RSCC Volume 1
Introduction to Photo Interpretation and Photogrammetry

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Geometry of Aerial Photography

I. Classification of Photographs

In his book on aerial photo interpretation, Paine presents a dichotomous key for classifying aerial photography. The key is listed as follows:

Photographs

Terrestrial Aerial

Vertical
Oblique

True Tilted High
Low

We can define vertical aerial photographs as a photo taken from an aerial platform (either moving or stationary) wherein the camera axis at the moment of exposure is truly vertical. In actuality, vertical airphotos with less than 3* tilt are considered vertical (for most photo interpretation purposes); while those with more than 3* tilt are considered oblique. There are two basic types of oblique aerial photography. These two types are:

1. High angle oblique; and

2. Low angle oblique.

In a high angle oblique, the apparent horizon is shown; while in a low angle oblique the apparent horizon is not shown. Often because of atmosphere haze or other types of obscuration the true horizon of a photo cannot really be seen. However we often can see a horizon in an oblique air photo. This is the apparent horizon.

The basic advantages of vertical air photos are:

1. The scale is essentially constant;

2. Measurements of directions are easier than on oblique photograph. Directions can also be measured more accurately;

3. Within limits a vertical aerial photograph can be used as a map (if grids and marginal data are added); and,

4. Vertical aerial photographs are often easier to interpret than oblique and are better for stereo (there is no masking).

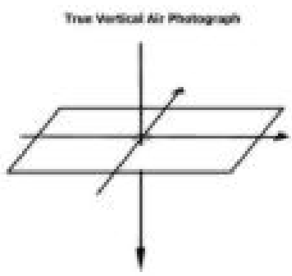
The advantages of an oblique aerial photograph include:

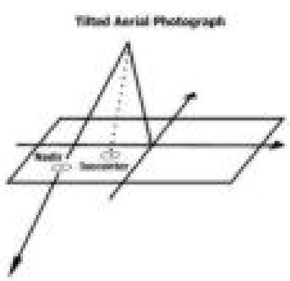
1. Given a constant altitude and camera you can cover a much larger area on a single photo;

2. The view of some objects is more familiar to the interpreter; and,

3. Some objects not visible on vertical photos may be seen on oblique.

(Paine talks about clearance and cloud cover; but that's a tricky one (too cloudy for vertical but maybe enough clearance for an oblique).





Three terms need defining here, they are Principal Point, Nadir and Isocenter. They are defined as follows:

1. Principal Point - The principal point is the point where the perpendicular projected through the center of the lens intersects the photo image.

2. Nadir - The Nadir is the point vertically beneath the camera center at the time of exposure.

3. Isocenter - The point on the photo that falls on a line half- way between the principal point and the Nadir point.

On a true vertical aerial photograph all three of these would be at the same point. There is no such thing as a true vertical aerial photo. All air photos have some degree of tip or tilt.

A quick review.

Vertical Airphotos (0-3* tilt)

3 Photo Centers: Principal Point, Nadir, Isocenter

These points are important because certain types of displacement and distortion radiate from them. It is the Isocenter of the aerial photo from which tilt displacement radiates. It is Nadir from which topographic displacement radiates.

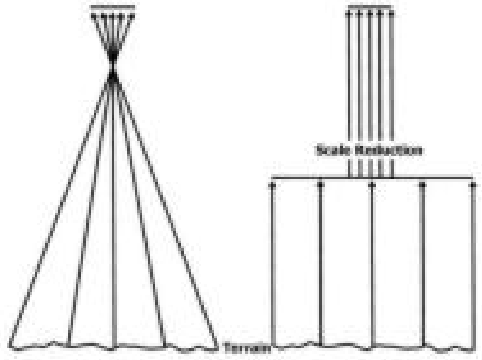
II. Perspective and Projection

Now lets talk about perspective and projection.

First lets consider the viewing perspective of a map. On a map objects and features are both planimetrically and geometrically accurate. That is objects are located on the map in exactly the same position relative to each other as they are on the surface of the Earth, except with a change in scale. This is due to the fact that maps use an orthographic projection (i.e. using parallel lines of site) and constant scale to represent features.

Aerial photographs on the other hand are created using a central or perspective projection. Therefore, the relative position and geometry of the objects depicted depends upon the location from which the photo was taken.

Now because of this we get certain forms of distortion and displacement in Air Photos.



III. Distortion and Displacement

There are basically four types of distortions and three types of displacement.

Types of distortion include:

1. Film and Print Shrinkage;
2. Atmospheric refraction of light rays;
3. Image motion; and,
4. Lens distortion.

Types of displacement include:

1. Curvature of the Earth;
2. Tilt; and,
3. Topographic or relief (including object height).

The effects of film shrinkage, atmospheric refraction and the curvature of the Earth are usually negligible in most cases - the exception is precise mapping projects. These types of distortions and displacement will not be discussed here. Image motion will be dealt with further in our lecture on camera systems. That leaves only lens distortion, tilt and topographic displacement to be discussed here. Of these lens distortion is usually the smallest of these. So displacement is typically the largest problem/effect impacting our analyses.

Both distortion and displacement cause changes in the apparent location of objects in photos. The distinction between the types of effects caused lies in the nature of the changes in the photos.

Distortion - Shift in the location of an object that changes the perspective characteristics of the photo.

Displacement - shift in the location of an object in a photo that does not change the perspective characteristics of the photo (The fiducial distance between an object's image and it's true plan position which is caused by change in elevation.)

These types of phenomena are most evident in terrain with high local relief or significant vertical features.

