

# The Photogrammetric Process

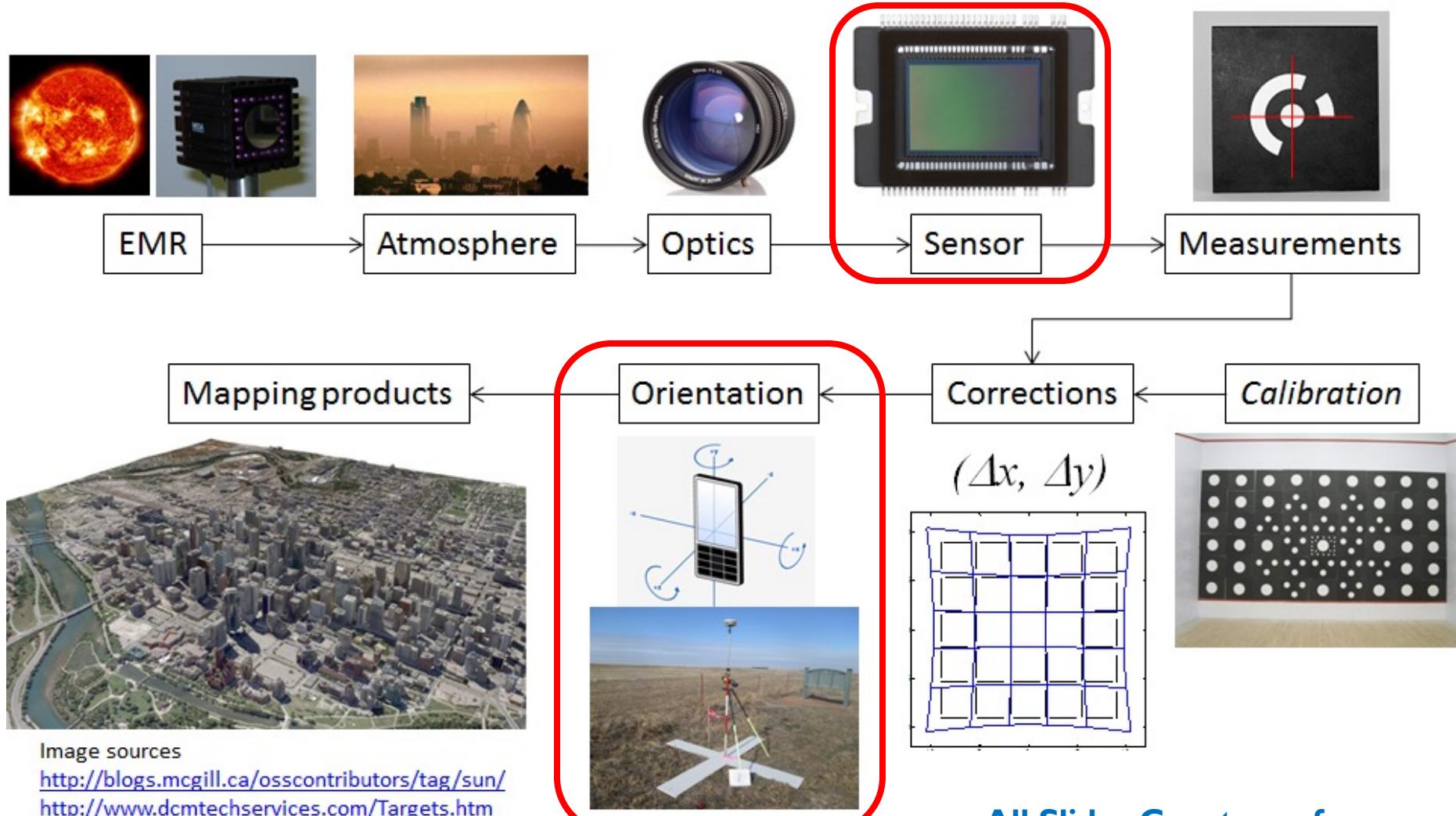


Image sources

<http://blogs.mcgill.ca/osscontributors/tag/sun/>

<http://www.dcmtechservices.com/Targets.htm>

<http://www.theguardian.com/environment/2011/jan/28/europe-air-quality-pollution>

<https://www.ephotozine.com/article/slrmagic-50mm-f-0-95-hyperprime-lens-review-23001>

<http://oneslidephotography.com/ccd-vs-cmos-dslr-camera-which-one-is-better/>

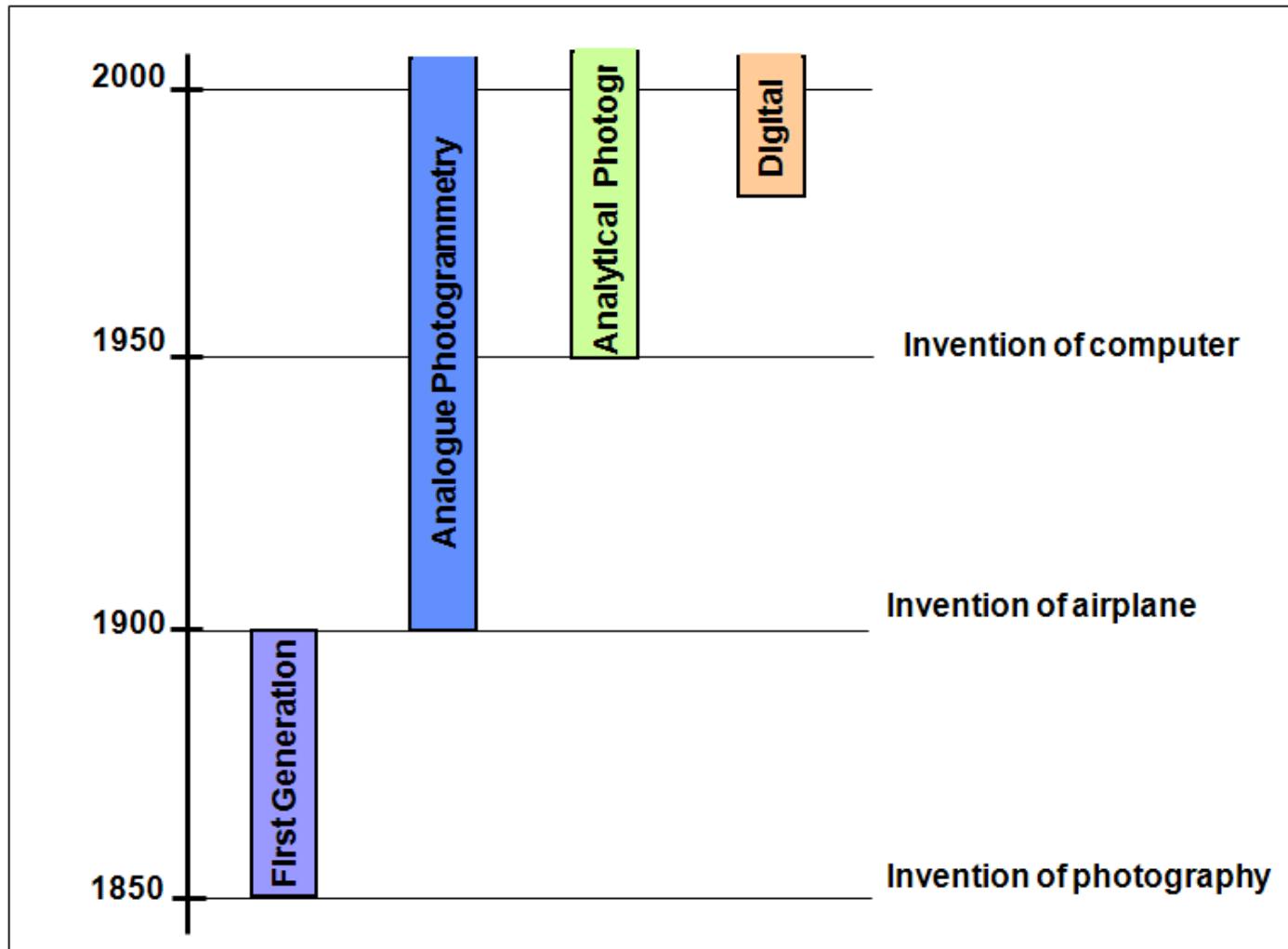
<http://www.rpsurveying.com/img/proj/ControlPoint.Full.png>

<http://www.3dcadbrowser.com/download.aspx?3dmodel=20756>

All Slides Courtesy of:

**Dr. Derek Lichti**  
**University of Calgary**

# Generations of Photogrammetry



Imagery courtesy of Ayman Habib

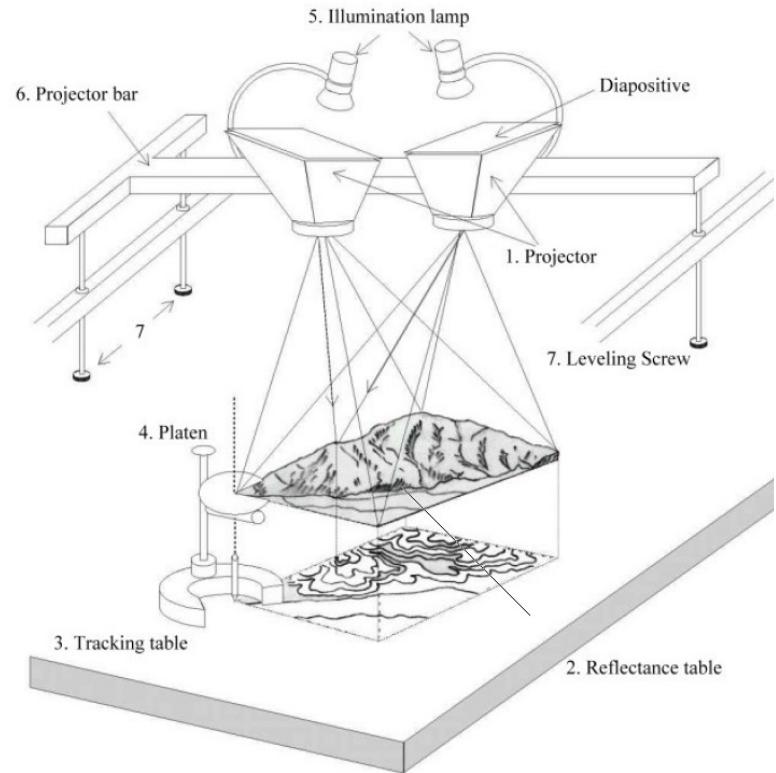
# Generations of Photogrammetry (cont'd)

