Chapters 1-4: Summary

- So far, we have been investigating the image acquisition process.
  - Chapter 1: General introduction
  - Chapter 2: Radiation source and properties
  - Chapter 3: Radiation interaction with the lens system
    - Factors affecting the precision and the accuracy of the image coordinate measurements
  - Chapter 4: Radiation interaction with the light sensitive material along the focal/image plane
    - Analog & digital imaging systems

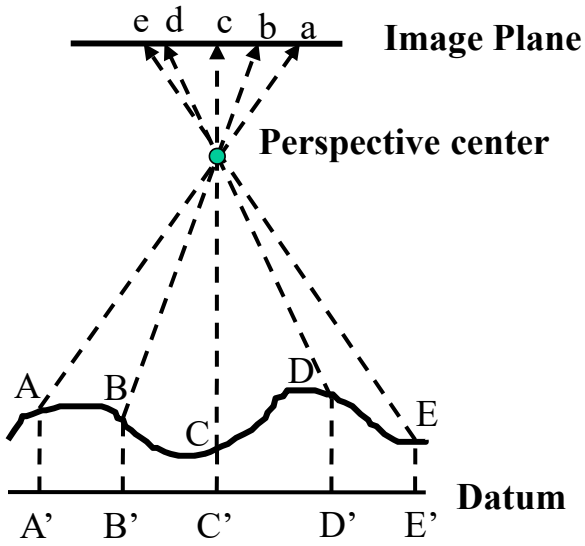
CE59700: Chapter 5

Vertical Photography

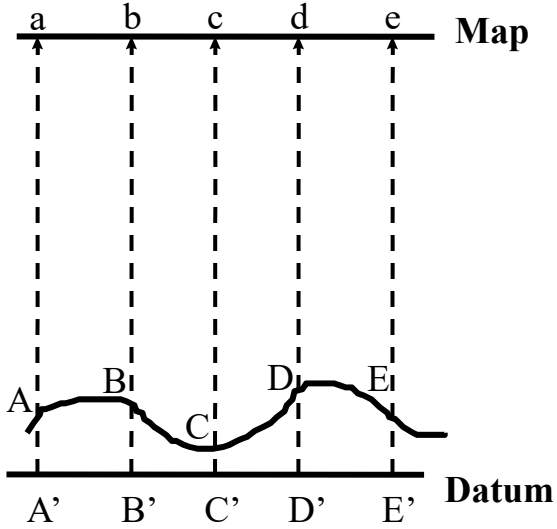
Overview

- Image versus map characteristics
- Vertical photography: definitions and characteristics
- Image scale
- Mathematical relationship between corresponding image and ground coordinates
- Relief displacement

An Image Versus a Map



Image

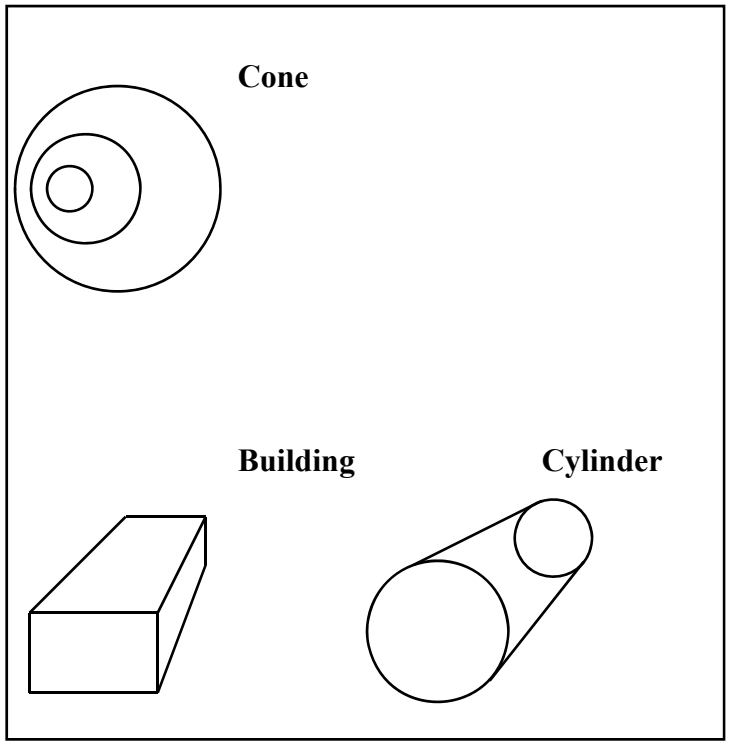


Map

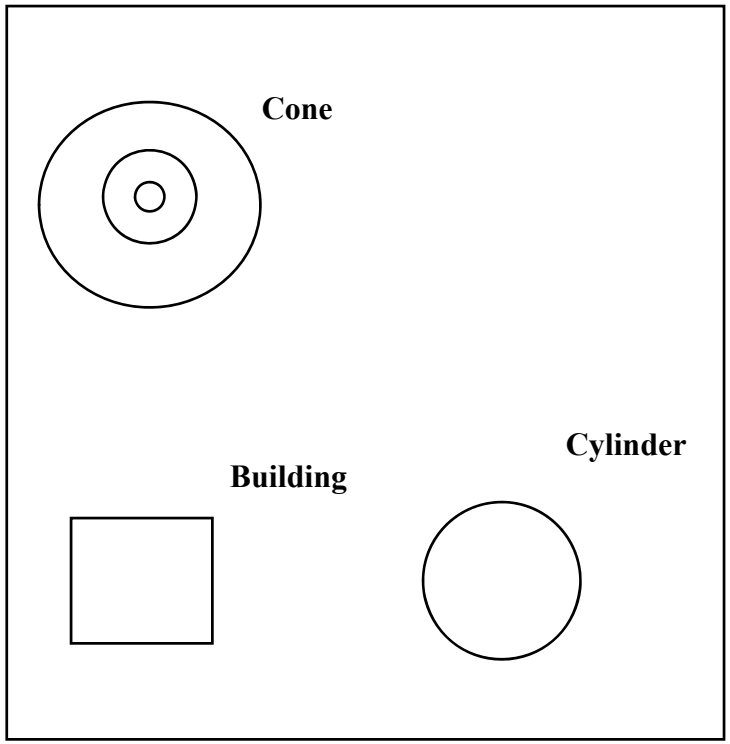
An Image Versus a Map

- Images have the following properties:
  - Perspective projection, and
  - Non-uniform scale.
- Maps, on the other hand, have the following characteristics:
  - Orthogonal (parallel) projection, and
  - Uniform scale.