As stated above we will consider here three main types of problems/effects caused by specific types of distortion and displacement. These are the problems/effects associated with:

1. Lens distortion;
2. Tilt Displacement; and,
3. Topographic Displacement.

Lens distortion - Small effects due to the flaws in the optical components (i.e. lens) of camera systems leading to distortions (which are typically more serious at the edges of photos). Car windows/windshields, carnival mirrors are probably the best know examples of this type of effect. These effects are radial from the principal point (making objects appear either closer to, or farther from the principal point than they actually are); and may be corrected using calibration curves.

Tilt Displacement - A tilted photograph presents a slightly oblique view rather than a true vertical record. All photos have some tilt. The perfect gyro stabilization unit, like the perfect lens, has yet to be built. Tilt is caused by the rotation of the platform away from the vertical. This type of displacement typically occurs along the axis of the wings or the flight line. Tilt displacement radiates from the isocenter of the photo and causes objects to be displaced radially towards the isocenter on the upper side of the tilted photo and radially outward on the lower side. If the amount and direction of tilt are known then the photo may be rectified.

Topographic Displacement - This is typically the most serious type of displacement. This displacement radiates outward from Nadir. Topographic displacement is caused by the perspective geometry of the camera and the terrain at varying elevations.

Topographic displacement is not necessarily bad as it allows:

1. Stereo viewing;
2. Height measurement; and,
3. Topographic mapping.

Note: From directly overhead a smokestack looks like a doughnut if there is no shadow. If the same smokestack is near the edge of the image you can see more of it's side.

Tell the story of trees drown by a reservoir and the displacement pattern on the photo.

The formula for topographic or height displacement on a single photo is:

d = r(h)/H = r(h)/(A-E)

h = d(H)/r = d(A-E)/r

Where:

d = Radial displacement (with respect to the Nadir) n the photo at the same scale as the Nadir.

r = Radial photo distance from Nadir (use PP) to the point of displacement (usually the top of the object).

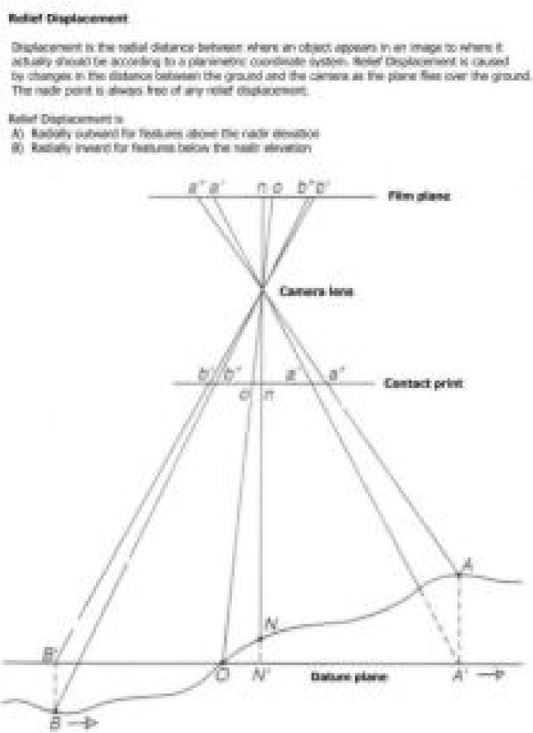
h = Height of the object or difference in elevation (E) between Nadir and displaced point.

H = Flying height above the base of the object (or above the Nadir in some situations).

A close look at the equations involved in the calculations of relief displacement show that some important general relationships are involved. These relationships can be stated as follows:

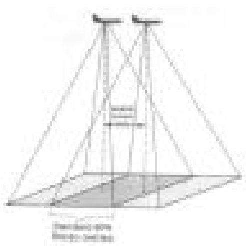
1. There is no topographic displacement at Nadir. If r is zero, then so is d.

2. Assuming datum elevation to be at Nadir, points above the datum are displaced radially away from Nadir while points below datum are displaced radially towards Nadir.



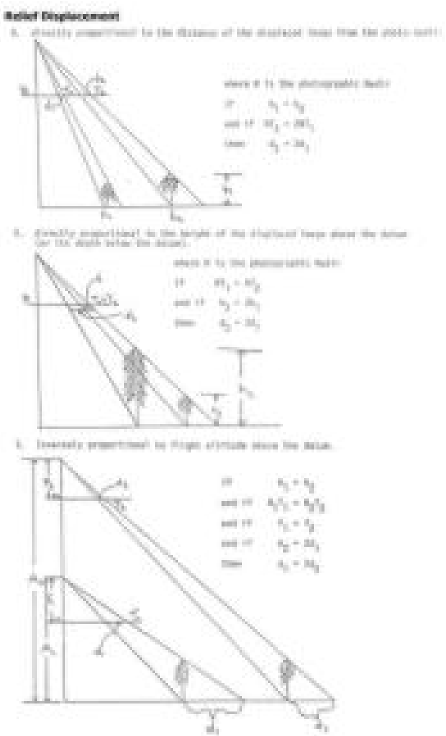
Relief Displacement

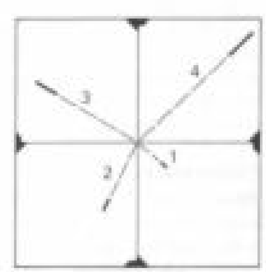
3. Topographic displacement varies directly with the radial distance from the Nadir to the object. A particular elevation two inches from the Nadir will have half the displacement as that same elevation four inches from the Nadir.



Overlap

4. Topographic displacement varies directly with the height of an object. A 100 ft. tree would be displaced twice as far as a 50 ft. tree the same distance from Nadir.





