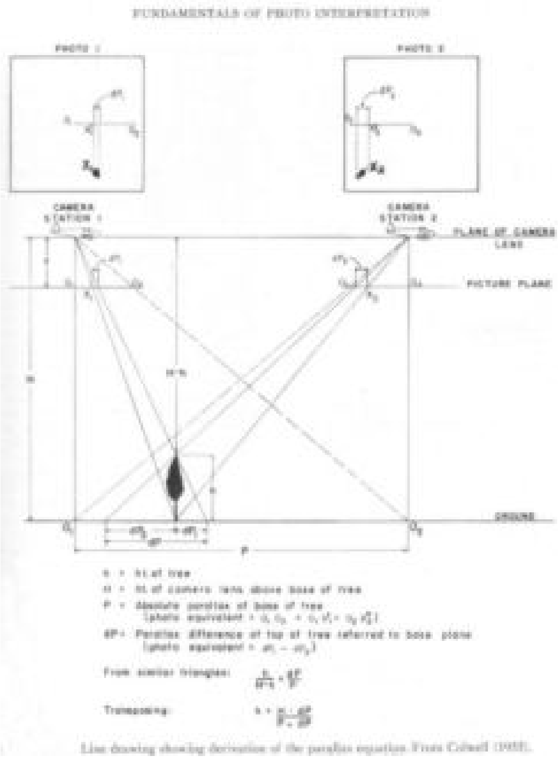
This is the most used method of measuring heights on air photos. There are many forms of the parallax equations. Avery and Berlin give one; Paine in his book lists three: 1) for mountainous terrain; 2) for level terrain; and, 3) the short cut equation.

What I will give here is the basic form of the equation:

$$Ho = \frac{Ha \times dP}{Pb + dP}$$

Where: Ho = The height of the object of interest;
Ha = Platform height or altitude above datum;
dP = Differential Parallax; and
Pb = Absolute Parallax.

So if the altitude of the aircraft above datum is: 1. known or can be calculated; and, 2. if, from the available stereo pairs, we can calculate the differential and the absolute parallax; then, 3. We can ascertain the heights of objects in the photos.



Important things to remember here include:

Ha, the height of the aircraft should be in the same units as the objects height. Feet are typically employed.

dP and Pb, should also be in the same units. Yet, here you would typically use hundredths of inches.

you need accurate measuring devices to get accurate measurements.

Now for a small trick.

If we can assume that:

1. Photo tilt is less than 3°;

2. Both negatives or positive transparencies of the stereo pair were taken from the same flying height;

3. Both nadirs and principle points are at essentially the same ground elevation; and,

4. The base of the objects to be measured are, essentially, at the same elevation as that of the principle point.

Then, we can substitute the average photobase of the stereo pairs being used can be substituted for Pb (absolute parallax).

Lets say, as Avery and Berlin do in their book (5th. ed.) on Pg. 78 and 79; that we are going to measure the height of the Washington Monument from a stereo pair.

The nominal photo scale we have is 1:4,800. We have gone in and corrected this in the area of the monument monument to 1: 4,600 at the base of the Monument. The camera focal length was 12 inches. So the flying height was what? 4,600 feet. The average photobase (P) of the stereopair is calculated to be: 4.40 inches.

Absolute stereo parallax at the base; and at the top of the monument is measured parallel to the line of flight with an engineers scale. The difference is: 2.06 in. - 1.46 in. This gives a dP of 0.60 in. So, 0.60 inches is the differential parallax of the displaced images.

Add scanned image here from my notes

Substituting these values into a form of our formula:

$$Ho = [H] \frac{dP}{Pb + dP}$$

$$Ho = 4{,}600 \text{ Ft.} \frac{0.60 \text{ in.}}{4.40 \text{ in.} - 0.60 \text{ in.}} = 552 \text{ feet}$$

The actual height of the Washington Monument is 555 feet. This is a very accurate measurement for this type of exercise. For example if we had used the nominal photo scale of 1: 4,800; instead of the corrected 1: 4,600 scale we would have gotten a height of 576 feet. A 21 foot error as opposed to the 3 foot error we did get. It just goes to show that the more time you put in setting up the problem and the more precise the instruments are the better (up to a point) the measurements that you can achieve. Well that's essentially it for stereo and height measurement.