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- ▶ **Analogue photogrammetry:**
  - ▶ Analogue imagery + stereo-viewing controlled by optical and mechanical devices
  - ▶ Analogue output
- ▶ **Analytical photogrammetry:**
  - ▶ Analogue imagery + stereo-viewing controlled by computers
  - ▶ Digital output
- ▶ **Digital photogrammetry:**
  - ▶ Digital imagery + stereo-viewing controlled by computers
  - ▶ Digital output
  - ▶ Automation capabilities (automatic matching and DEM generation)

# Analogue Photogrammetry

## ► Wild A8 analogue stereo plotter



# Analytical Photogrammetry

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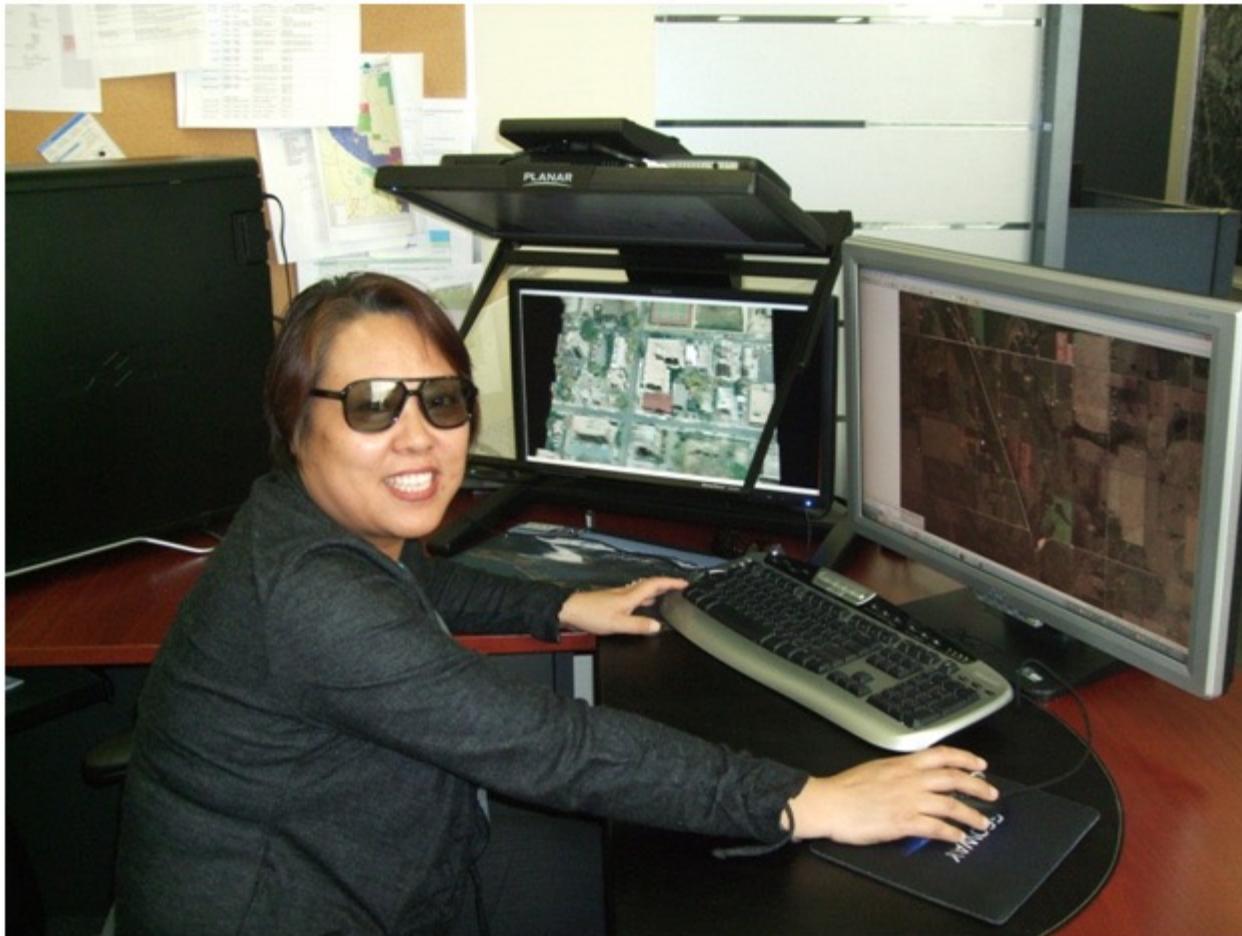
## ► Leica SD2000



<http://www.blom-uk.co.uk/2011/02/a-day-in-the-life-of-a-photogrammetry-manager/>

# Digital Photogrammetry

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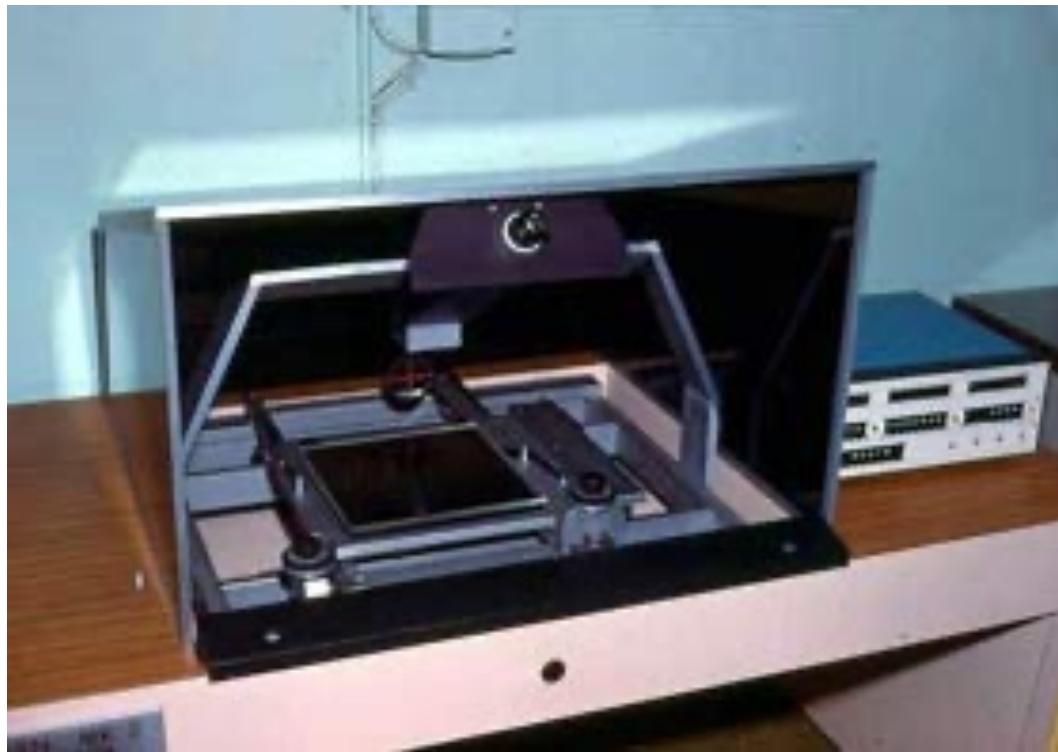
<http://www.challengergeomatics.com/technology/photogrammetry.php>

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# Monocomparator

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## ▶ Kern monocomparator



<http://b-29s-over-korea.com/aerial%20photography/aerial%20photography-pg2.html>

# Stereocomparator

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- ▶ Wild PUG stereocomparator



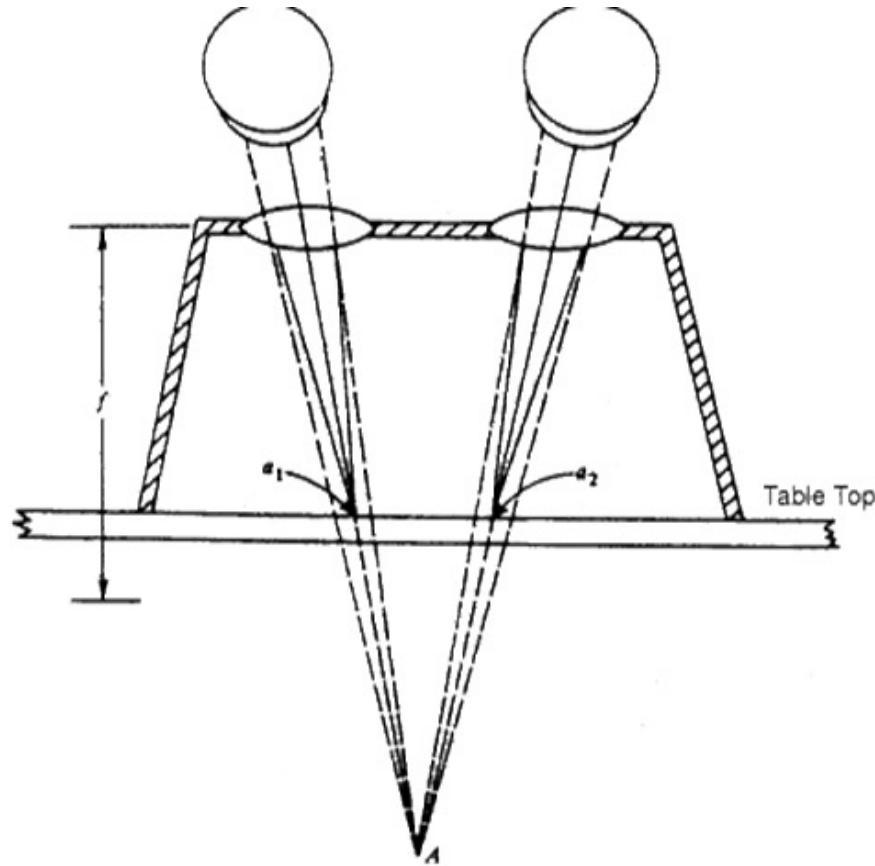
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# Stereoscopic Viewing