Relief Displacement

5. Topographic displacement varies inversely with the flying height of the base of the object. As a result there is little apparent topographic displacement on space photography.

The reason for small relief displacement from space is that to achieve a given scale a shorter focal length lens requires flying at a lower altitude. The effect of using short focal length lenses is to increase topographic displacement, distortion and the apparent depth of the third dimension (vertical exaggeration) in stereoscopic images).

To get a scale of 1: 20,000 you fly at 10,000 ft. with a six inch focal length lens; but at 20,000 ft. with a 12 inch focal length lens.

Basically, then the most important cause of object displacement on aerial photography is local relief. Remember here that there are times when increased displacement can be a good thing (e.g. for height measurements). So in flat areas you may want to use a short focal length lens to achieve a given scale.

From Space then you can still use extremely long lenses with little displacement.

IV. Orthophotography

Briefly, here there is a growing use of orthophotography today. If you remember back to our discussion of maps at the beginning of the lecture you will remember that orthographic projection depict thing in their true plan position. Basically what happens in the production of orthophotographs is that the original photographs are employ to create a stereo-model which is scanned, by very expensive (today) equipment (orthophotoscope), in very small segments; displacements are corrected and the resulting strips are merged to create a photograph that is essentially a map, actually a planimetrically accurate photo-map. On an orthophoto distances, areas, and directions can all be accurately measured more easily. The U.S. Geological Survey's National Mapping Division is doing all revisions of the 1: 24,000 topographic map updates using digital orthophotography. These ortho photo maps show more detail than the older cartographic product due to the actual image background.

Original & Ortho Rectified Air Photo

So, the advantages here are:

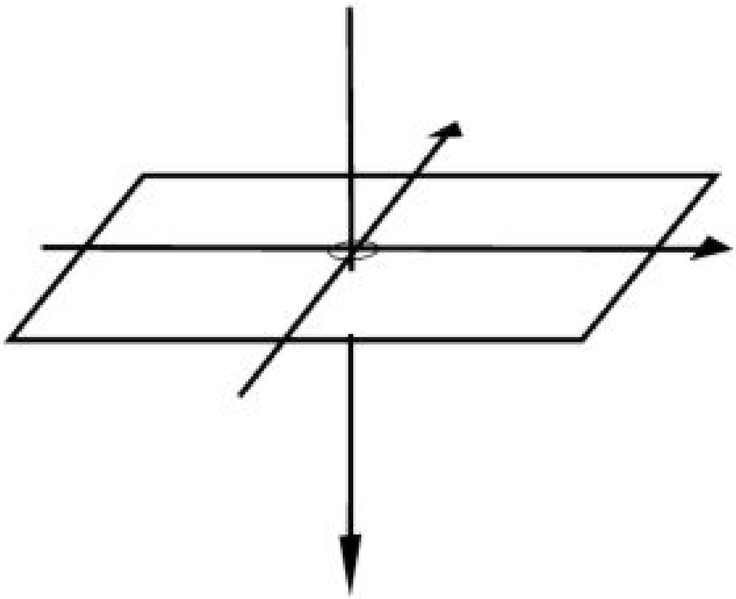
1. Greater detail than a map
2. Equal planimetric accuracy

But, the disadvantages are:

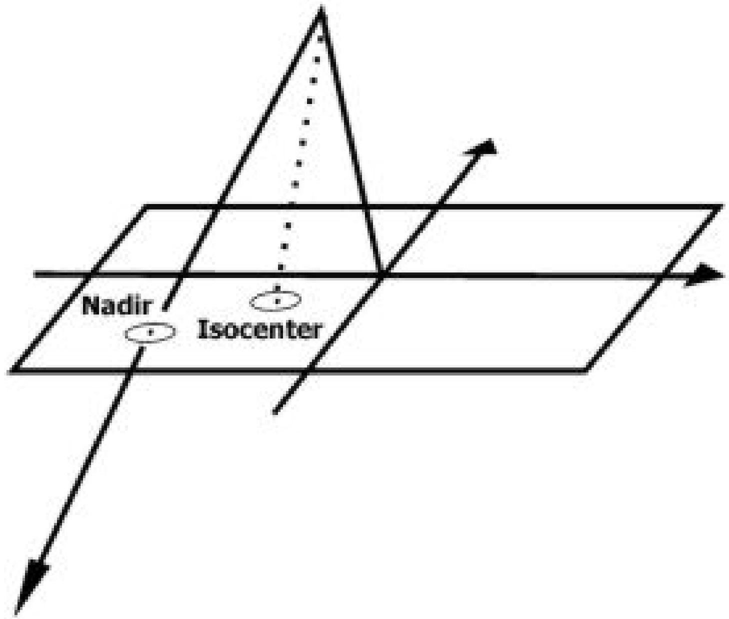
1. Lower resolution than the original photos