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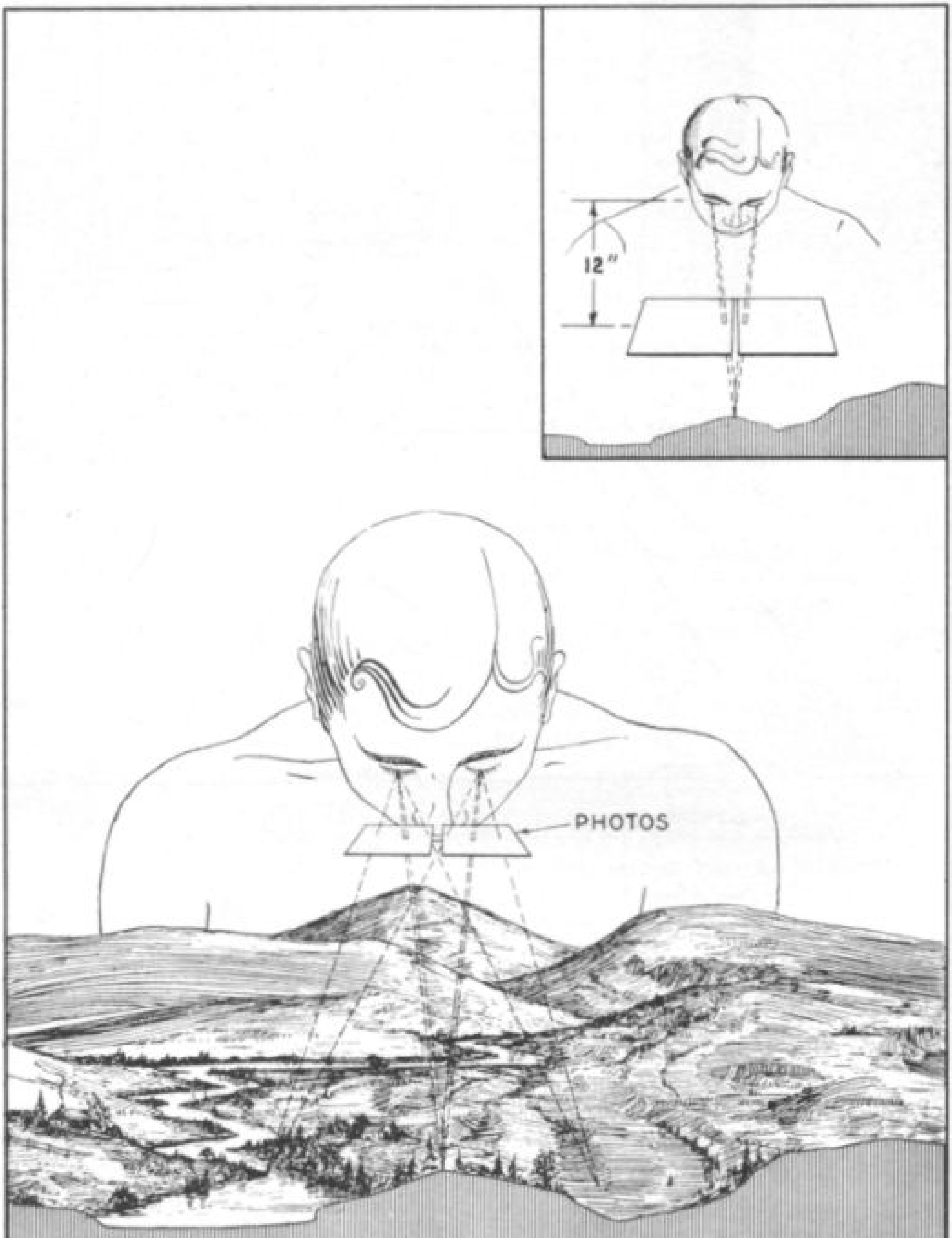