Perspective Versus Orthogonal Projection



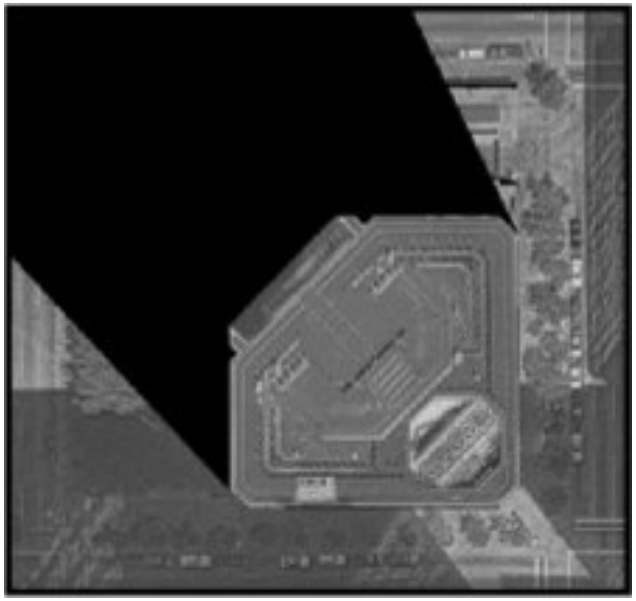
Perspective Projection



Orthogonal Projection

Perspective Versus Orthogonal Projection

Perspective Projection



Orthogonal Projection

http://www.e-topo.com/etoposite/pages/ortho_photography.aspx

Perspective Versus Orthogonal Projection

Perspective Projection

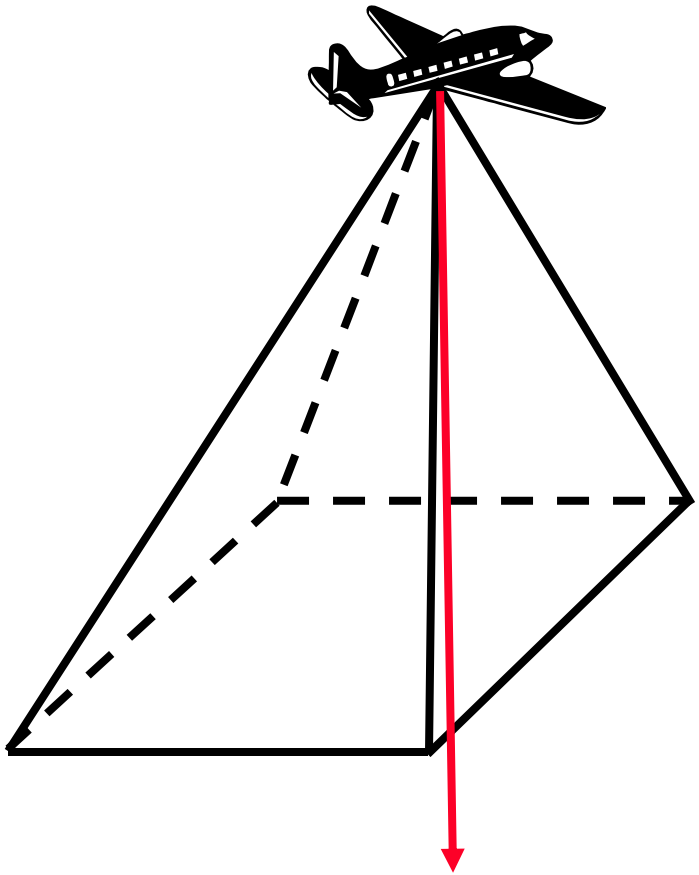
Orthogonal Projection

Perspective Versus Orthogonal Projection

- Perspective Projection
- Orthogonal Projection

http://www.swisstopo.admin.ch/internet/swisstopo/en/home/products/images.html

Vertical Photography

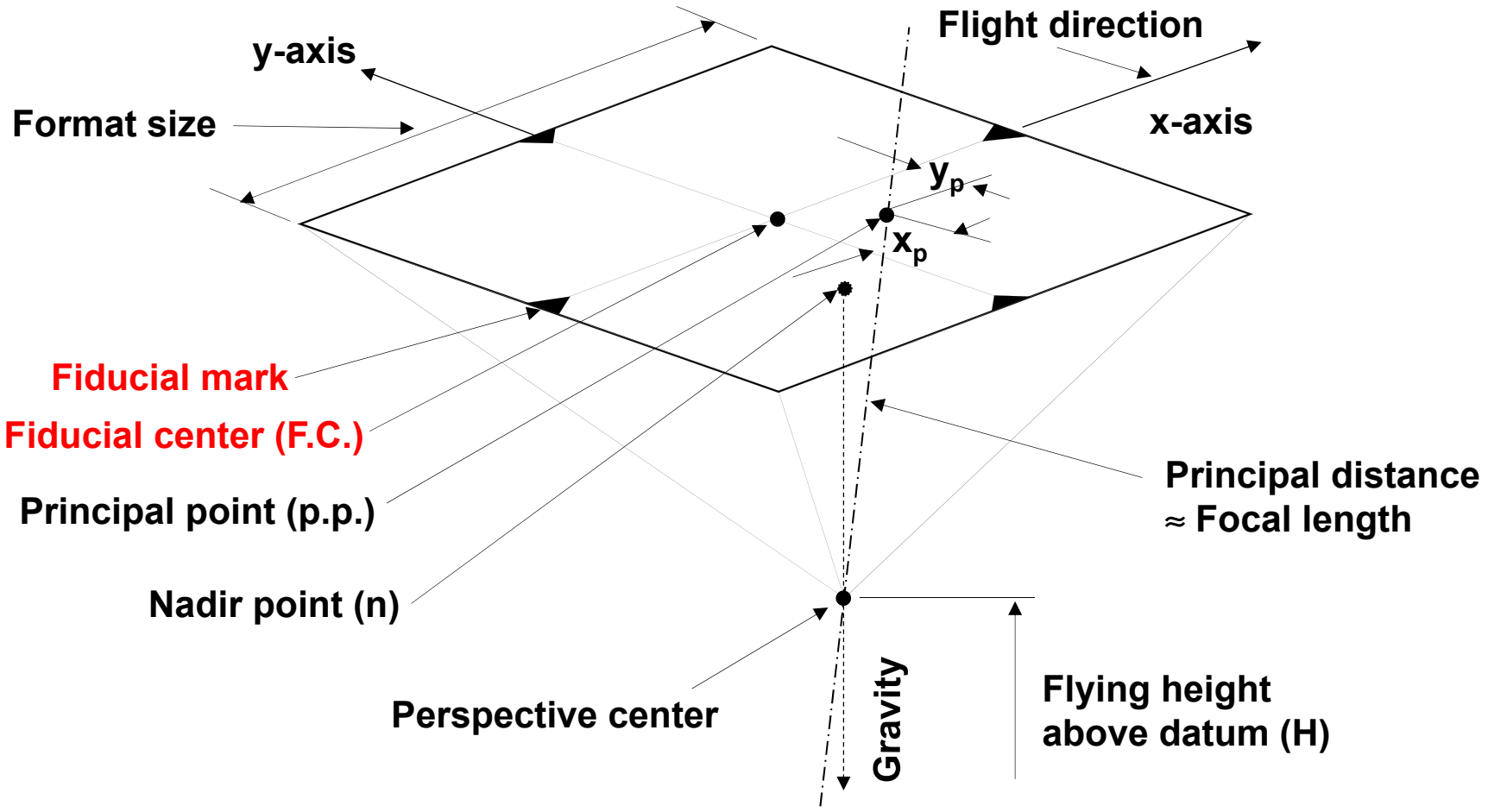


- Optical axis coincides with the plumb line → vertical image.

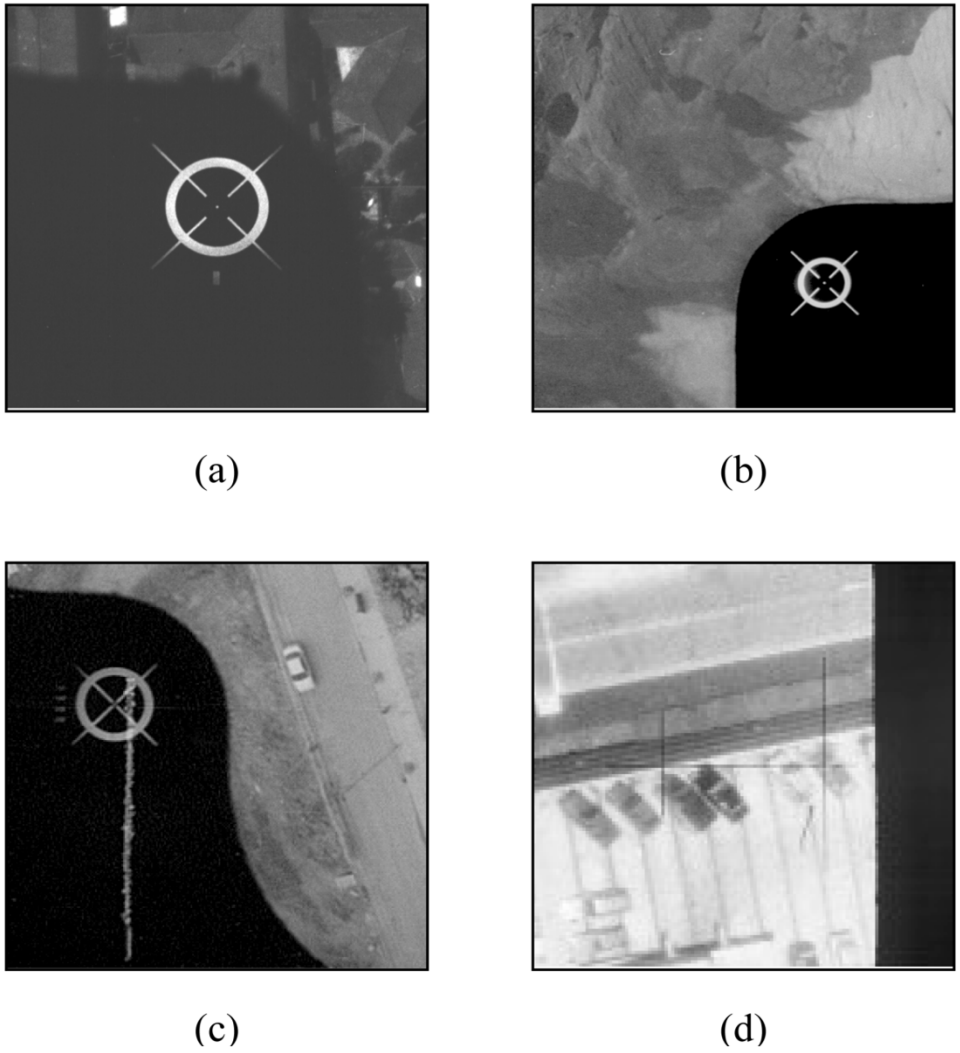
Vertical Photography

- Vertical images are taken with the camera optical axis coinciding with the plumb line (True Vertical Image).
- Nearly Vertical Image: There is a tilt angle between the camera optical axis and the plumb line of ±3˚.

Basic Elements of a Vertical Aerial Image



Fiducial Marks in Analog Metric Cameras



(a) (b) (c) (d)

Basic Definitions

- Nadir Point (n): The intersection of the plumb (gravity) line through the perspective center with the image plane.
- Principal Point (PP): The intersection of the normal to the image plane through the perspective center with the image plane.
  - The normal to the image plane is assumed to coincide with the optical axis.
- Principal Distance (c): The normal distance between the perspective center and the image plane (compare with the focal length - refer to the lens equation).
  - Sometimes, it is denoted as the camera constant.

Basic Definitions

- Flying Height (H): The elevation of the perspective center above the stated datum.
- X-axis of the image coordinate system:
  - The line in the image plane through opposite fiducial marks that are almost parallel to the flight direction.
- Y-axis of the image coordinate system:
  - The line in the image plane through opposite fiducial marks that are almost normal to the flight direction.

Image Scale

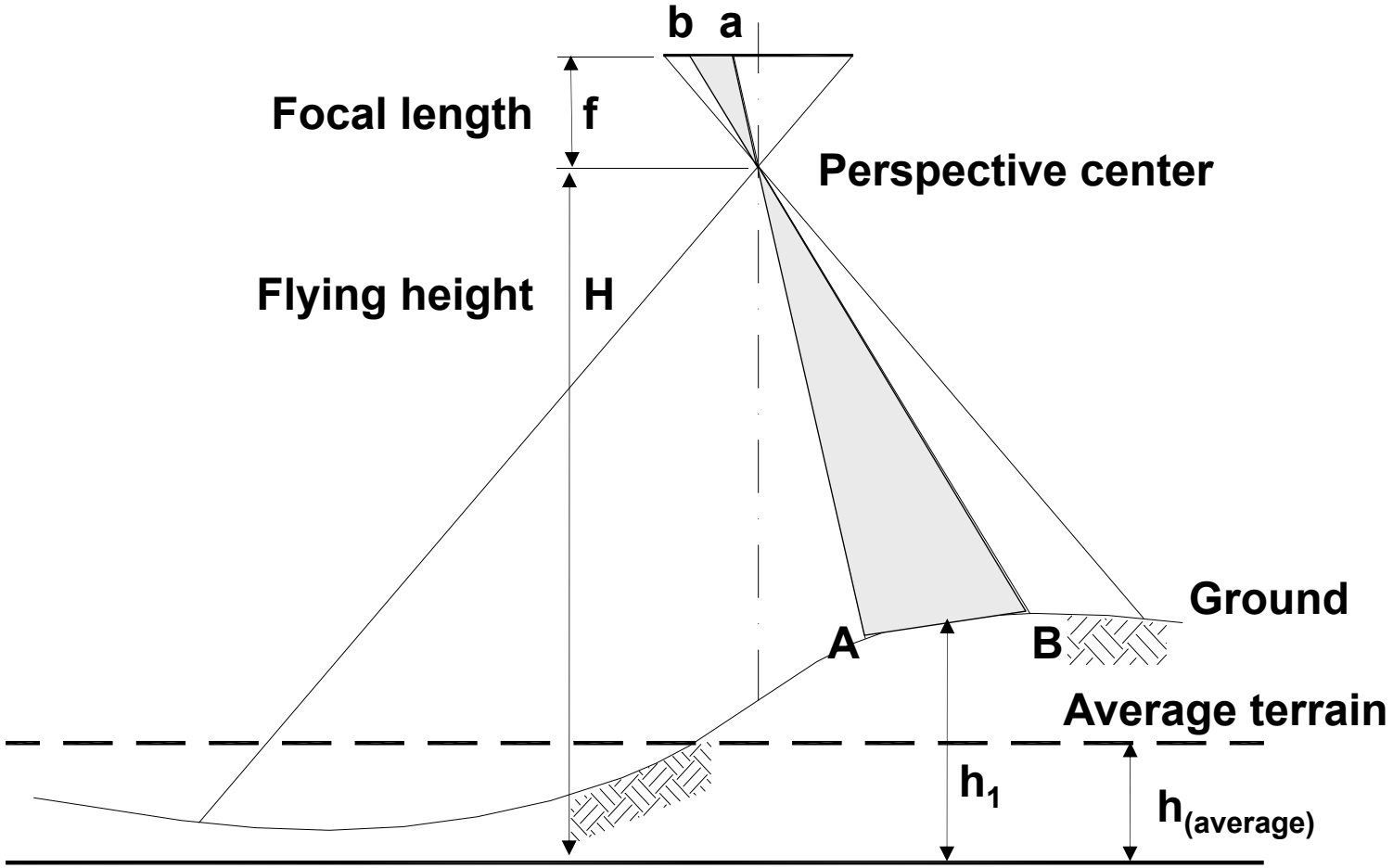
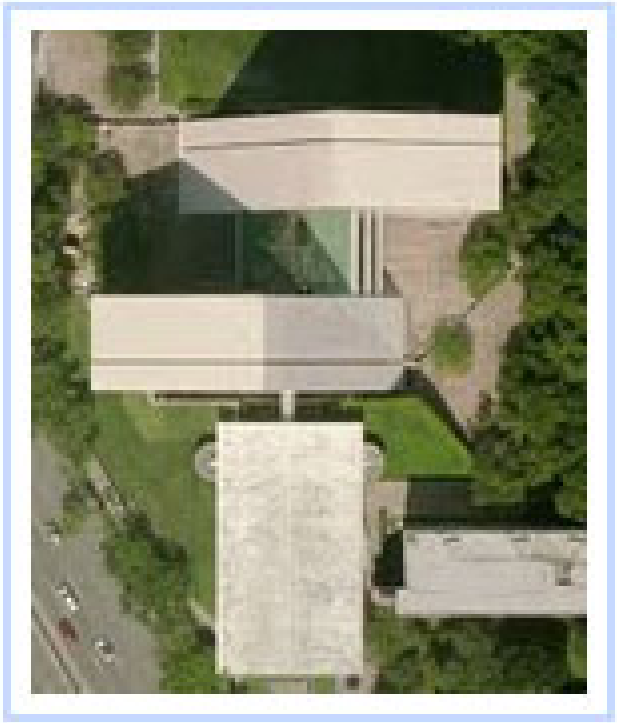