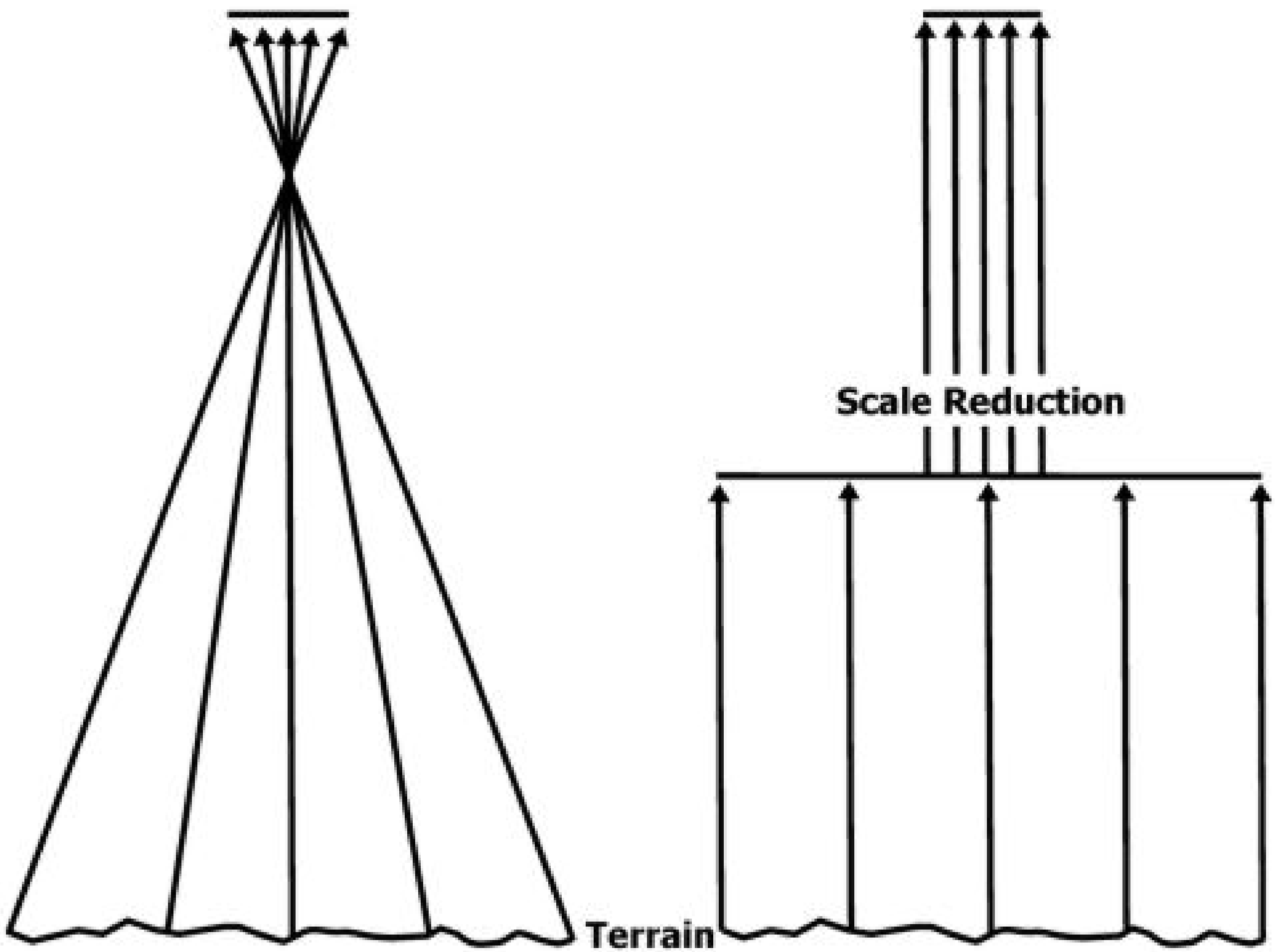
2. Some loss of information with loss of resolution
3. Loss of stereoscopic capability.