## ► Mirror stereoscope



## ► Pocket stereoscope



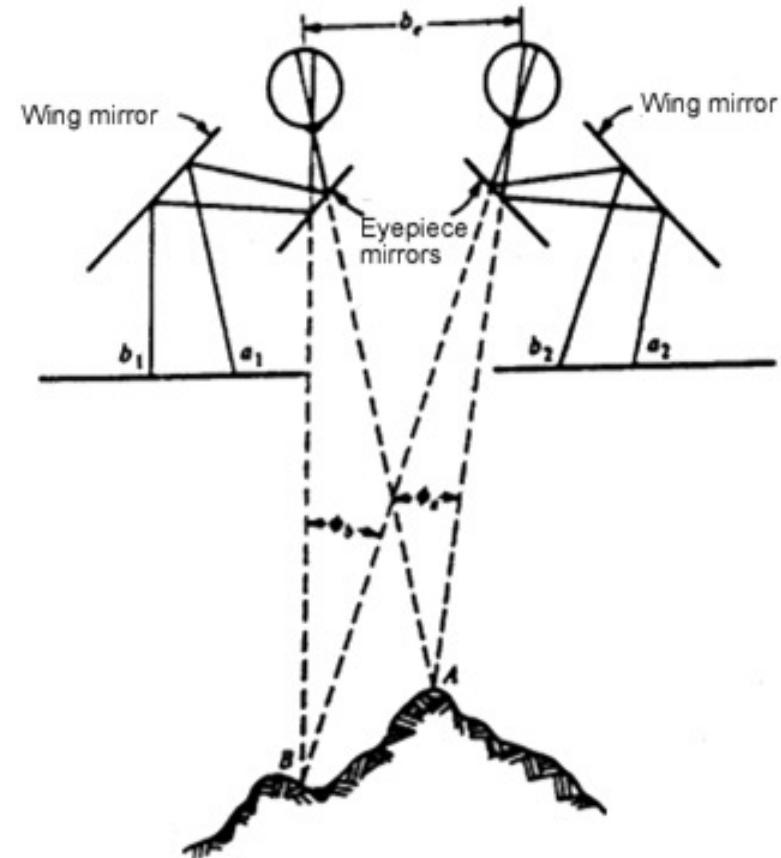
[http://nptel.ac.in/courses/105104100/lectureC\\_32/C\\_32\\_3.htm](http://nptel.ac.in/courses/105104100/lectureC_32/C_32_3.htm)

T: <http://www.sokkia.com.tw/pd/lift-1>

B: [http://www.cpsisc-elearning.com.au/learningobjects/read-and-interpret-basic-image-data/resources/html/res\\_stereoscopes.htm](http://www.cpsisc-elearning.com.au/learningobjects/read-and-interpret-basic-image-data/resources/html/res_stereoscopes.htm)

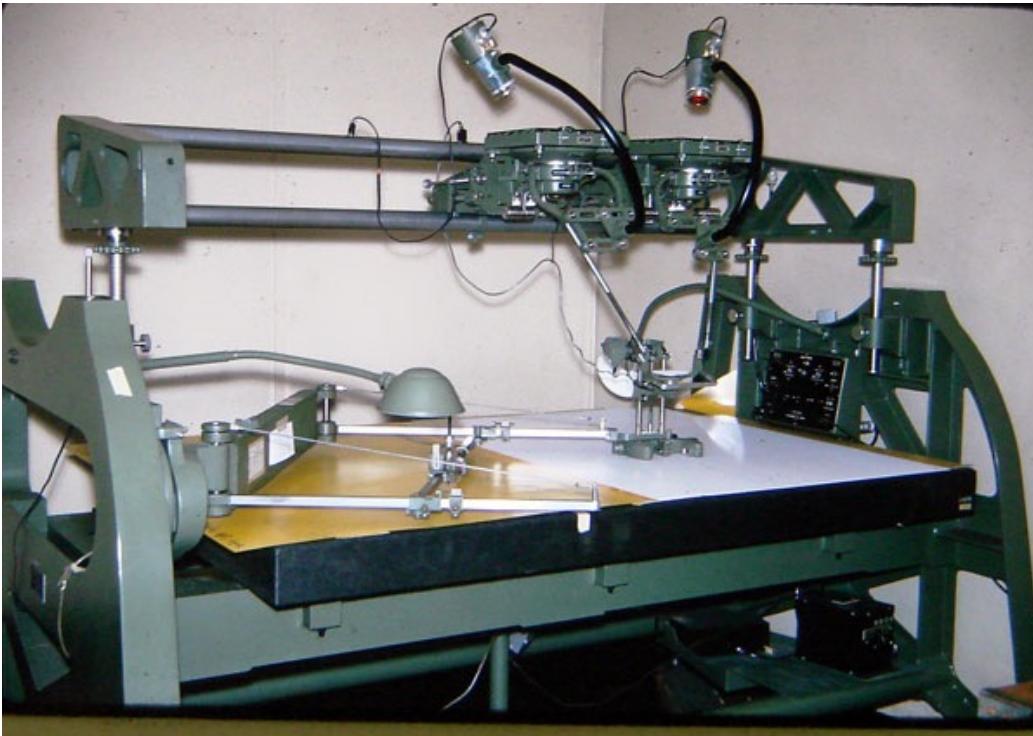
# Stereoscopic Viewing (cont'd)

## ► Wild B8 stereoplotter



# Stereoscopic Viewing (cont'd)

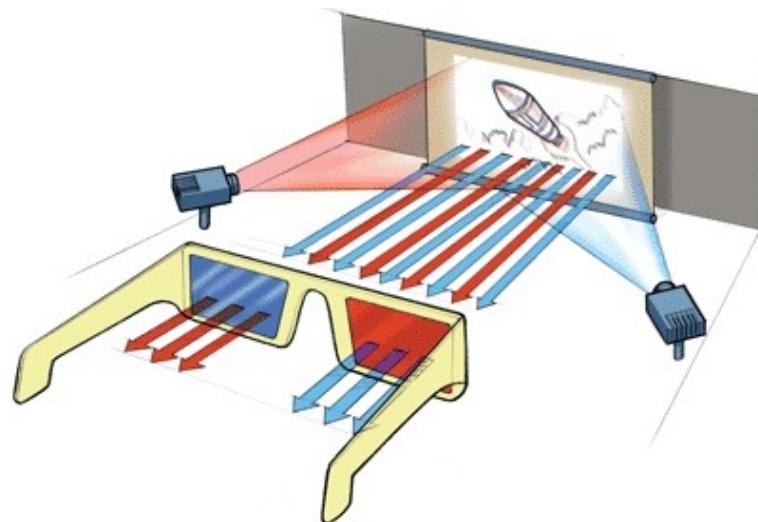
## ► Kelsh anaglyph stereoplotter



<http://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0CAMQjxxqFQoTCK2nm56ts8gCFU43iAodDx4C8A&url=http%3A%2F%2Fnationalmap.gov%2Fustopo%2F125history.html&psig=AFQjCNGSqAi2uiiyGMdI3cOB5GzqXtK2kw&ust=144410119649081>



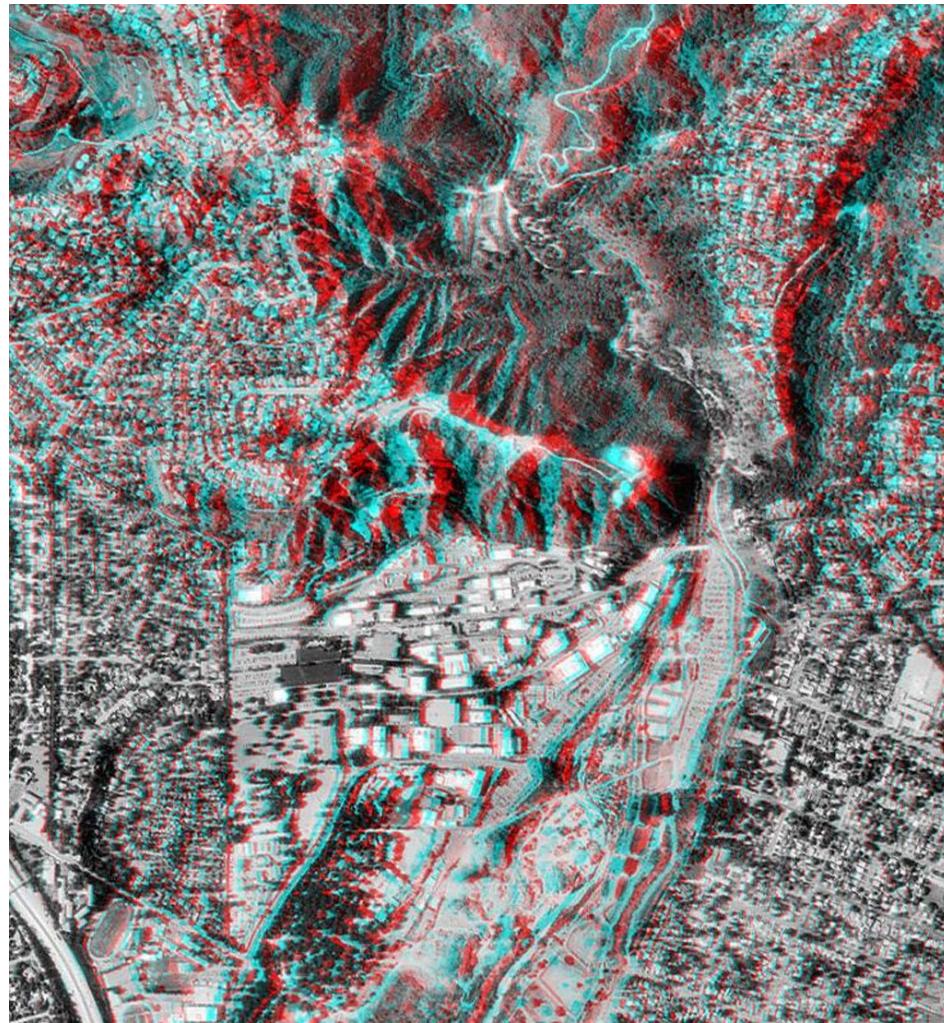
<http://www.berezin.com/3d/3dglasses.htm>