b a
Focal length
f
Perspective center
Flying height
H
Ground
A
B
Average terrain
h1
h(average)

Image Scale

- Image scale: It is the ratio between a distance on the image and the corresponding distance on the ground.
- Since the image is a central projection, it does not have a uniform scale (only one exception exists).
- Image Scale = ab / AB = c / (H - h) – Assuming vertical photography
- Exception: Vertical image over a flat horizontal terrain has a uniform scale (i.e., it can be used as a map).

Tilt Effect on Image Scale



Vertical photographs

Oblique photographs

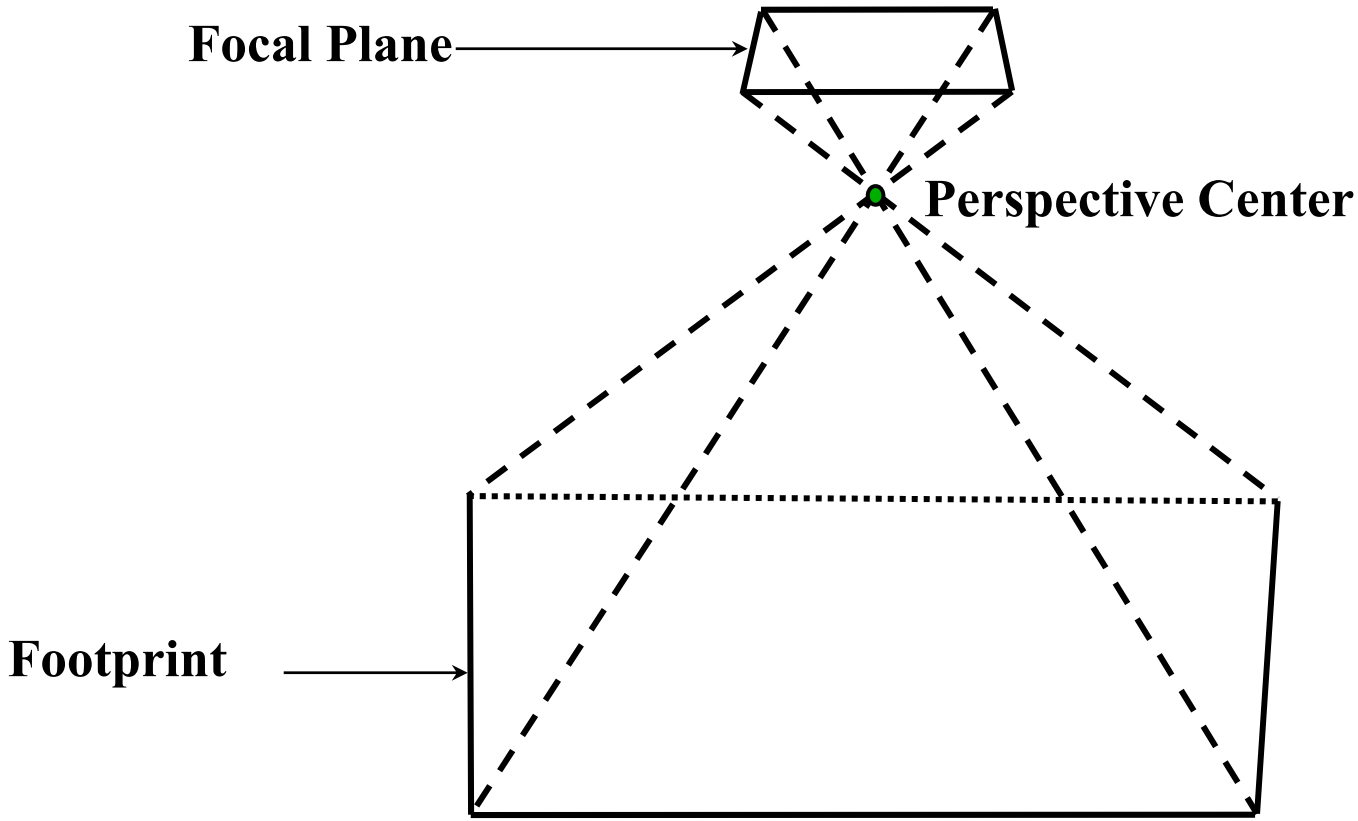
http://civisit.com/blog/?p=52

From Image to Ground Coordinates

From Image to Ground Coordinates

- Objective:
  - Derive the ground coordinates of object points from the measured coordinates of the corresponding image points.
- Assumptions:
  - We are dealing with a vertical image.
  - We are dealing with an image captured by frame camera:
    - Captured by analog or digital camera
    - Analog or digital format
    - Diapositive

Frame Camera



- The image footprint is captured through a single exposure.

Negative Versus Positive

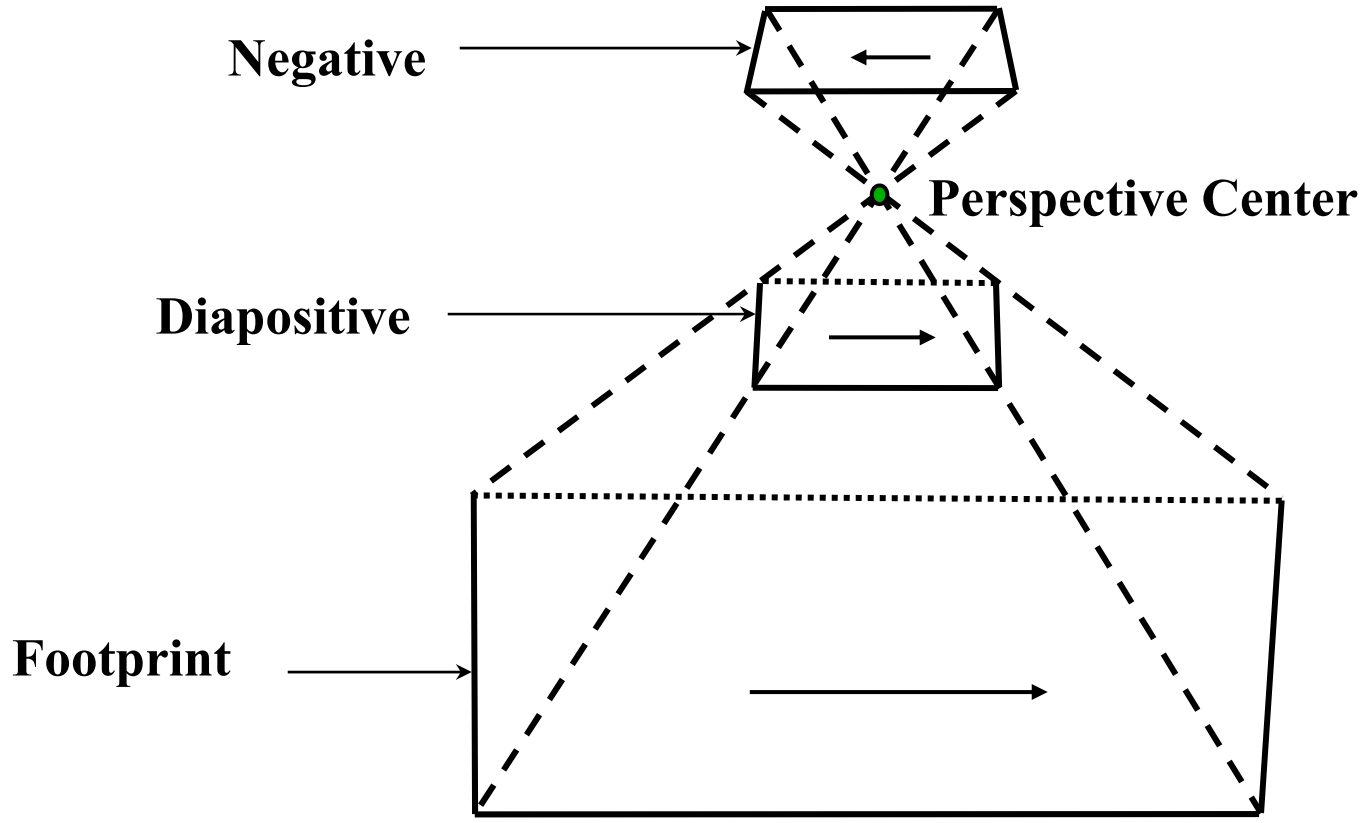
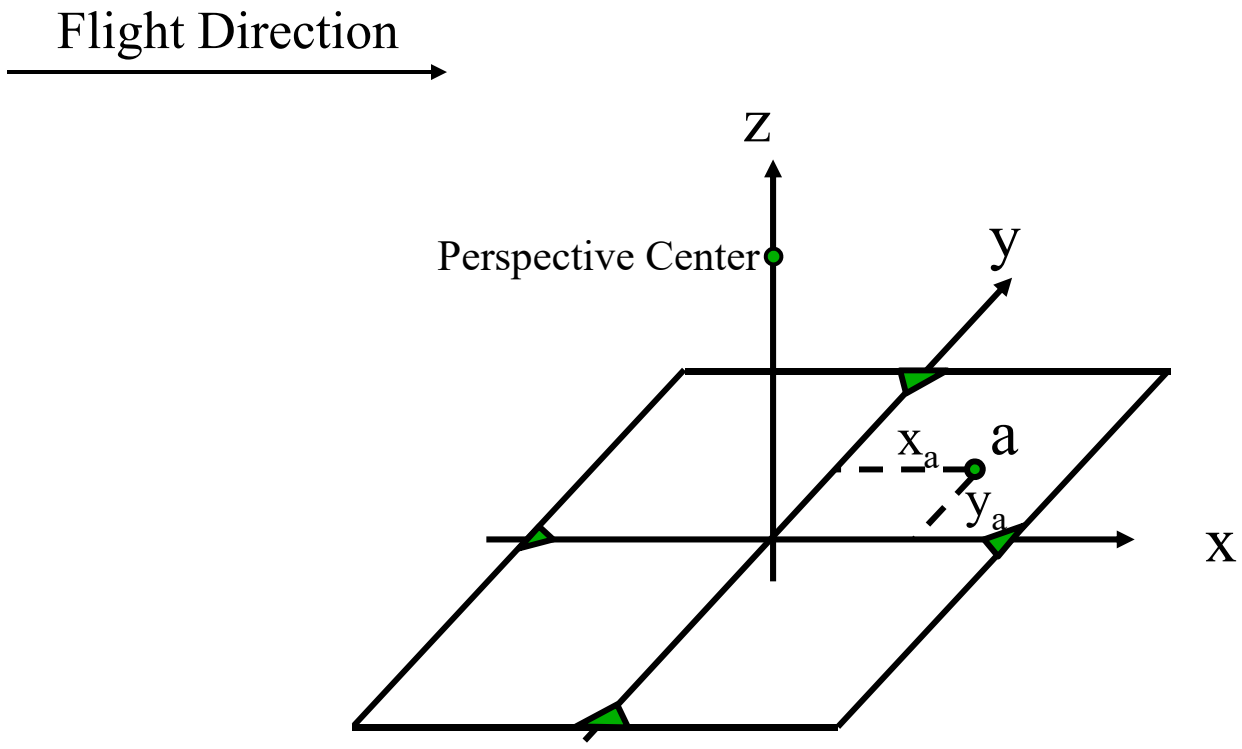