True Vertical Air Photograph



Tilted Aerial Photograph



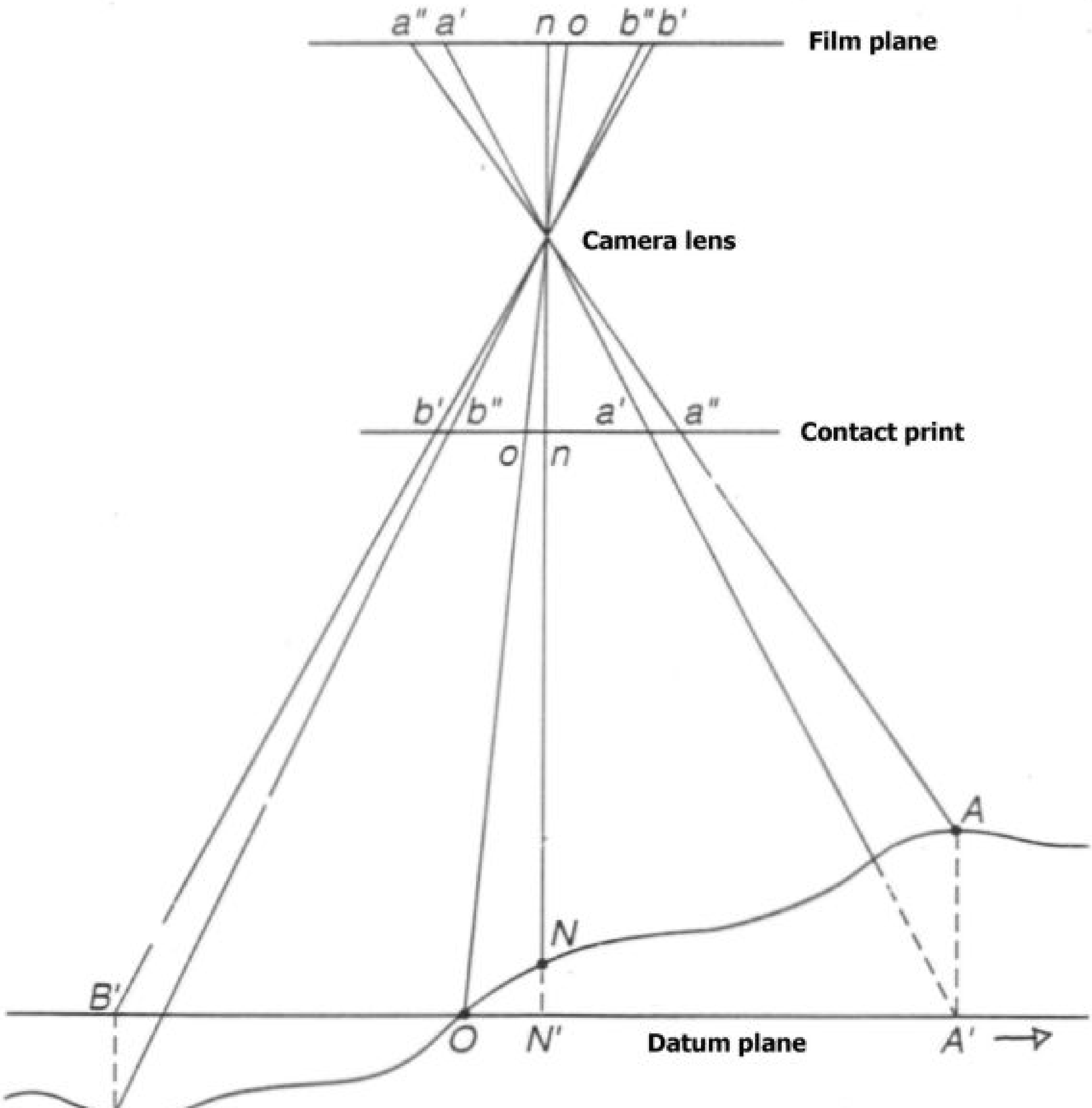


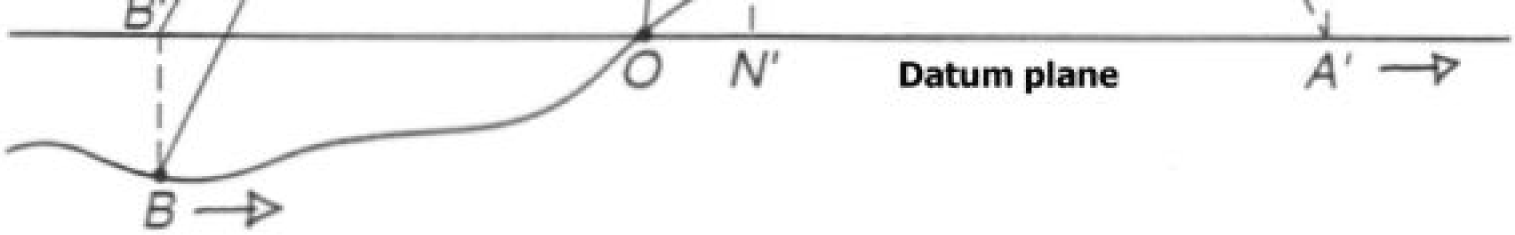
Scale Reduction
Terrain

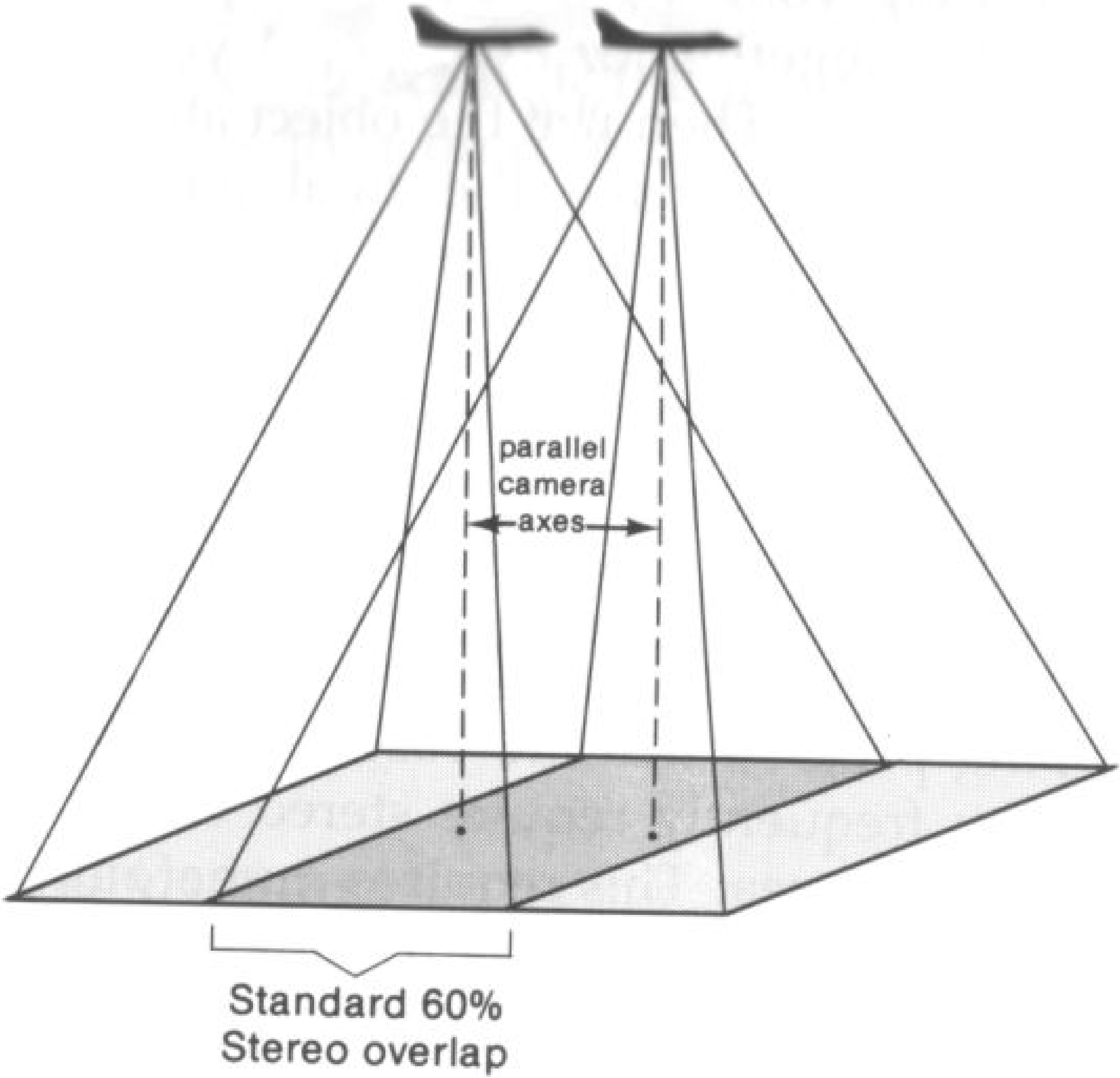
Relief Displacement

Displacement is the radial distance between where an object appears in an image to where it actually should be according to a planimetric coordinate system. Relief Displacement is caused by changes in the distance between the ground and the camera as the plane flies over the ground. The nadir point is always free of any relief displacement.

Relief Displacement is
A) Radially outward for features above the nadir elevation
B) Radially inward for features below the nadir elevation