<http://www.phonearena.com/image.php?m=Articles.Images&f=name&id=38007&popup=1>

# Stereoscopic Viewing (cont'd)

- ▶ Anaglyph image



<http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA02721>

# Stereoscopic Viewing (cont'd)

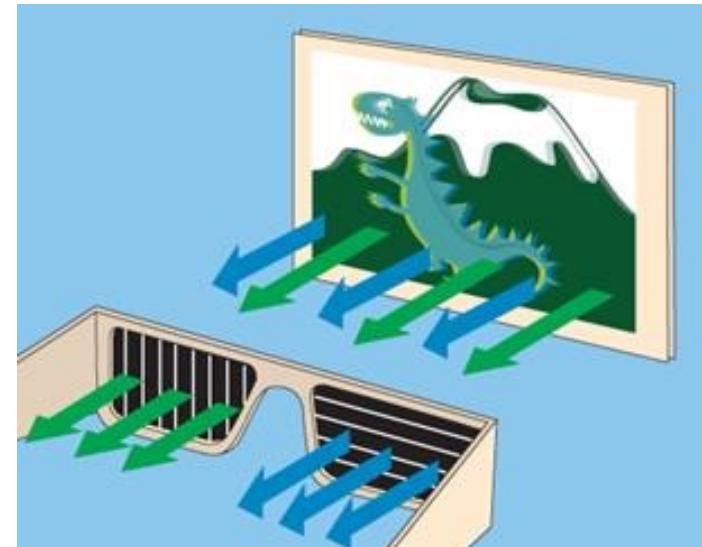
## ▶ Digital photogrammetric workstation



Polarized glasses



<http://www.best-3dtvs.com/guides/3d-glasses-active-vs-passive/>

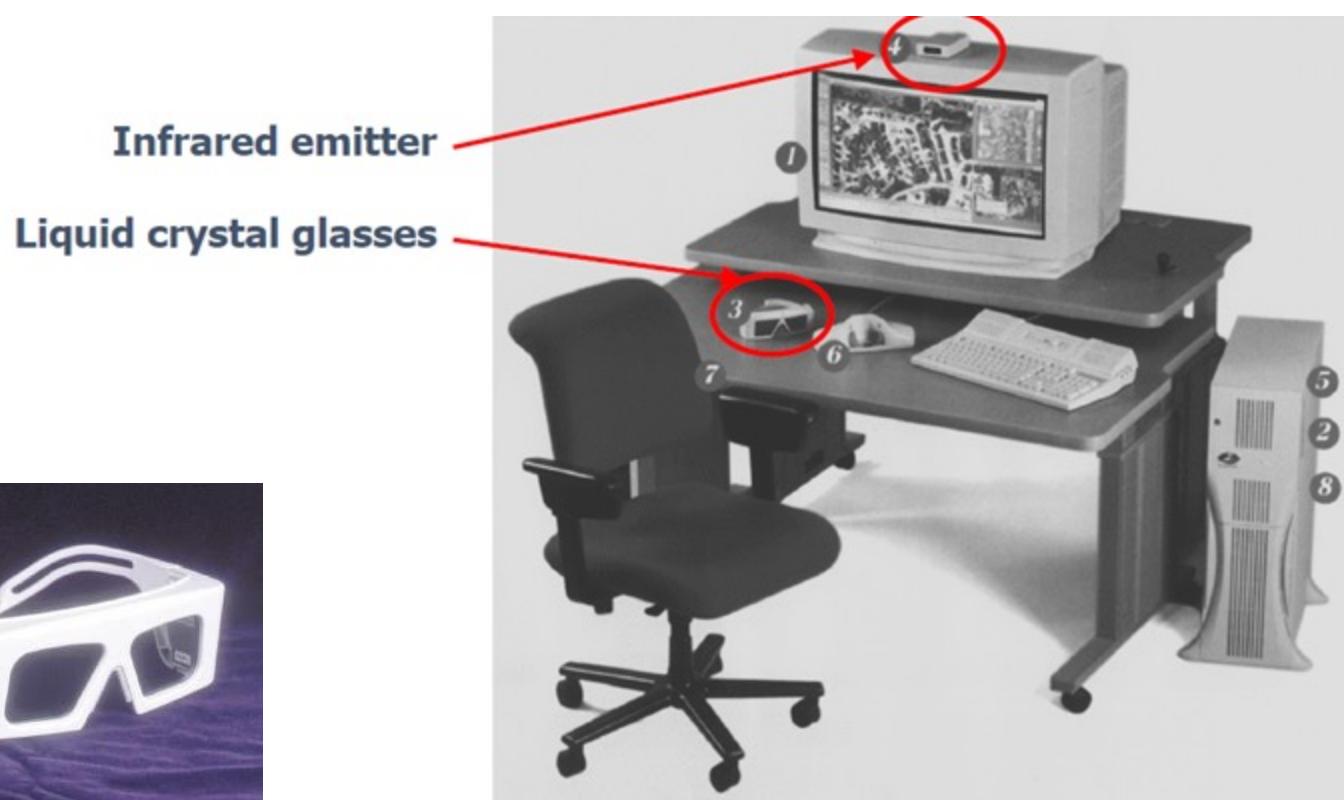


<https://www.e-education.psu.edu/geog480/node/456>

<http://www.phonearena.com/image.php?m=Articles.Images&f=name&id=38007&popup=1>

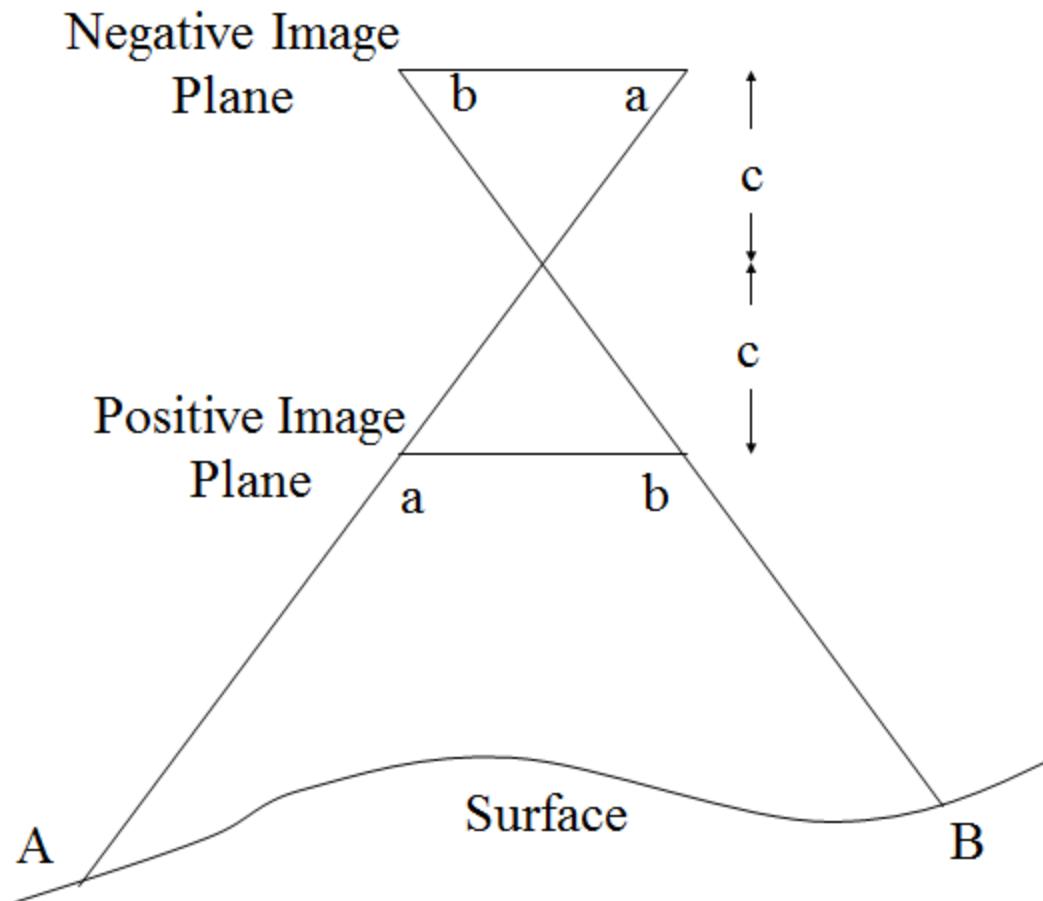
# Stereoscopic Viewing (cont'd)

## ► Digital photogrammetric workstation



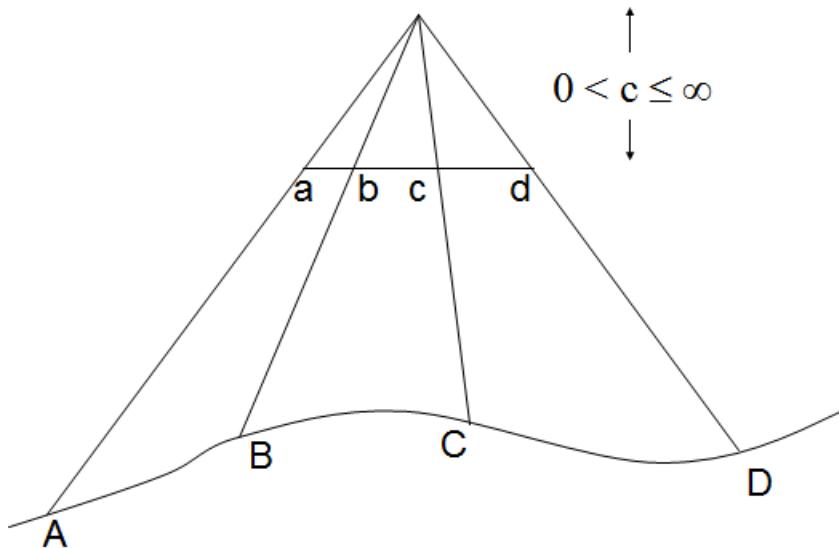
# Perspective Projection

## ▶ Pinhole camera model

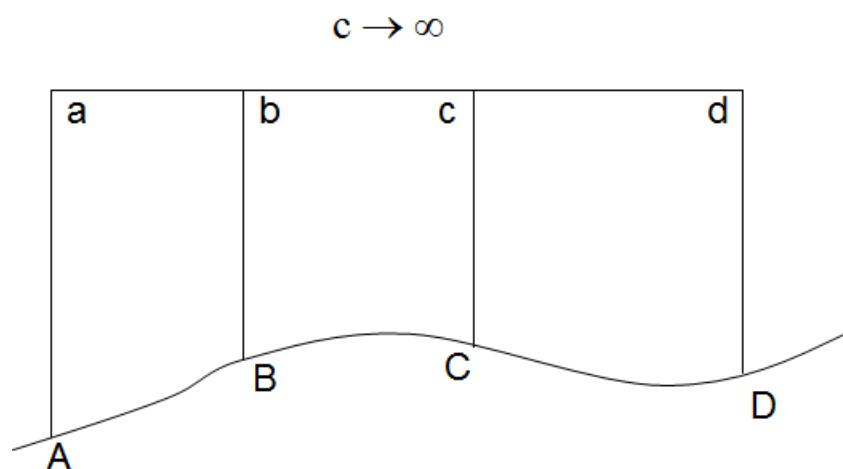


# Perspective Projection (cont'd)

- ▶ Perspective image (acquired)