Image Coordinate Systems

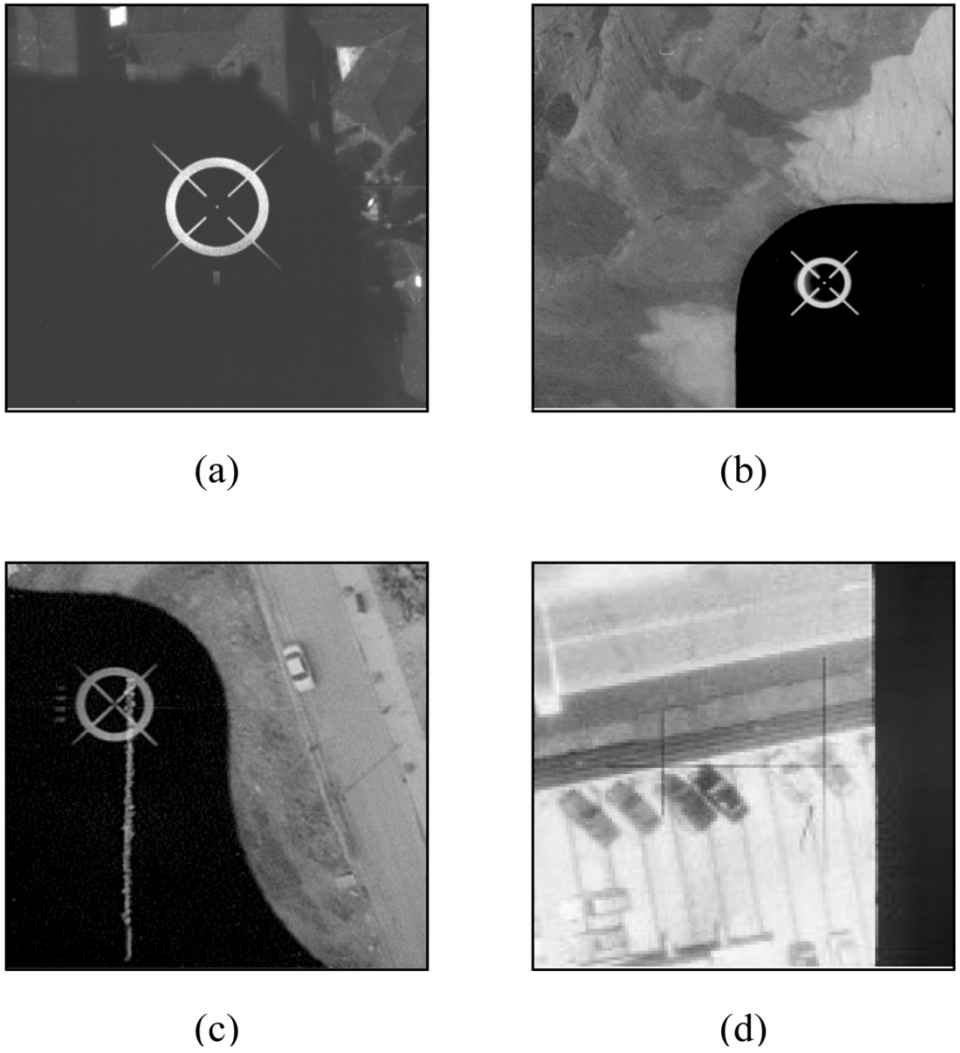


- Assumption: principal point coincides with the Fiducial center.

Analog Camera: RC30

http://www.kasurveys.com/Sensors.html

Fiducial Marks in Analog Metric Cameras

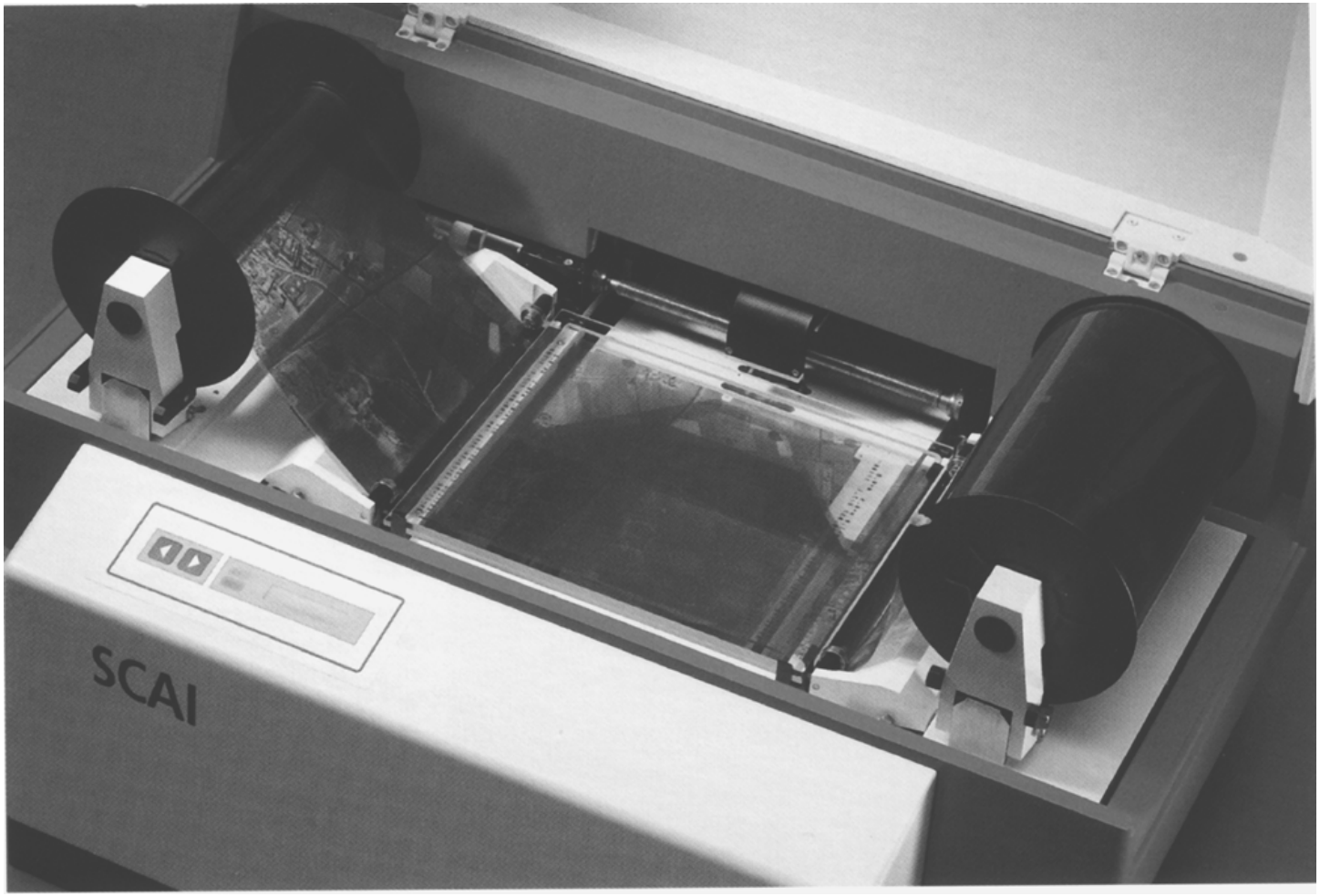


(a) (b) (c) (d)

Image Coordinate System: Digital Images

- Digital images can be acquired through either:
  - Scanning analog images
  - Direct use of digital cameras
- For scanned analog images, the image coordinate system is defined in the same way as analog imagery captured by metric cameras.
- For digital images captured by digital cameras, the image coordinate system is defined by the central row(s) and the central column(s).