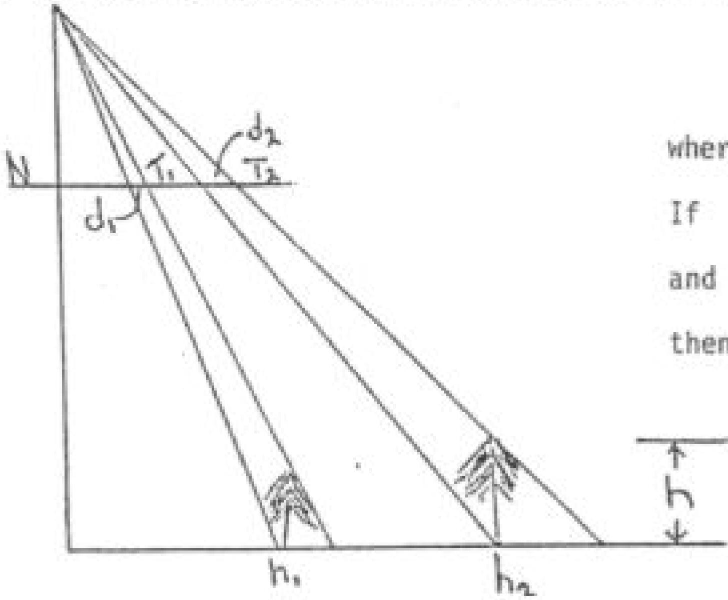



B'
O
N'
Datum plane
A'
B


parallel
camera
axes
Standard 60%
Stereo overlap

Relief Displacement

A. directly proportional to the distance of the displaced image from the photo nadir.



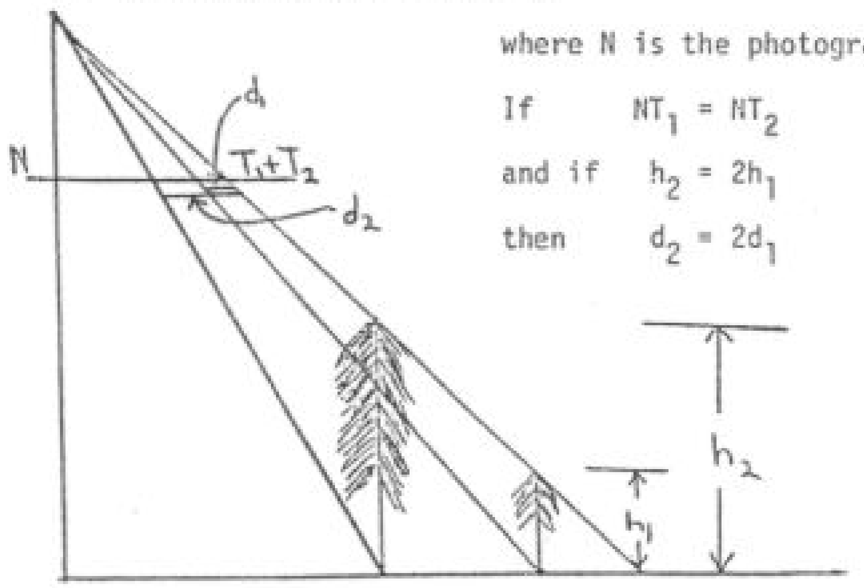
where N is the photographic Nadir

If $h_1 = h_2$