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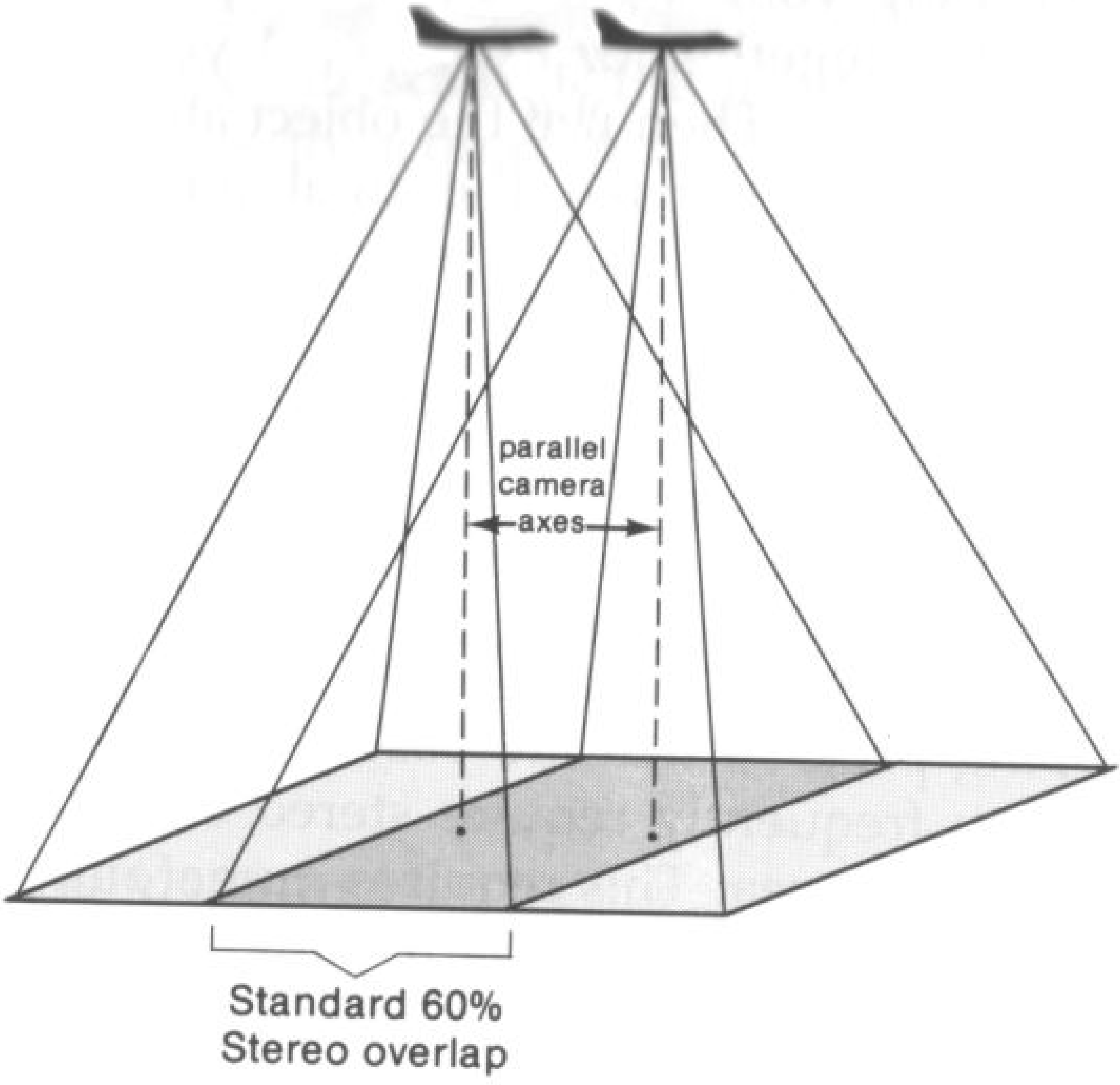
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