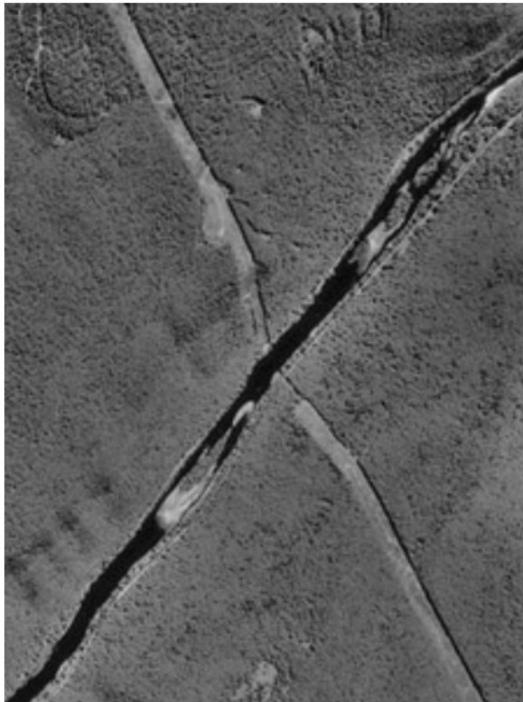


- ▶ Orthoimage (product)

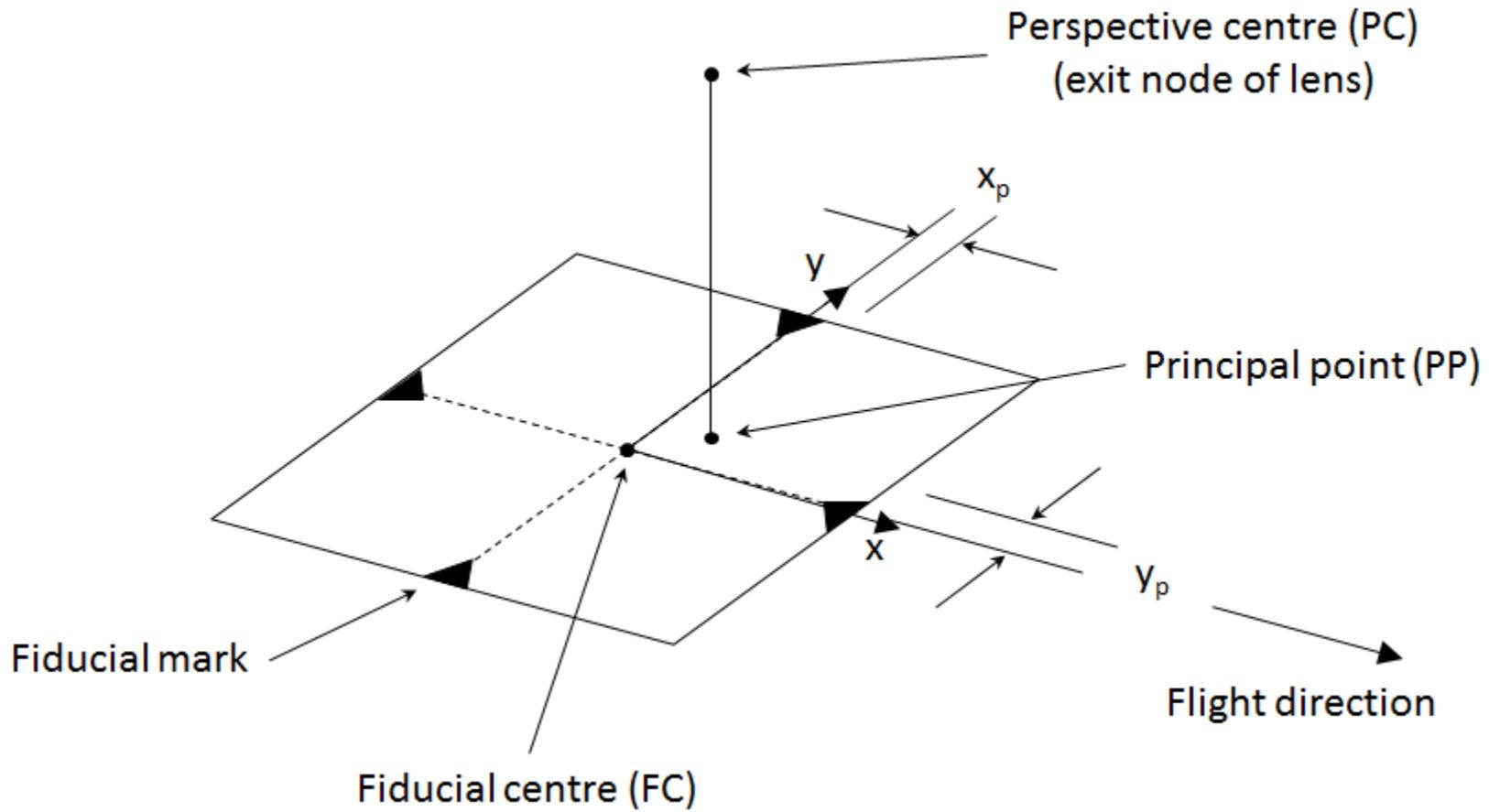


# Perspective Projection (cont'd)

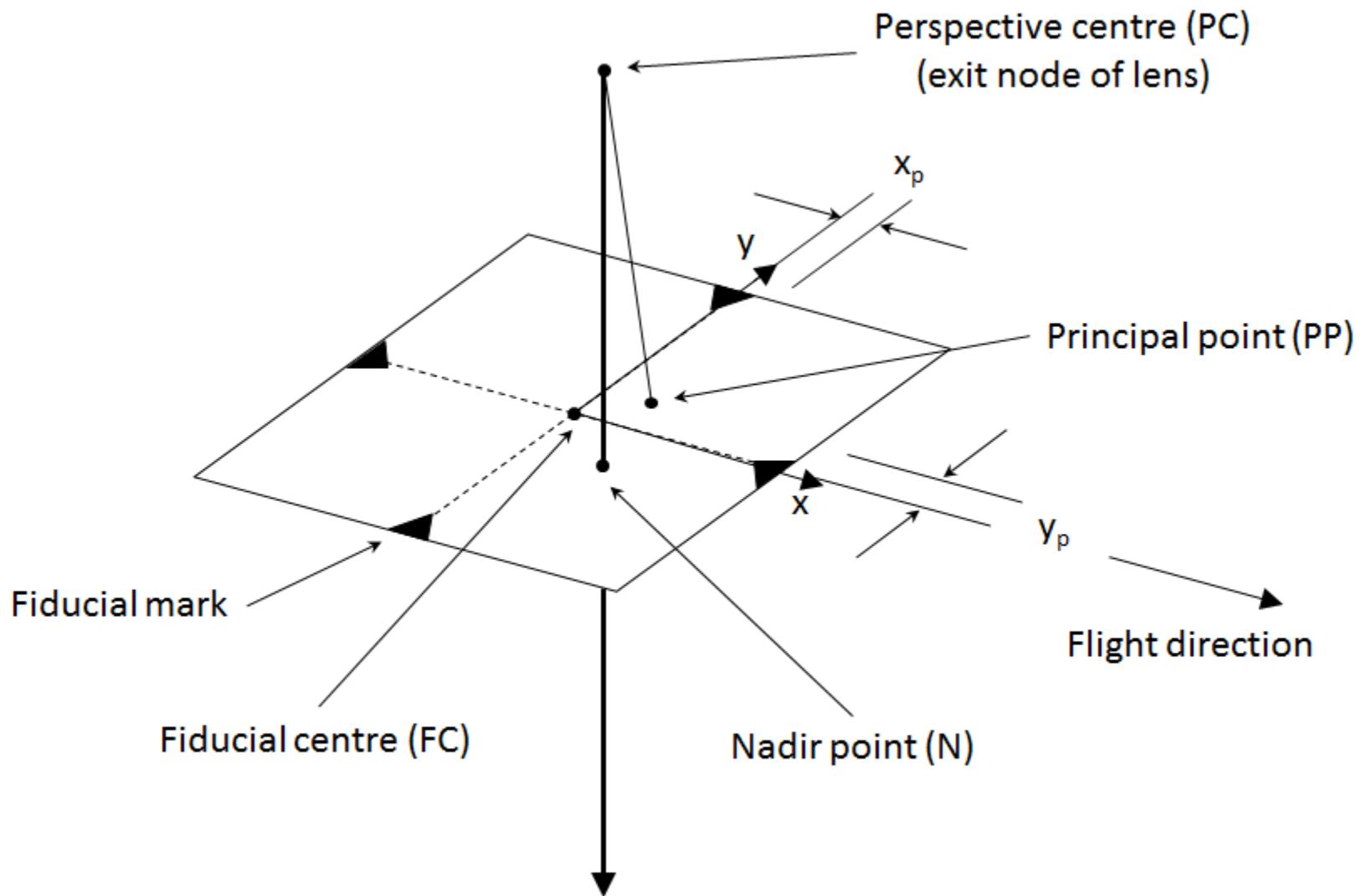
- ▶ Perspective image  
(acquired)
- ▶ Orthoimage (product)