Example of Photogrammetric Scanner

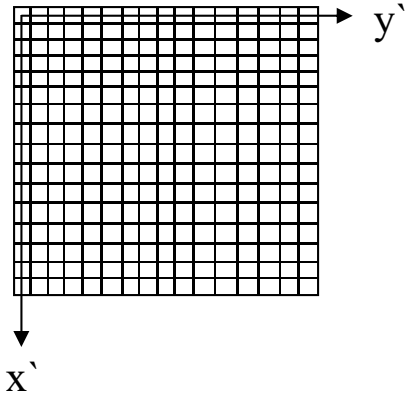


http://cmapspublic.ihmc.us/rid=1J5T5YMZV-15ZNLP5-1JMD/Balayeur%20optique.bmp

Digital Camera: DMC™

http://cmapspublic.ihmc.us/rid=1235786299998_244221932_24870/Photogramm%C3%A9trie%20-%20cam%C3%A9ras%20num%C3%A9riques.jpg

Digital Images captured by Digital Cameras



Pixel Coordinates

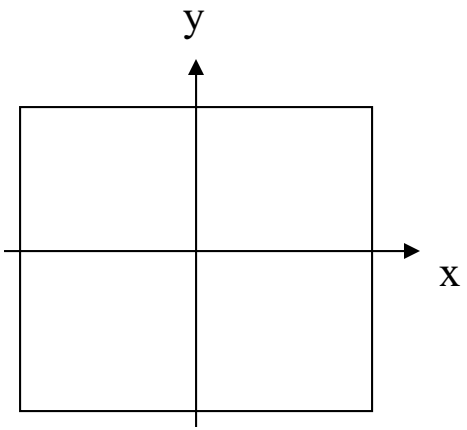


Image Coordinates

Pixel to Image Coordinate Transformation

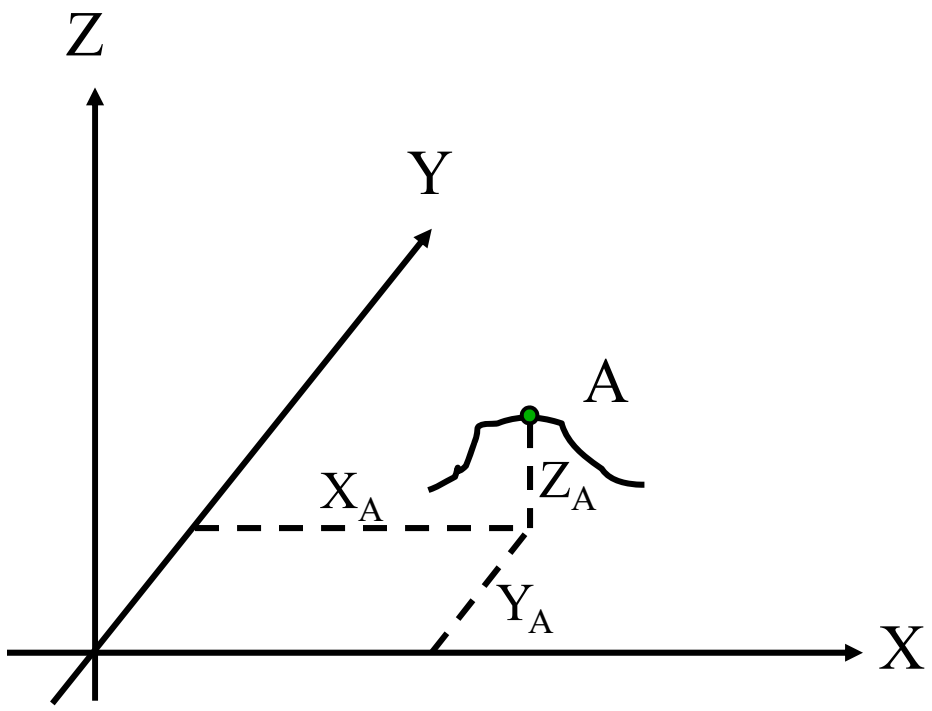
$$x = (y' - n_c / 2.0) \times y\_pix\_size$$

$$y = (n_r / 2.0 - x') \times x\_pix\_size$$

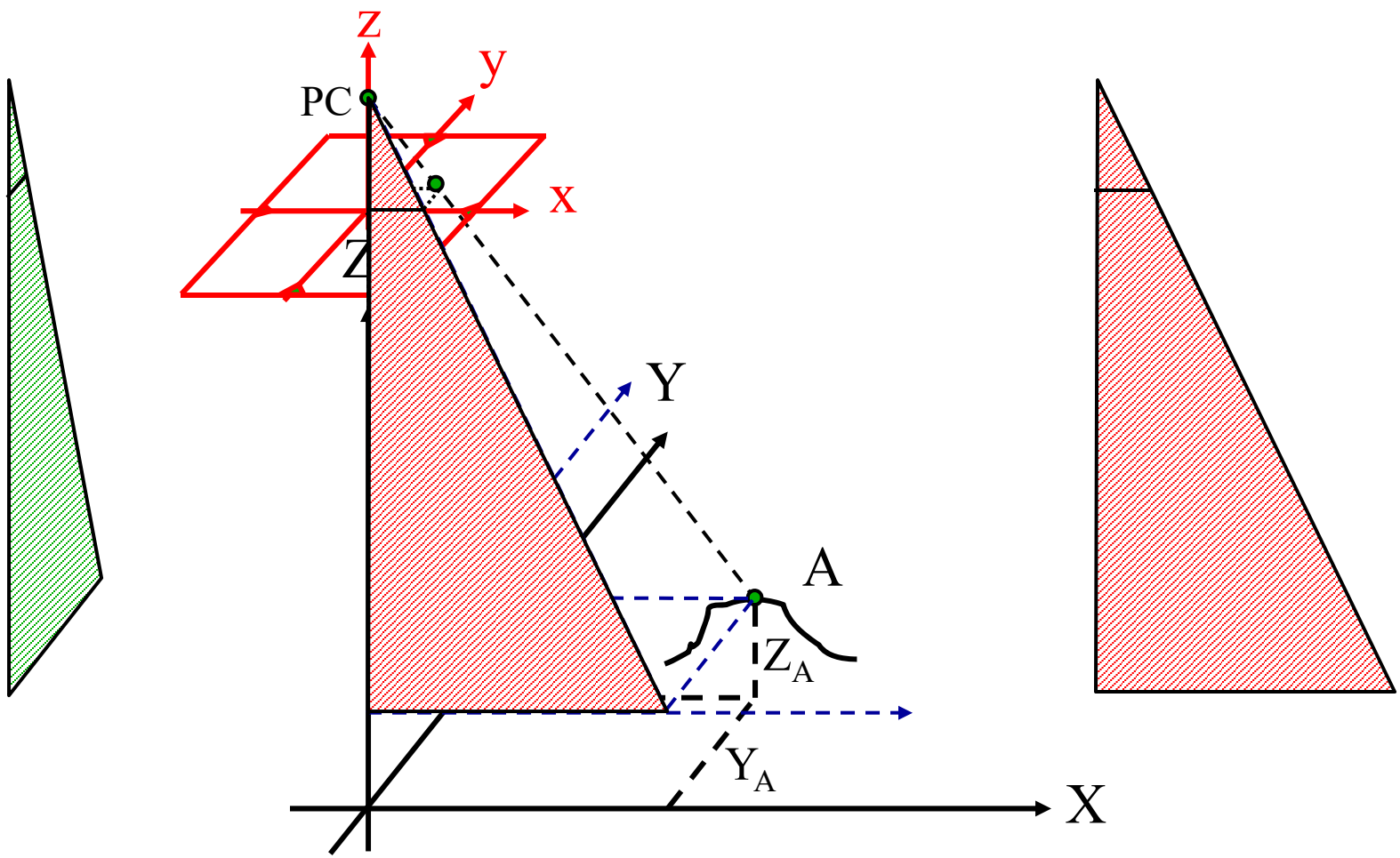
where :

n_c	*Number of columns*
n_r	*Number of rows*
x_pix_size	*Pixel size along the row direction*
y_pix_size	*Pixel size along the column direction*

Ground Coordinate System



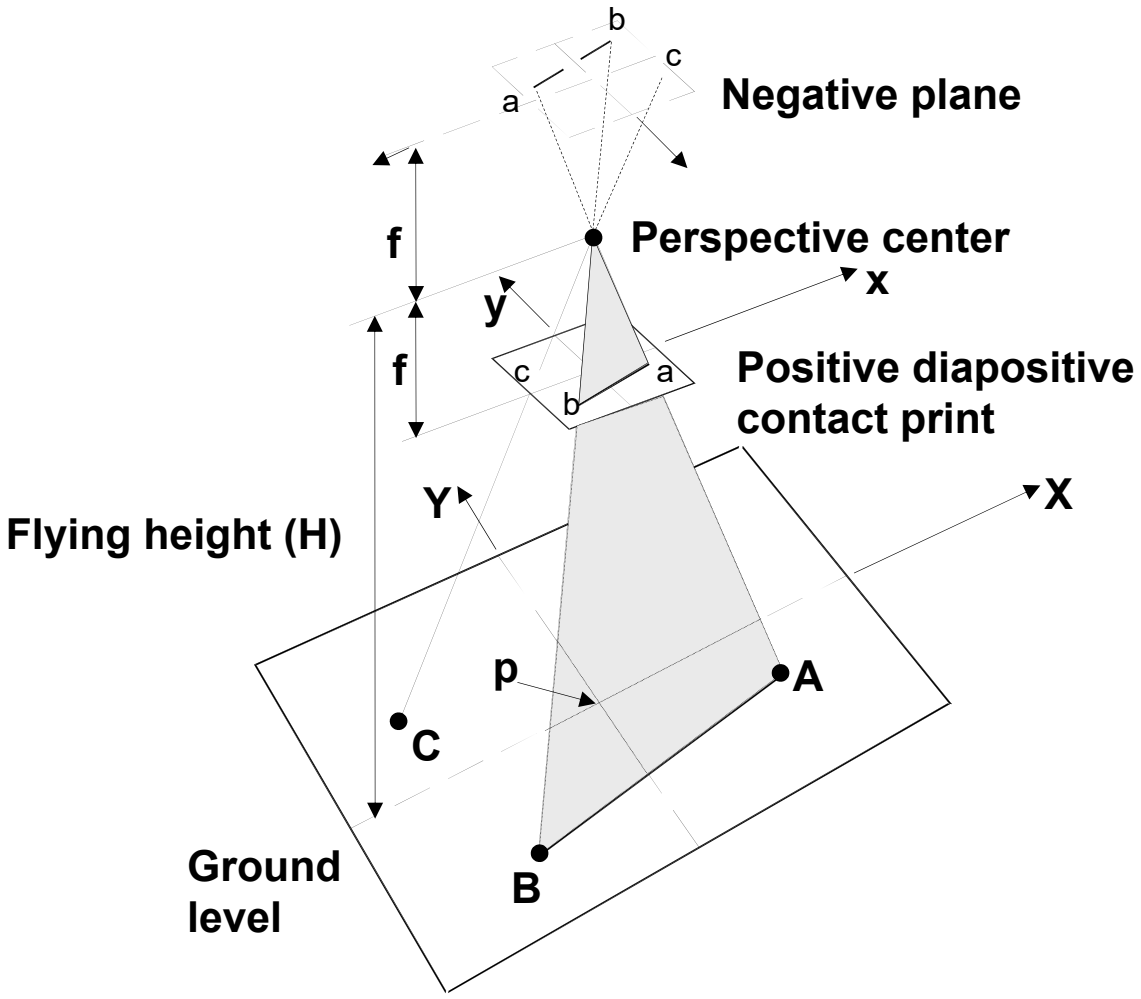
Ground Coordinates from Image Coordinates



Ground Coordinates from Image Coordinates

- Assumptions:
  - Vertical imagery,
  - The image and ground coordinate systems are parallel,
  - The origin of the ground coordinate system is vertically below the perspective center, and
  - The principal point coincides with the Fiducial center
- From similar triangles, one gets:
  - $X_A = x_a \ (H - h_A) / c$
  - $Y_A = y_a \ (H - h_A) / c$