and if $NT_2 = 2NT_1$

then $d_2 = 2d_1$

B. directly proportional to the height of the displaced image above the datum (or its depth below the datum).



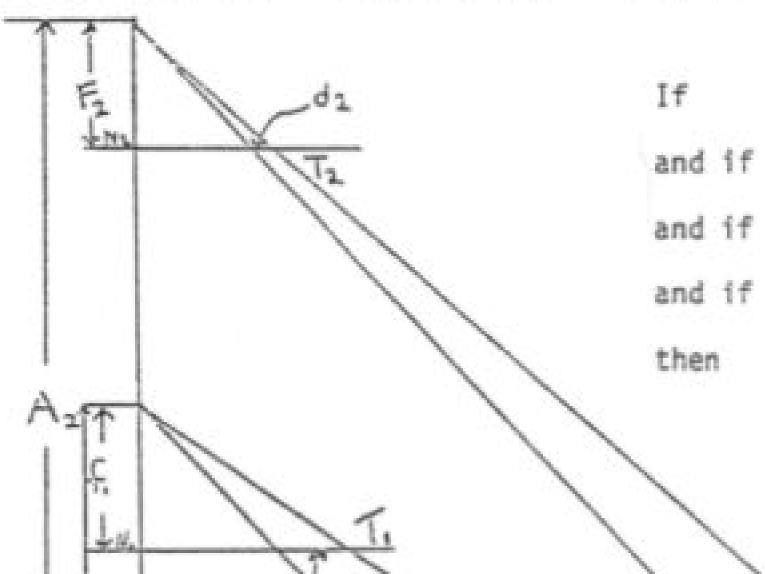
where N is the photographic Nadir

If $NT_1 = NT_2$

and if $h_2 = 2h_1$

then $d_2 = 2d_1$

C. Inversely proportional to flight altitude above the datum.