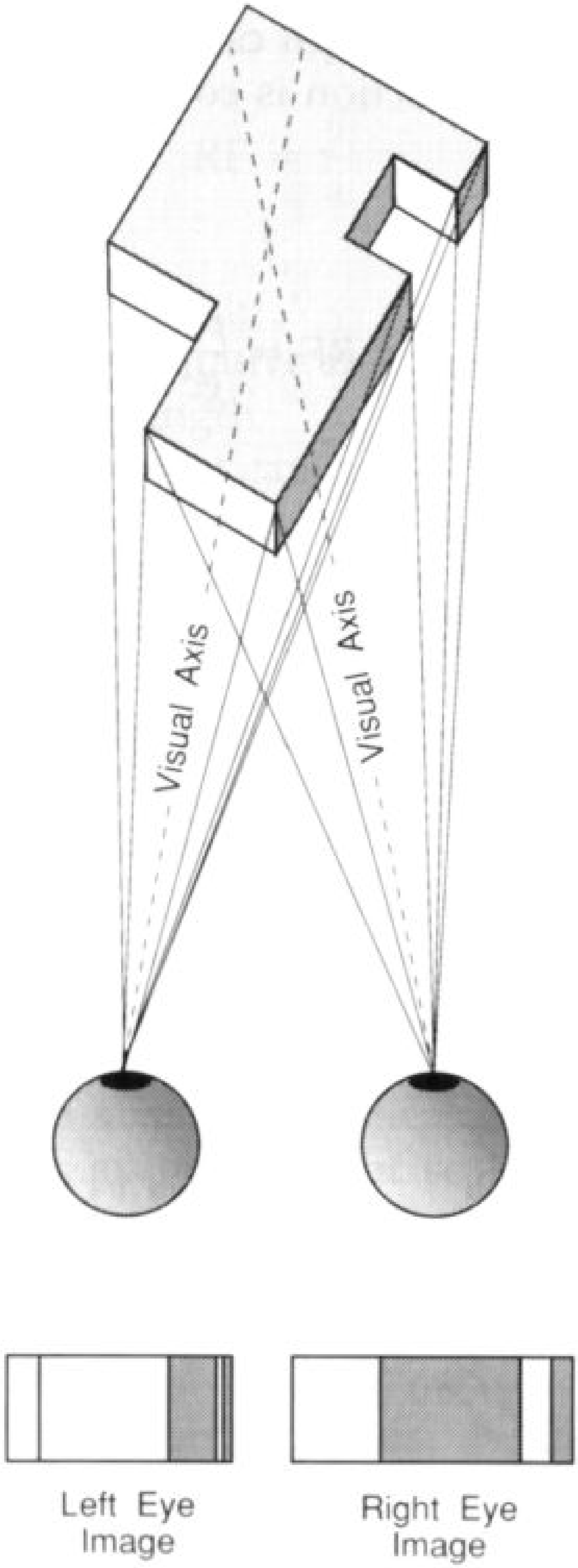
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Visual Axis
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Right Eye Image