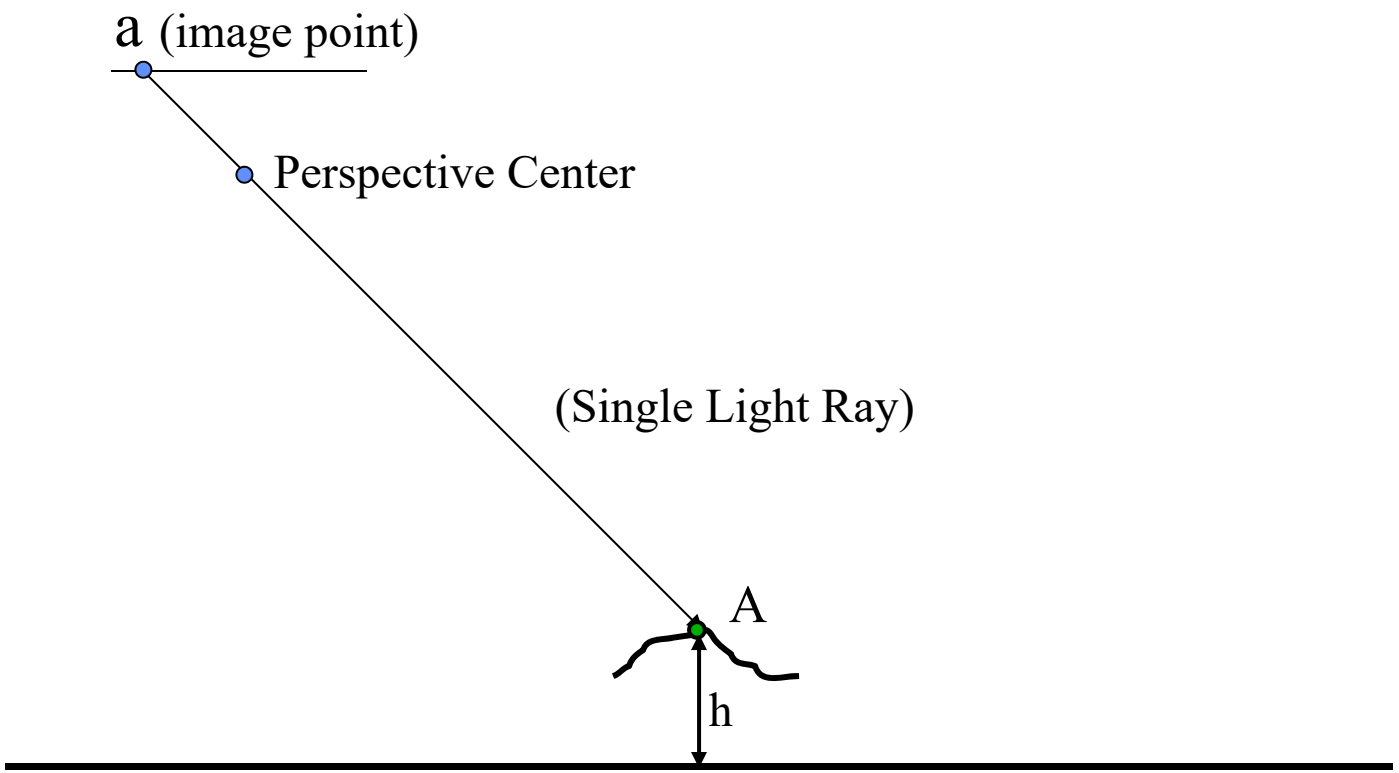
Ground Coordinates from Image Coordinates



Single Photo Positioning?

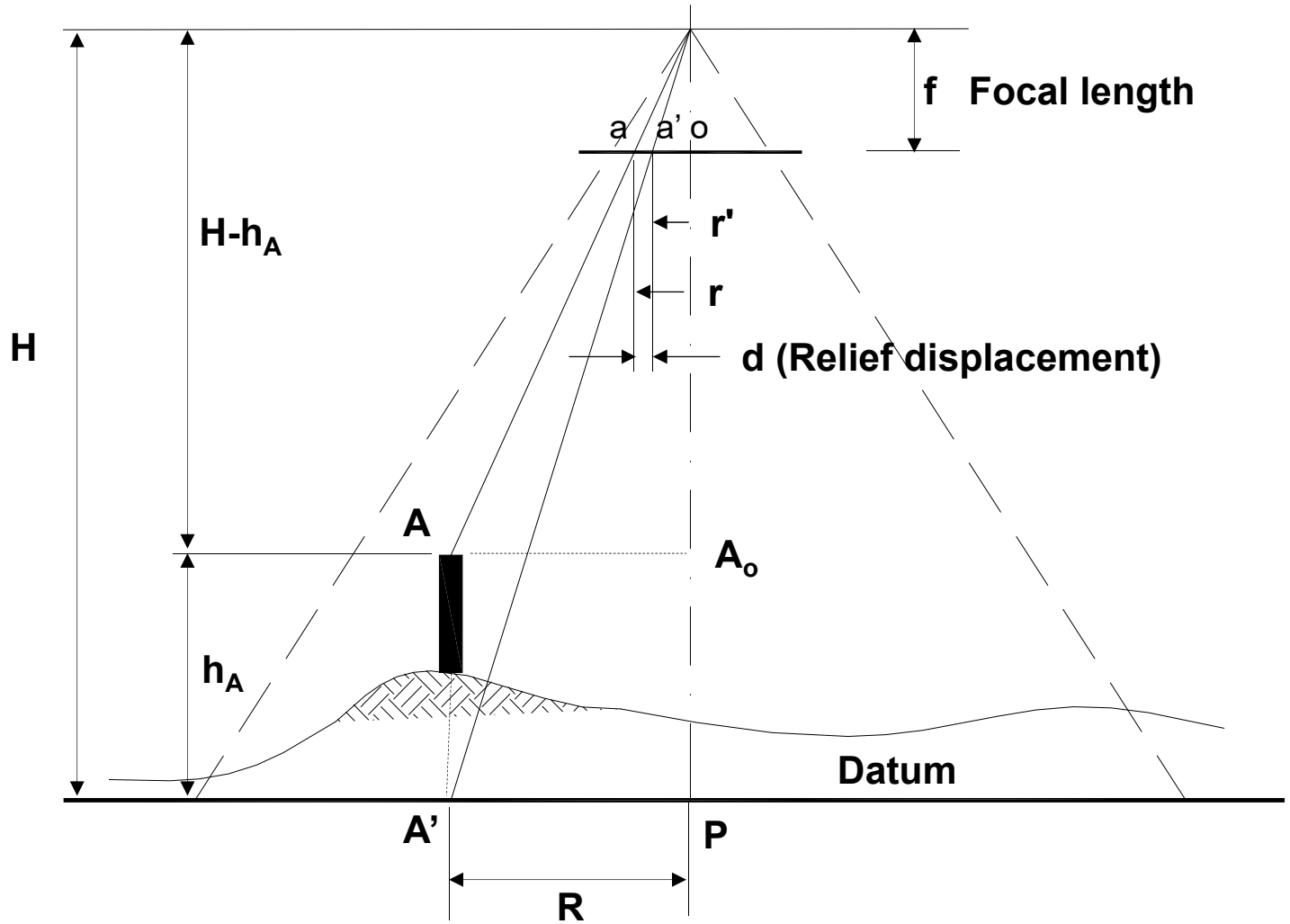
- Question:
  - Can we derive the three-dimensional coordinates of an object point from a single photo?
- Answer:
  - No
- We assumed that we know the height of the object point under consideration.

Single Photo Positioning?