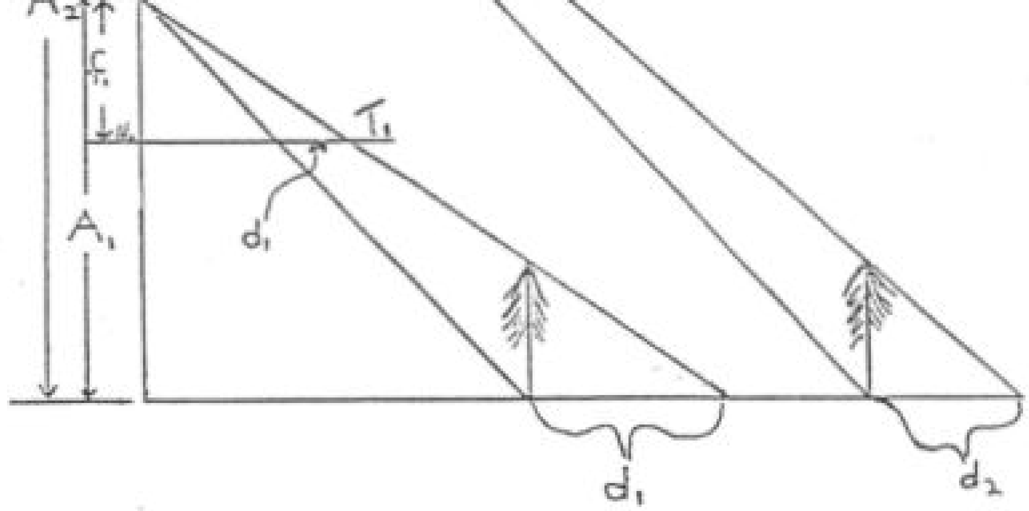
If $h_1 = h_2$

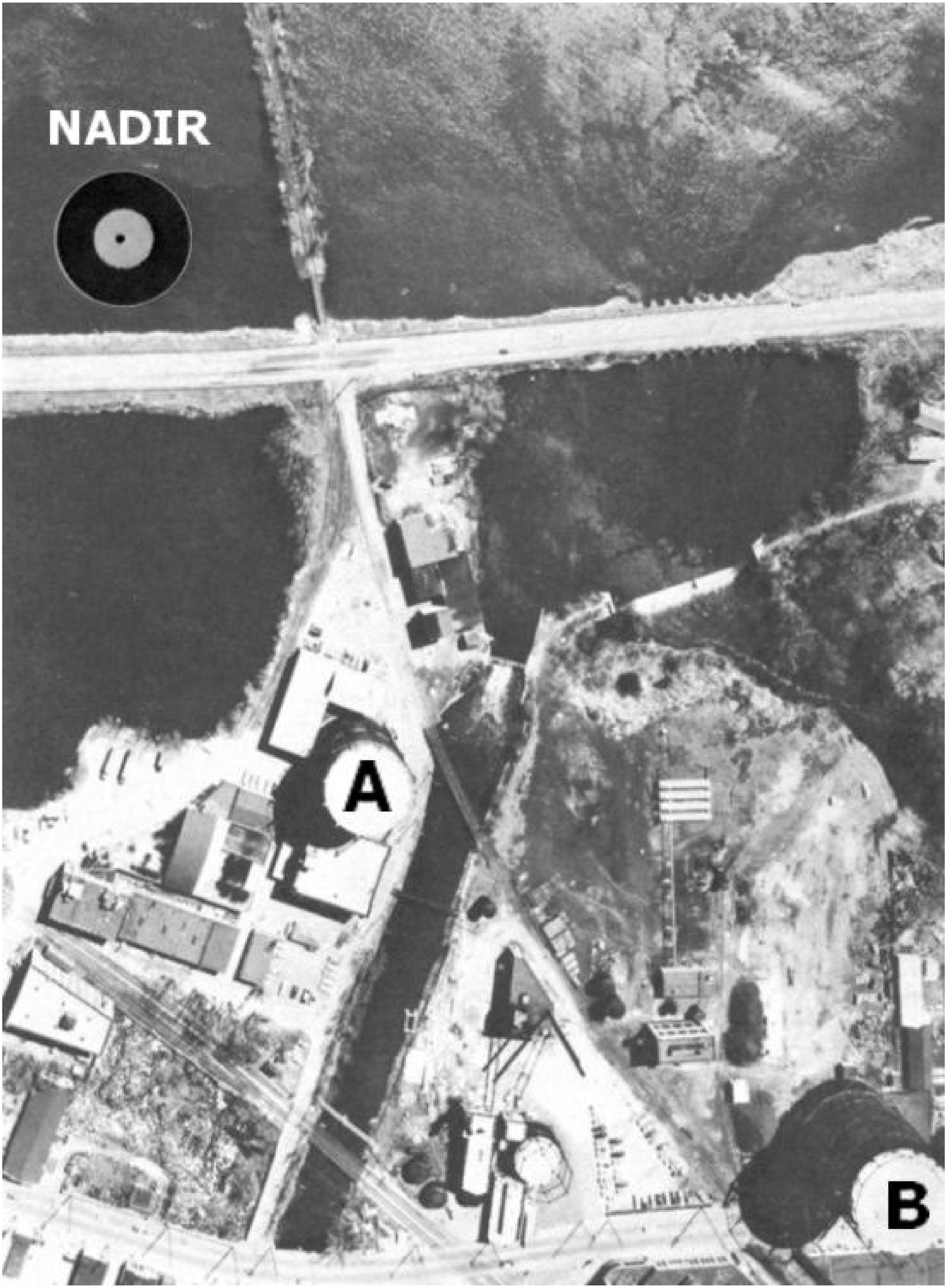
and if $N_1T_1 = N_2T_2$

and if $f_1 = f_2$

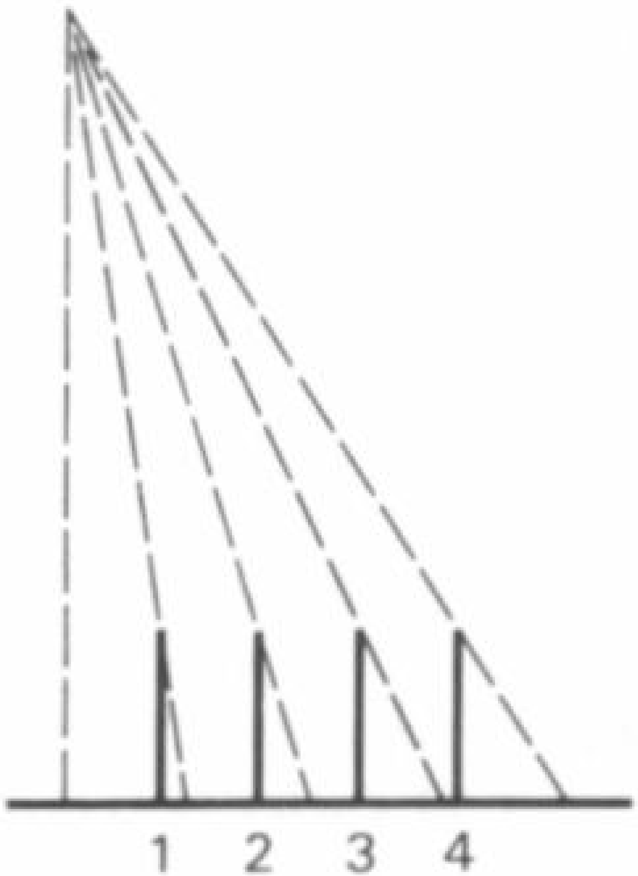
and if $A_2 = 2A_1$

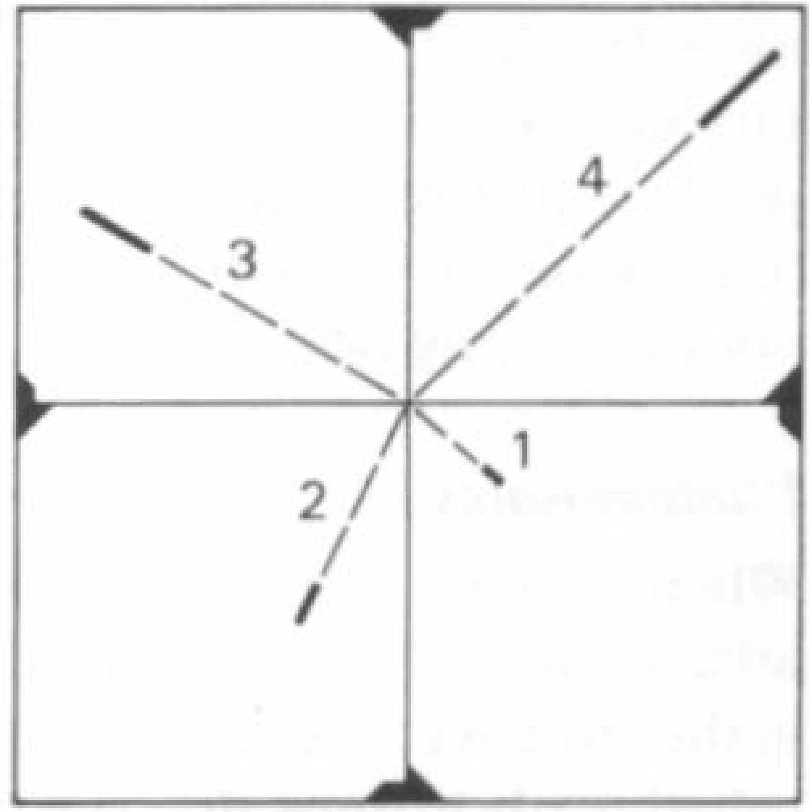
then $d_1 = 2d_2$


A₂
f₁
T₁
d₁
A₁
d₁
d₂


NADIR
A
B


B


1
2
3
4


4
3
1
2