Left Eye Image

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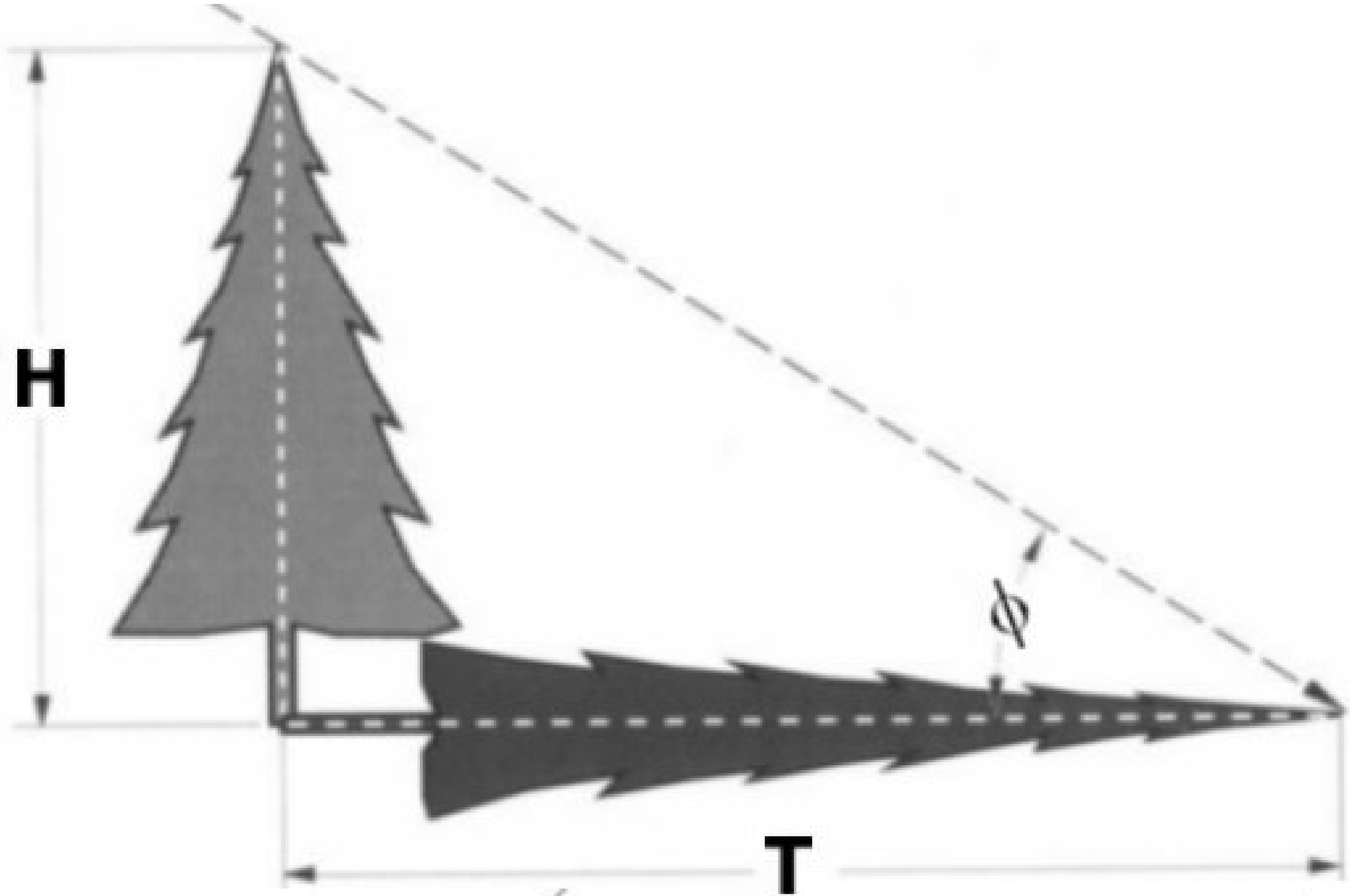
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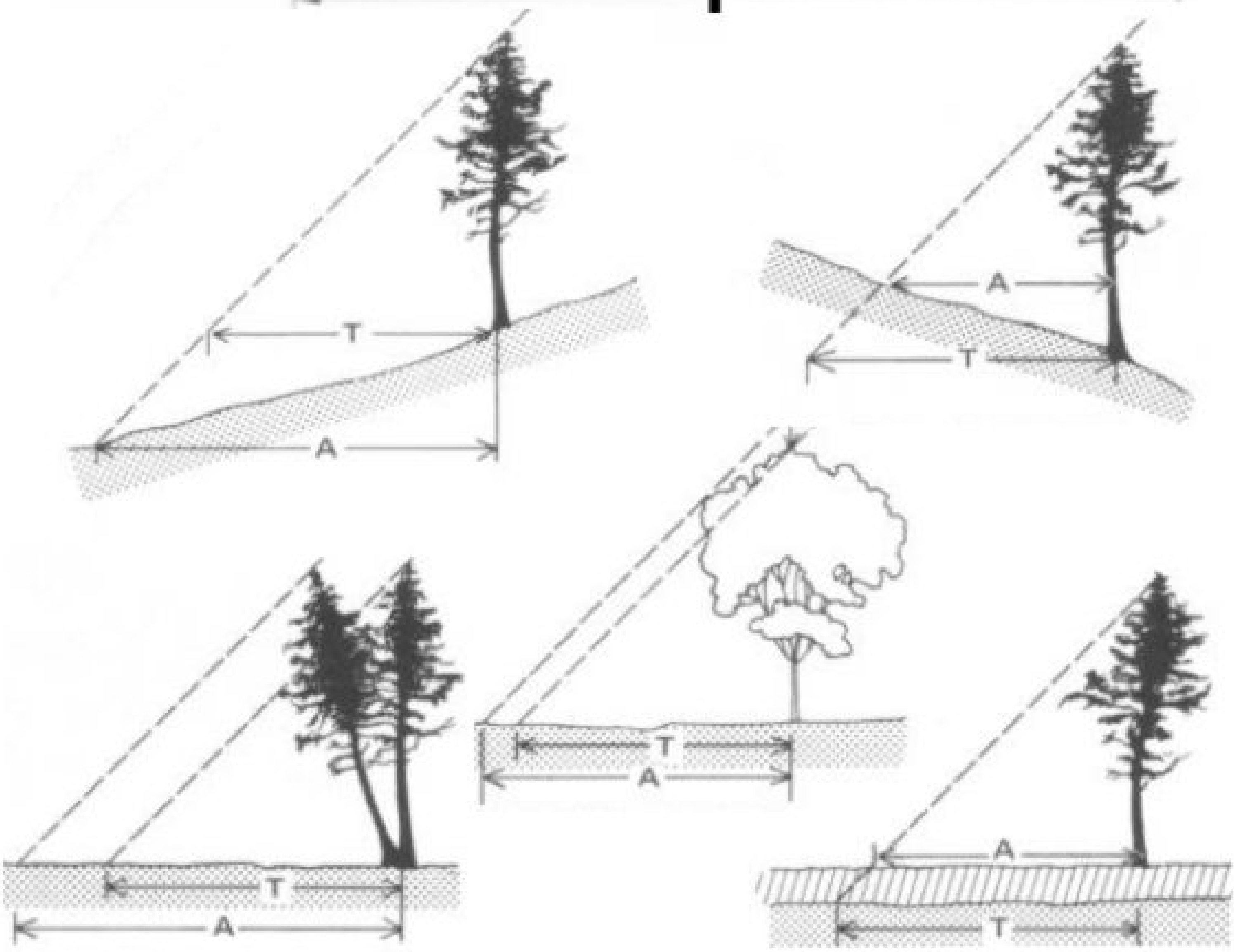
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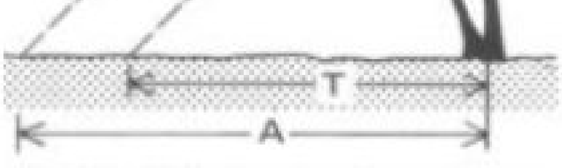