Relief Displacement

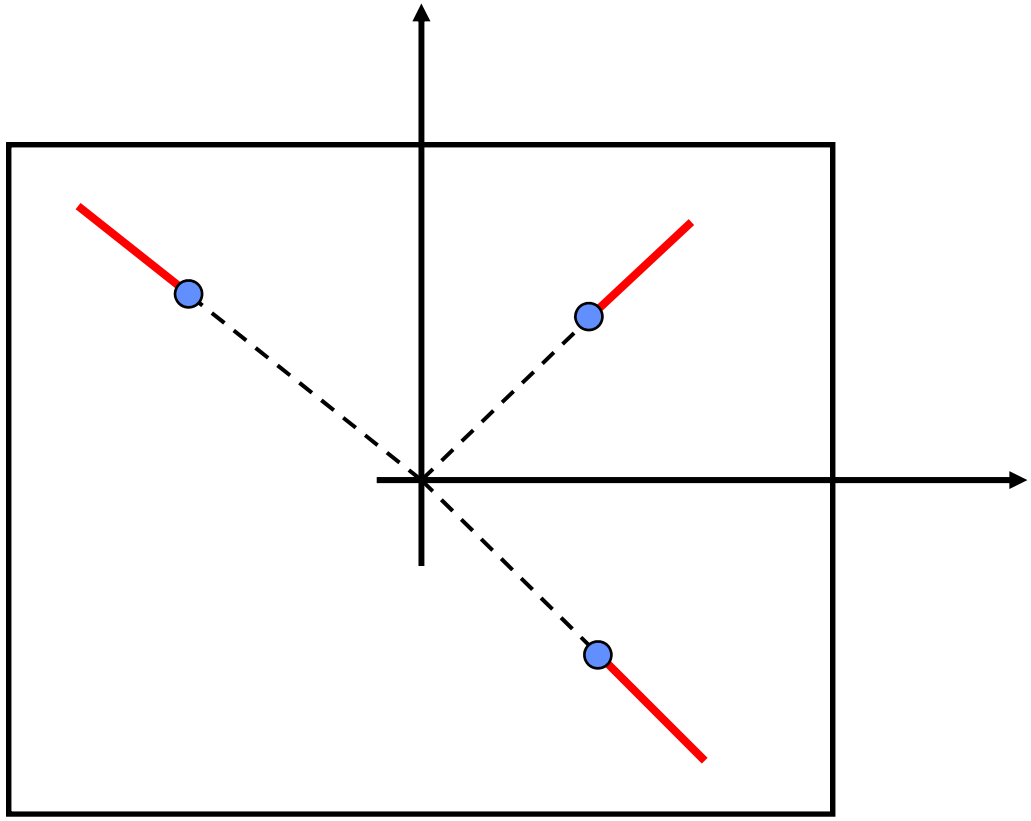
Relief Displacement



Relief Displacement

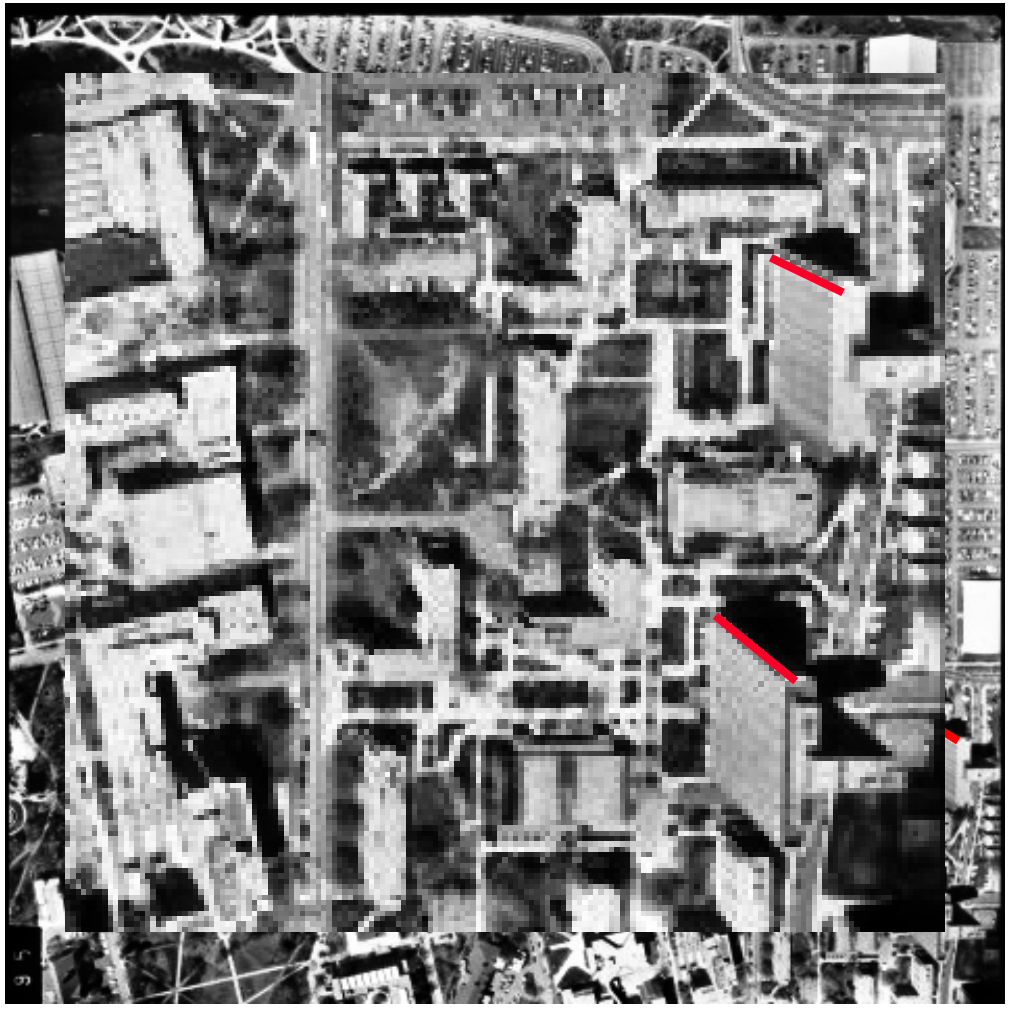
- The shift in the photographic position of an image point caused by the height of the corresponding object point above or below the datum.
- From similar triangles, one gets:
  - $d_a = r\, h_A / H$
- Relief displacement occurs along the radial direction from the nadir point.
- For vertical imagery over flat horizontal terrain, the effect of relief displacement simulates a uniform change in the scale.

Relief Displacement



- Assumption: nadir point coincides with the Fiducial center.

Relief Displacement



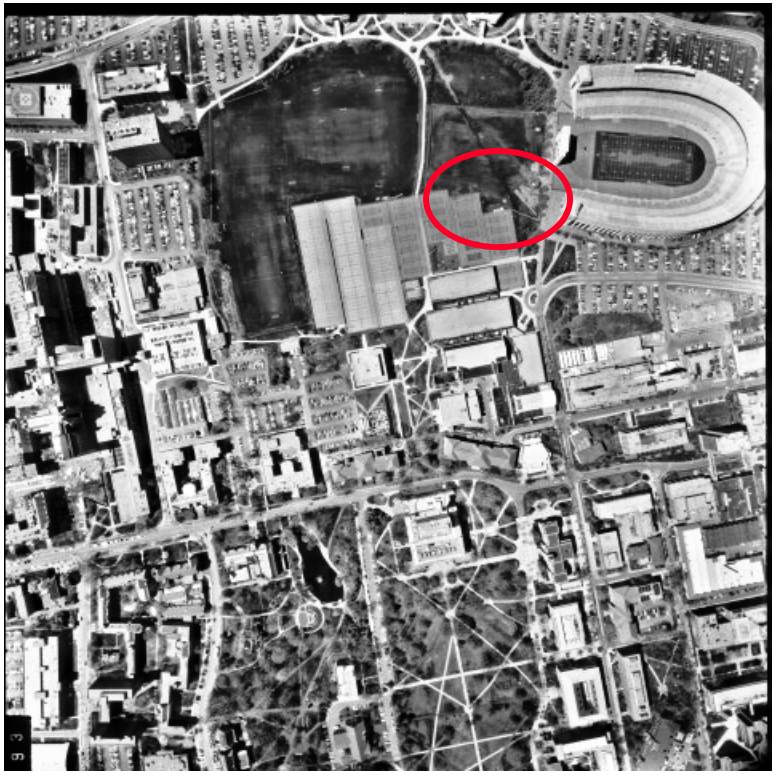
Relief Displacement

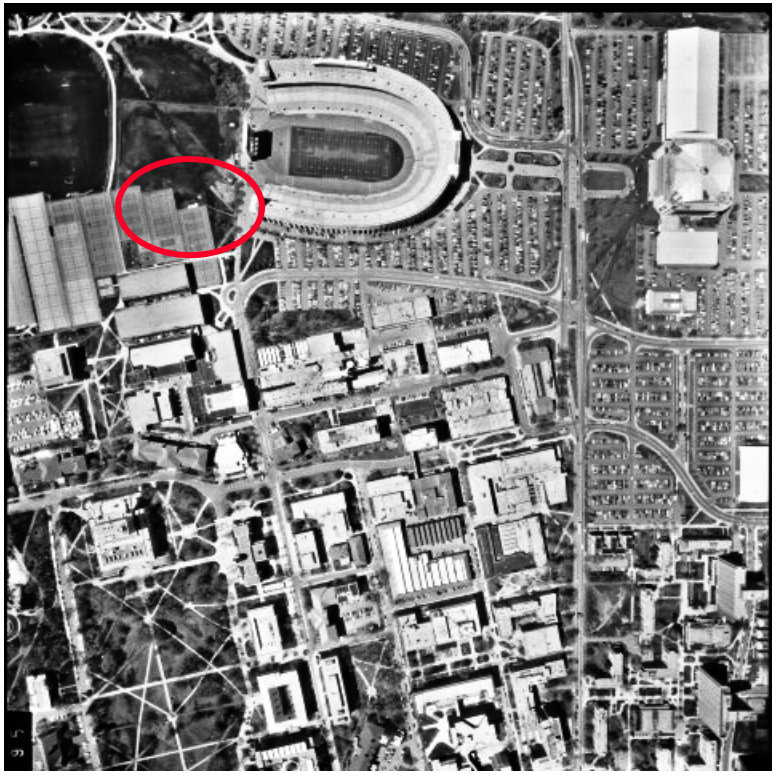
Patch from the left image

Patch from the right image

- Where are the principal points?

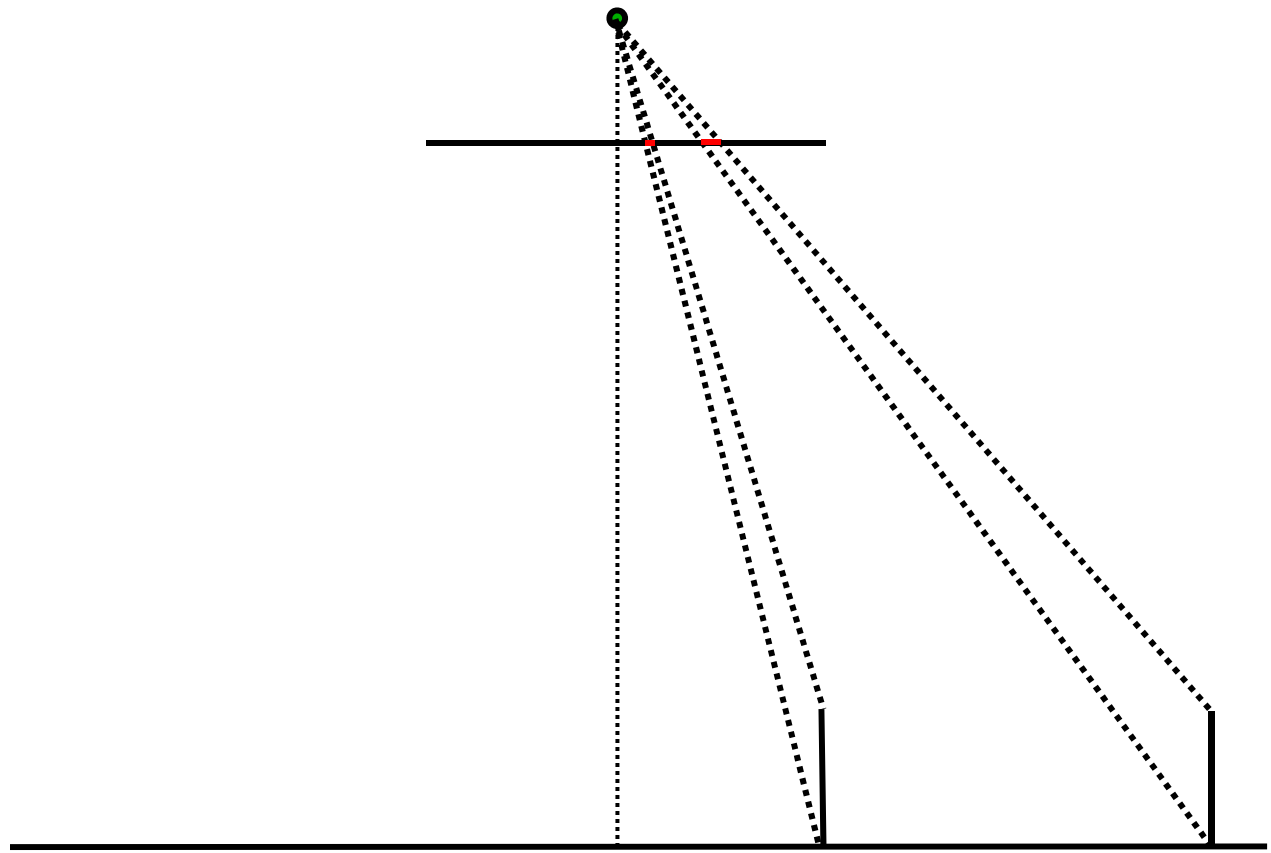
Relief Displacement





Light pole

Relief Displacement



- Relief Displacement increases with the radial distance.