# Vertical Image

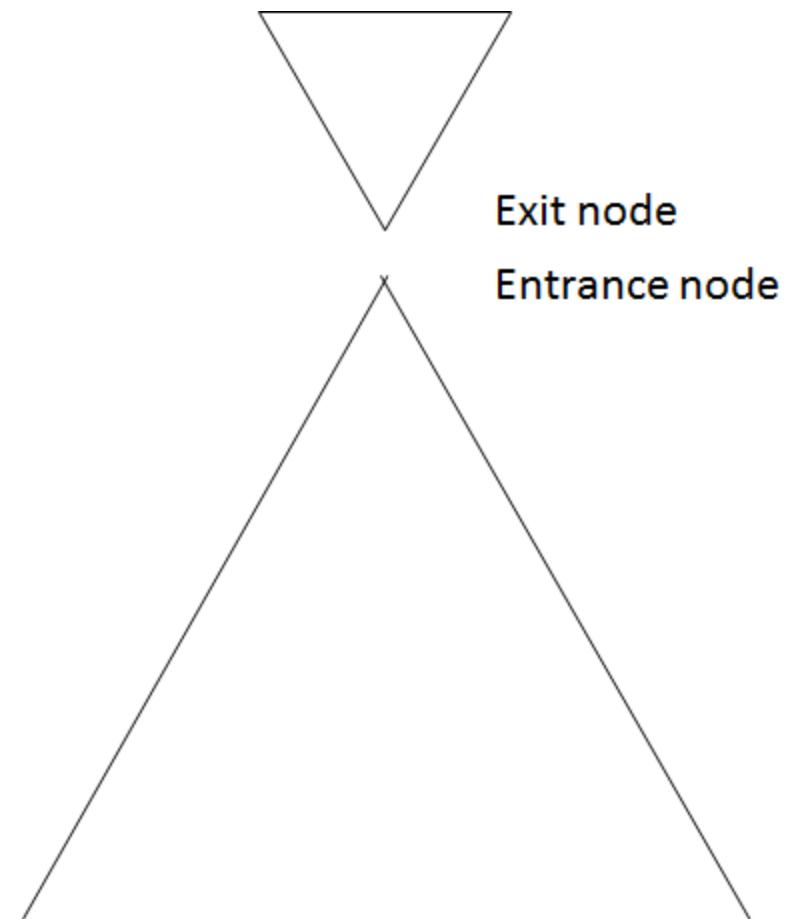
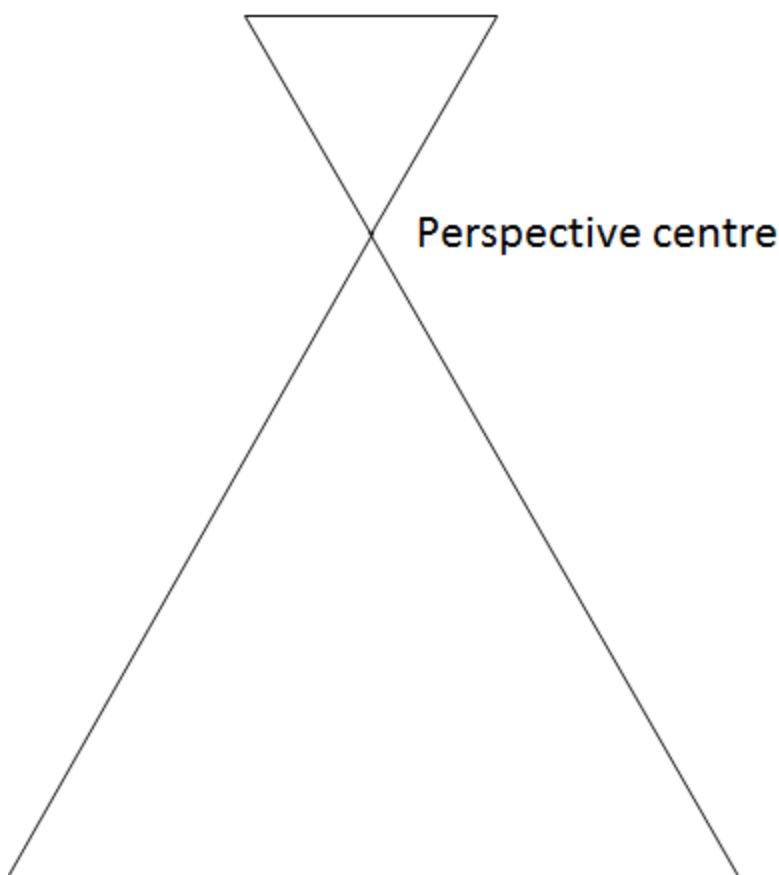


# Near-Vertical Image



# Perspective Centre (PC)

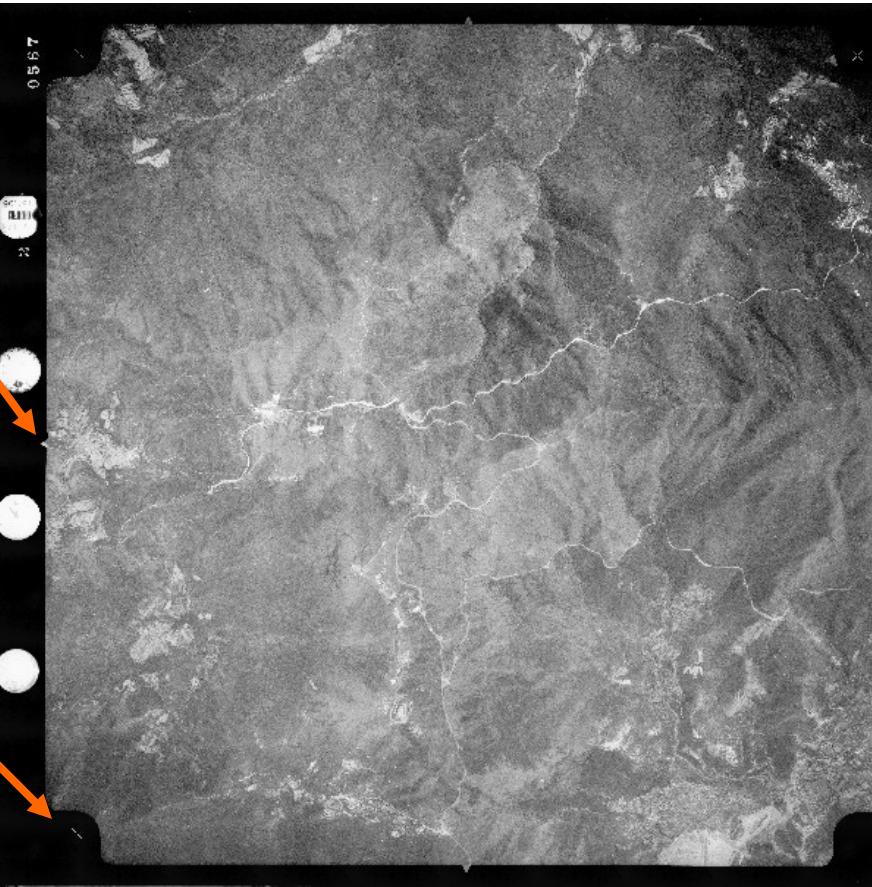
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# Fiducial Mark Locations