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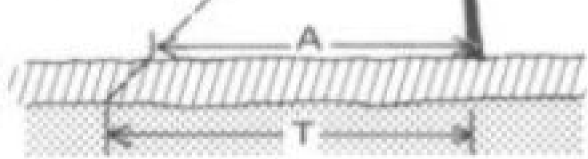
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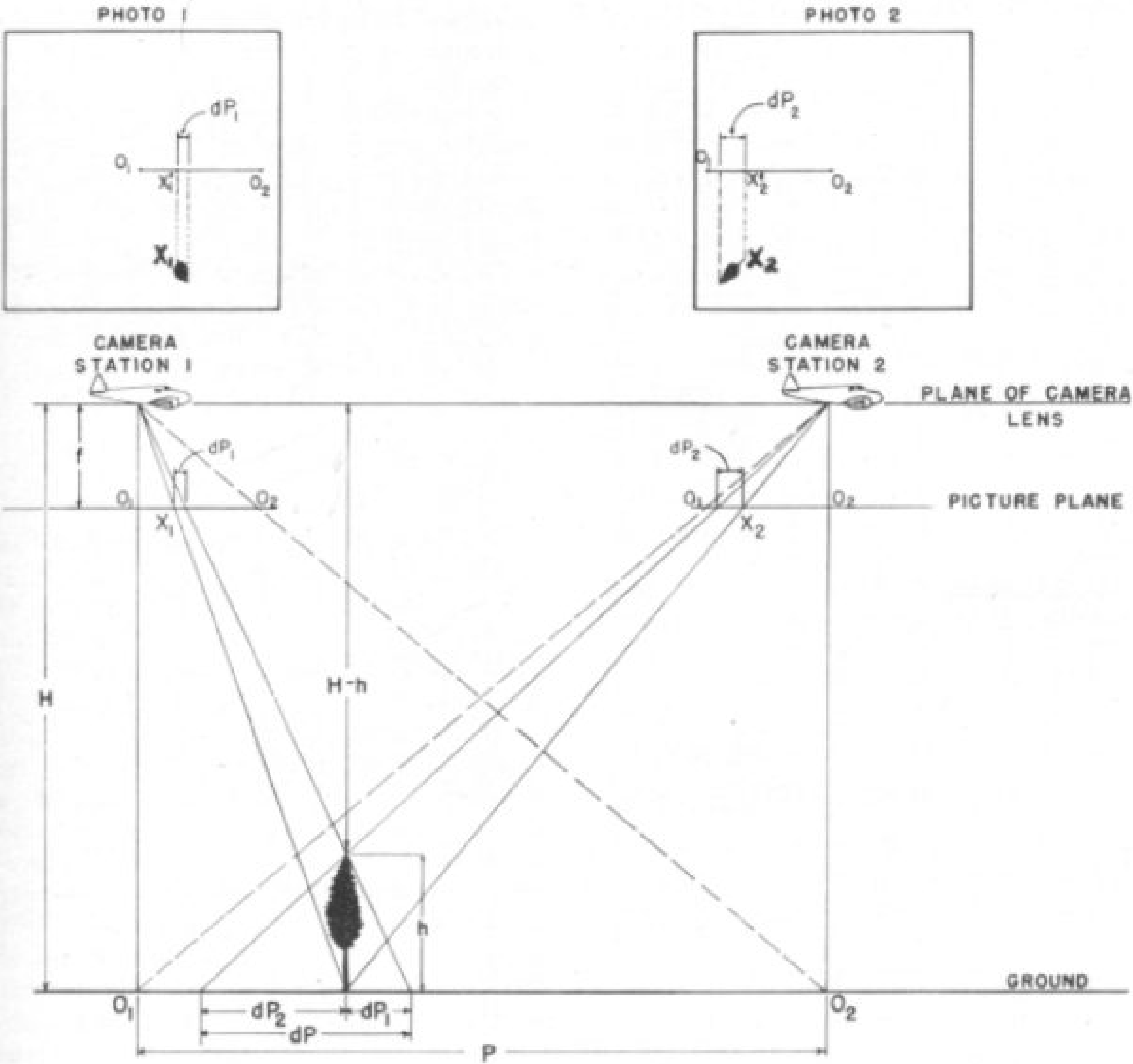

h = ht. of tree

H = ht. of camera lens above base of tree

P = Absolute parallax of base of tree (photo equivalent = $O_1 O_2 = O_1 X_1' + O_2 X_2'$)

dP = Parallax difference of top of tree referred to base plane (photo equivalent = $dP_1 - dP_2$)

From similar triangles: $$\frac{h}{H-h} = \frac{dP}{P}$$

Transposing: $$h = \frac{H \cdot dP}{P + dP}$$

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Line drawing showing derivation of the parallax equation. From Colwell (1955).