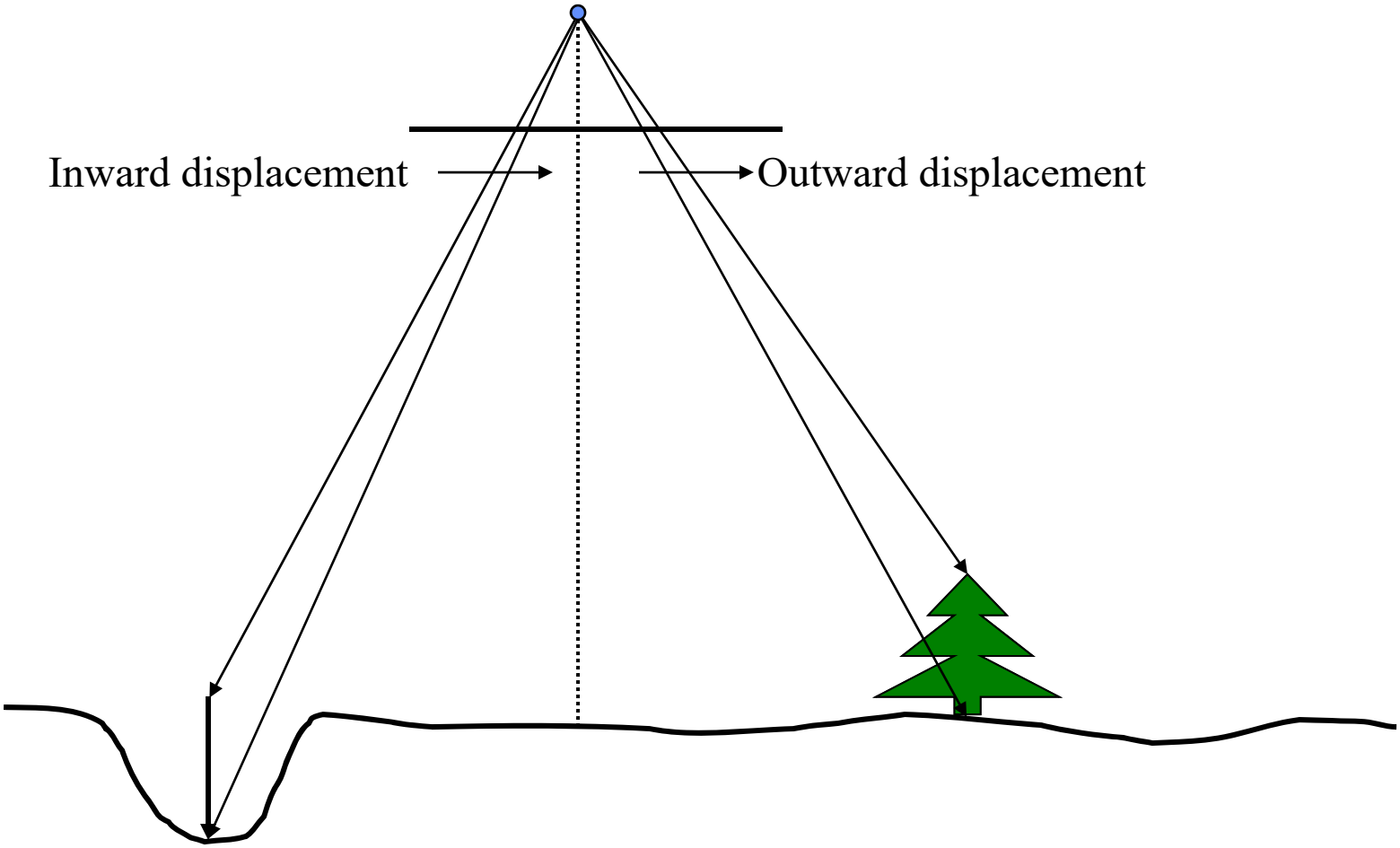
Relief Displacement

- Relief Displacement is directly proportional to:
  - Radial distance from the nadir point, and
  - Object height above the datum.
- Relief Displacement is inversely proportional to:
  - Flying height above the datum.
- Relief displacement causes occlusion.

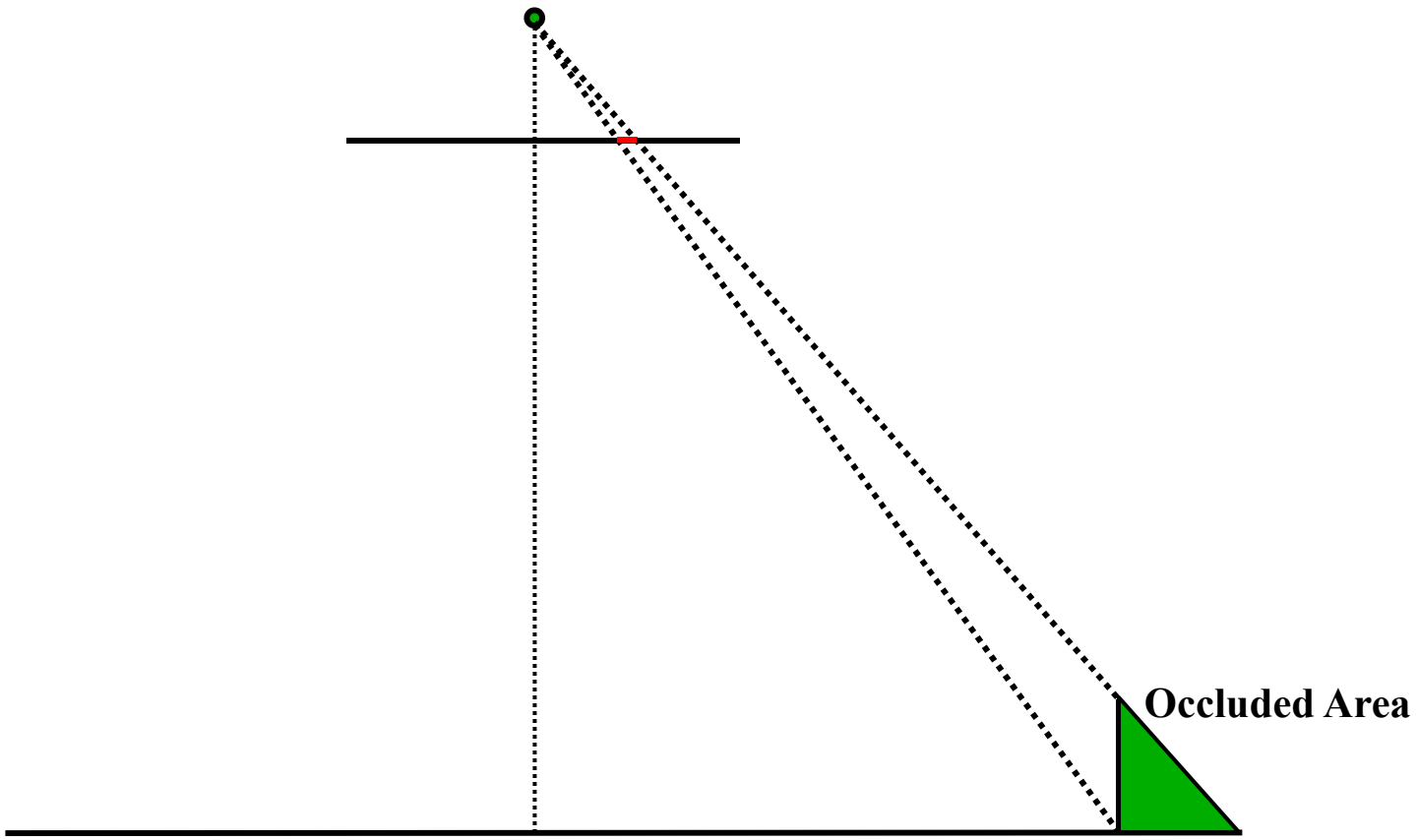
Relief Displacement: Characteristics

- Relief displacement is outward for points whose elevations are above the datum (diapositive).
- Relief displacement is inward for points whose elevations are below the datum (diapositive).
- Relief displacement occurs along radial direction from the nadir point of the image.
  - For vertical photographs: The nadir point (n), the principal point (PP), and the Fiducial center (FC) are very close to each other.

Relief Displacement: Characteristics



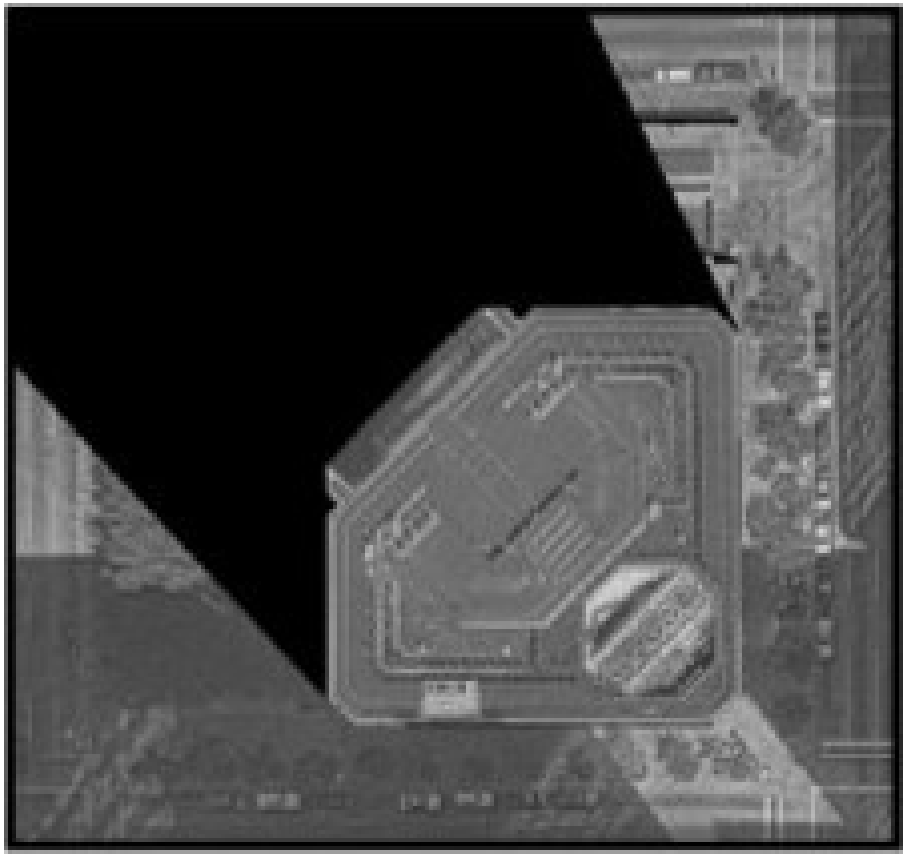
Relief Displacement & Occlusion



Relief Displacement & Occlusion

http://www.e-topo.com/etoposite/pages/ortho_photography.aspx

Relief Displacement & Occlusion



Occluded Area

http://www.e-topo.com/etoposite/pages/ortho_photography.aspx

Relief Displacement & Occlusion

Relief Displacement & Occlusion

Relief Displacement & Occlusion

Patch from the left image

Patch from the right image

- Where are these patches relative to the original images?

Relief Displacement & Occlusion