Wild Avigon—1963

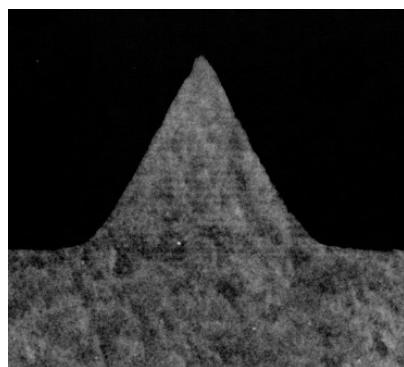
Side Fiducial  
Mark



Corner Fiducial  
Mark

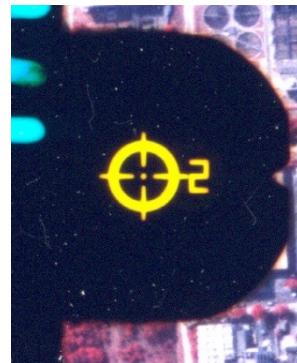
# Fiducial Mark Styles

Wild Avigon—1963

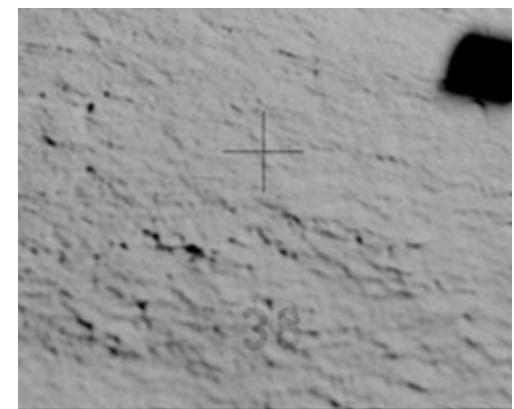


Side Fiducial  
Mark

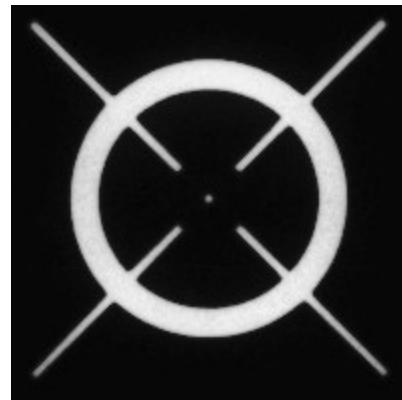
Zeiss RMK Top—2002



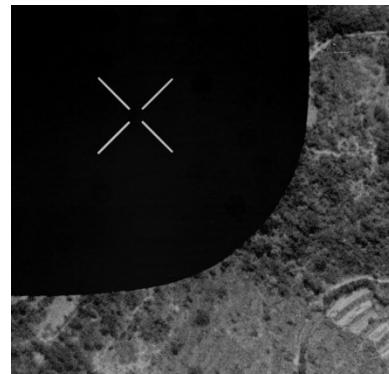
Reseau cross



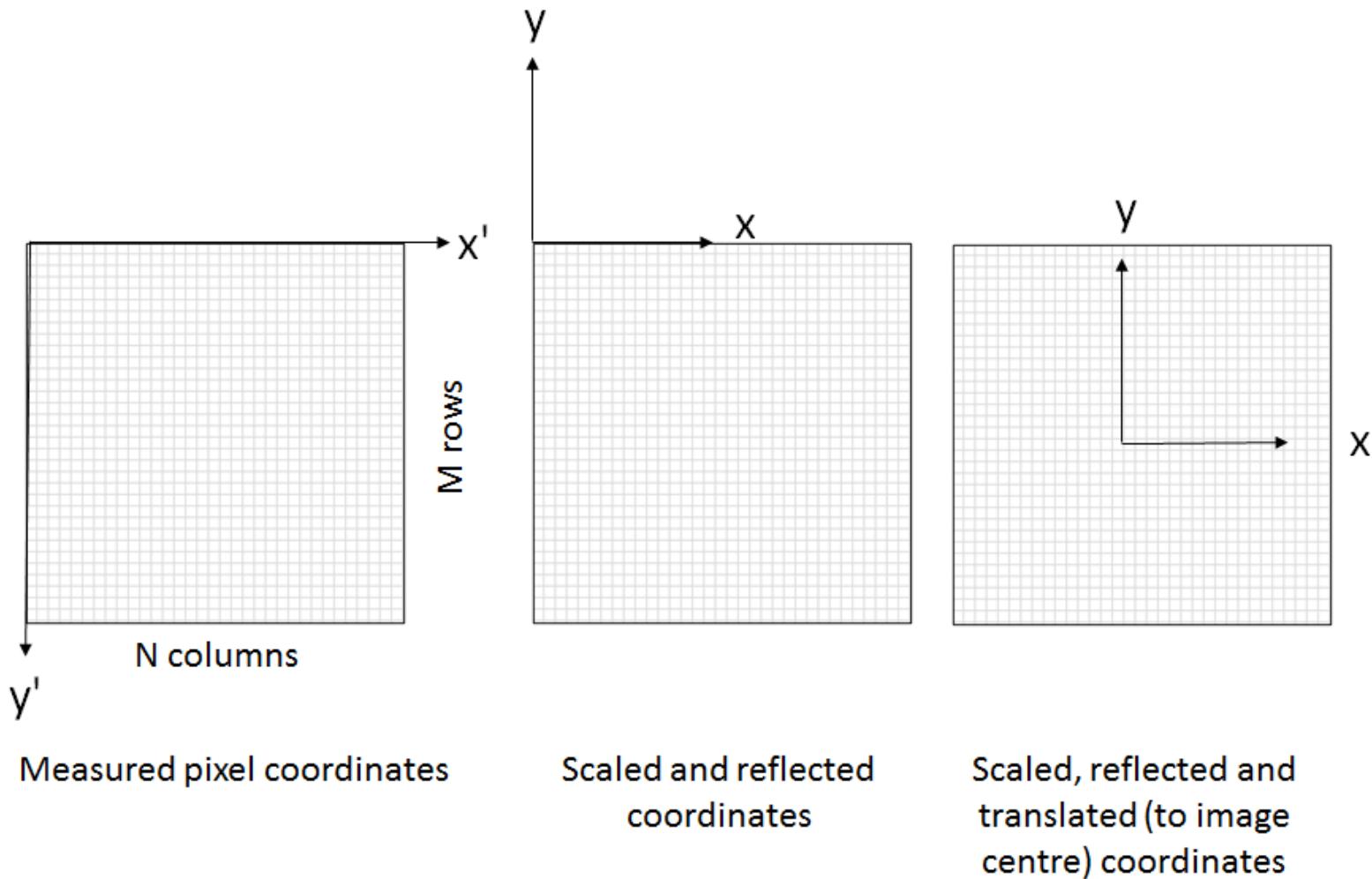
Wild RC 10—1983



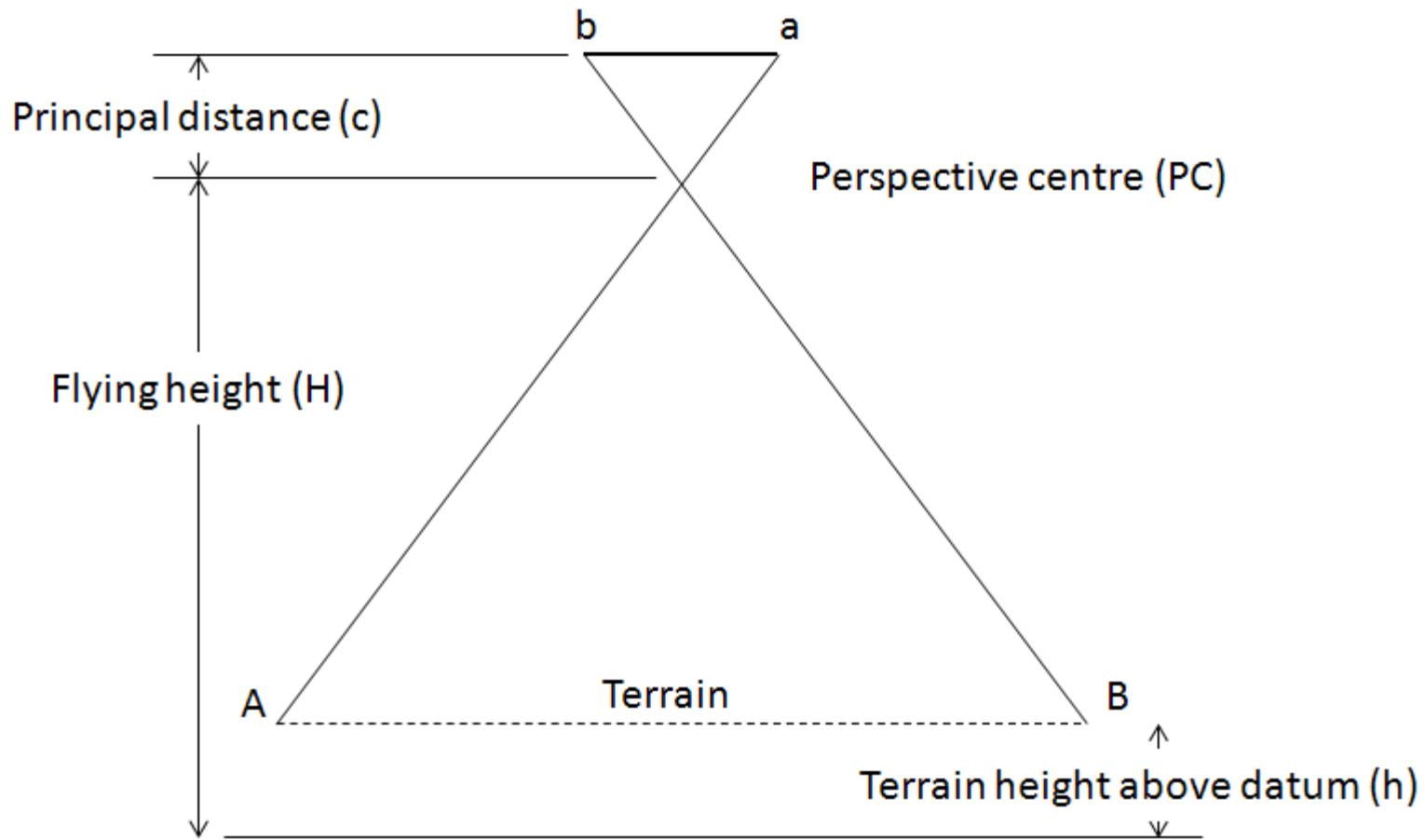
Corner Fiducial  
Mark



# Digital Images captured by Digital Cameras



# Image Scale—Ideal Case

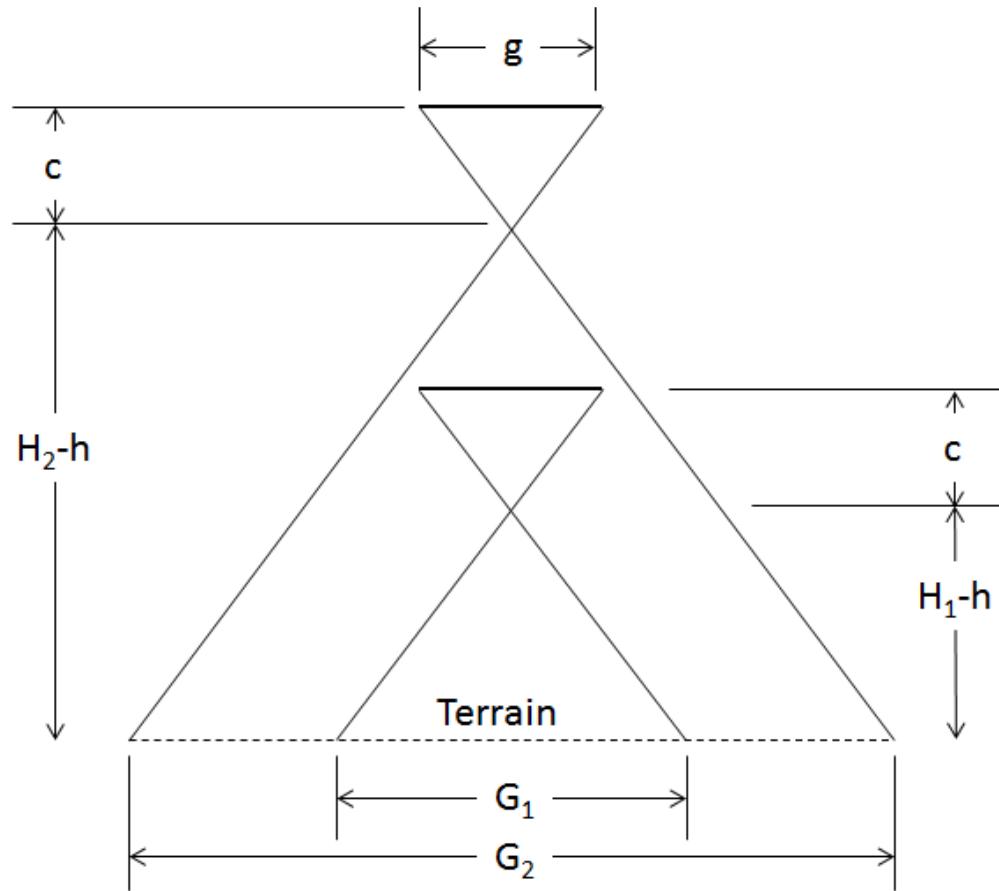


# Scale Examples

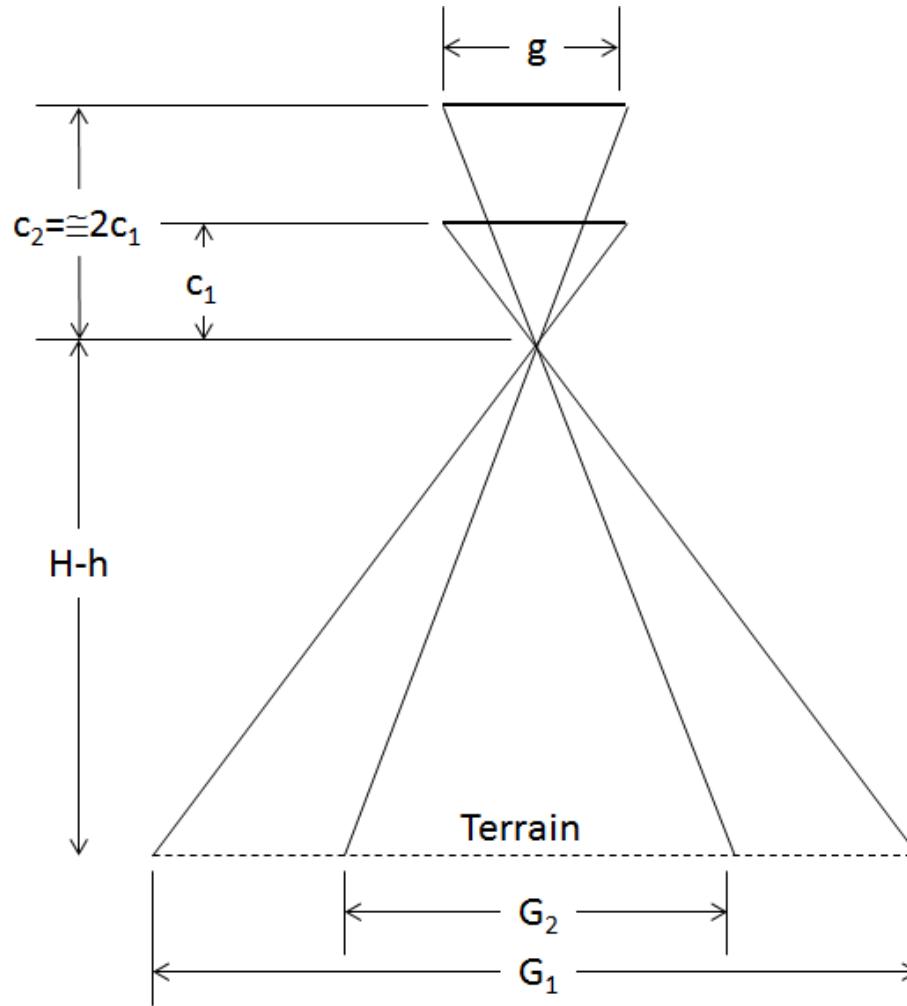
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Sensor/platform	Focal length	Acquisition height/ standoff distance	Scale
IKONOS Satellite image	10 m	680 km	1:68 000
Metric aerial camera	152 mm	3050 m	1:20 000
Prosilica GE4900C on UAV	35 mm	80 m	1:2300
SLR image of engineering building	24 mm	5 m	1:200
Chest X-ray image	2 m	1.7 m	1:0.85

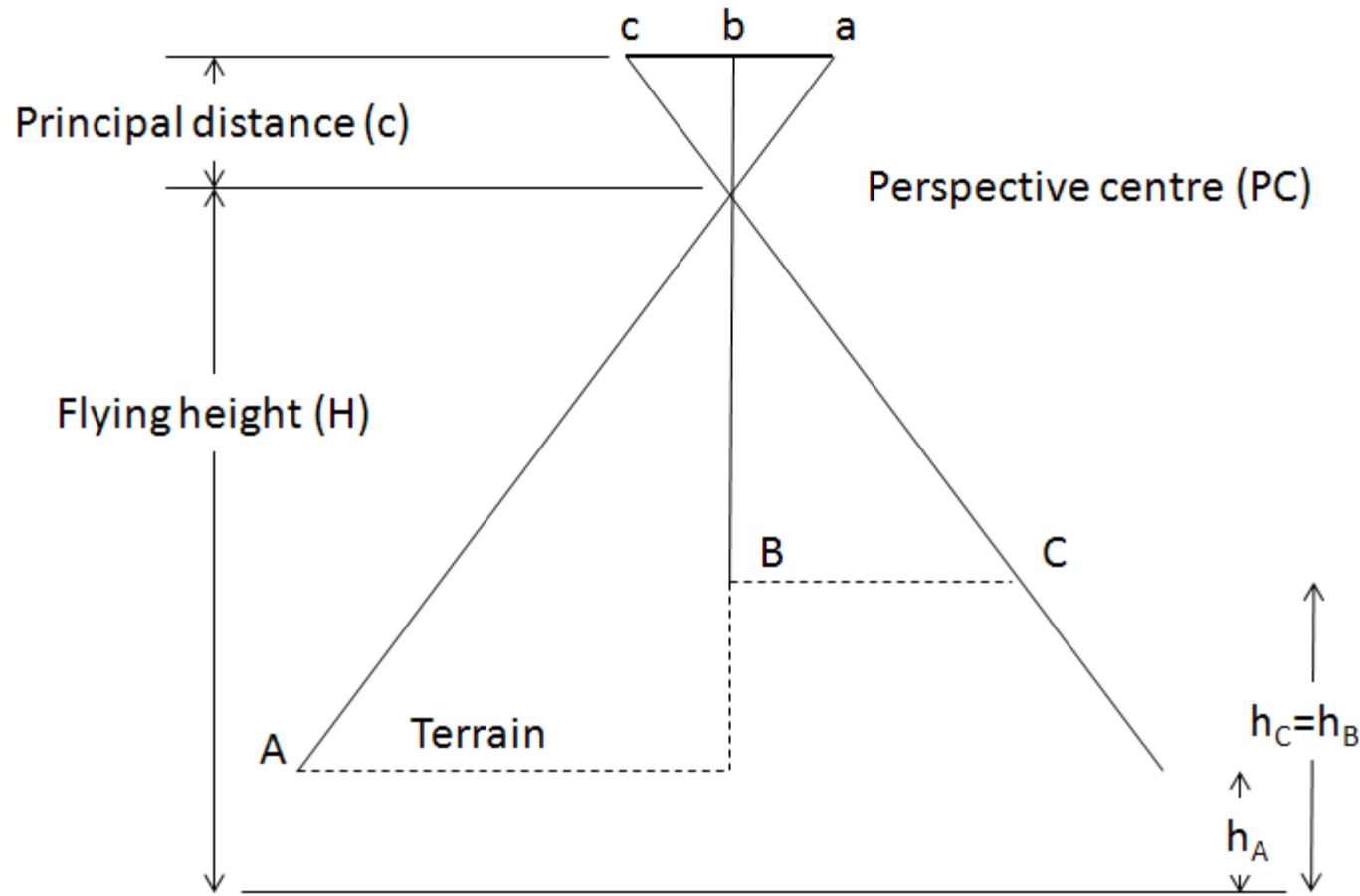
# Effect of Flying Height on Scale



# Effect of Focal Length on Scale

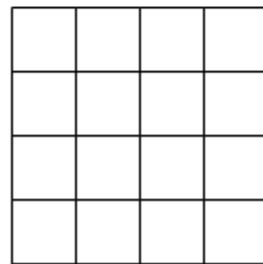
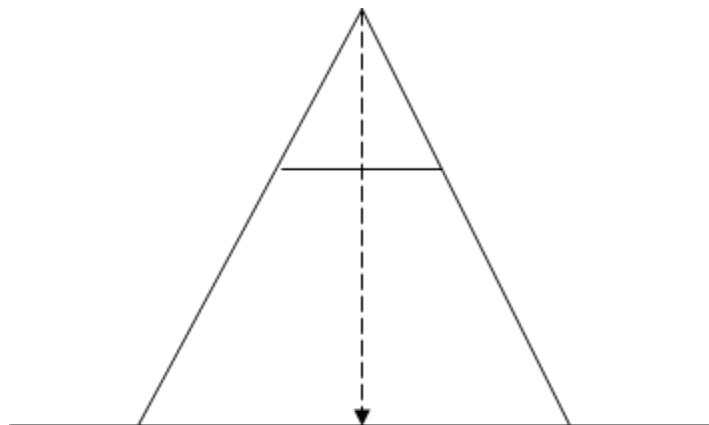


# Effect of Terrain on Image Scale

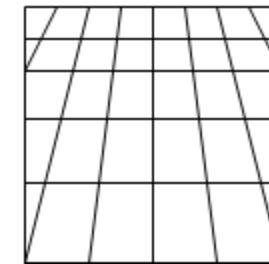
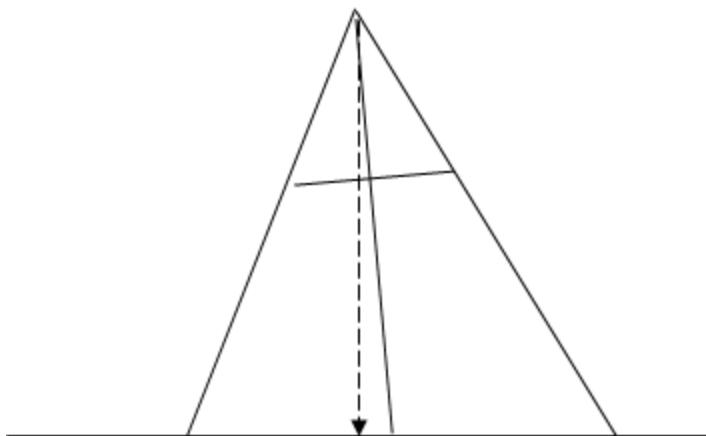


# Tilt Displacement

▶ Vertical image

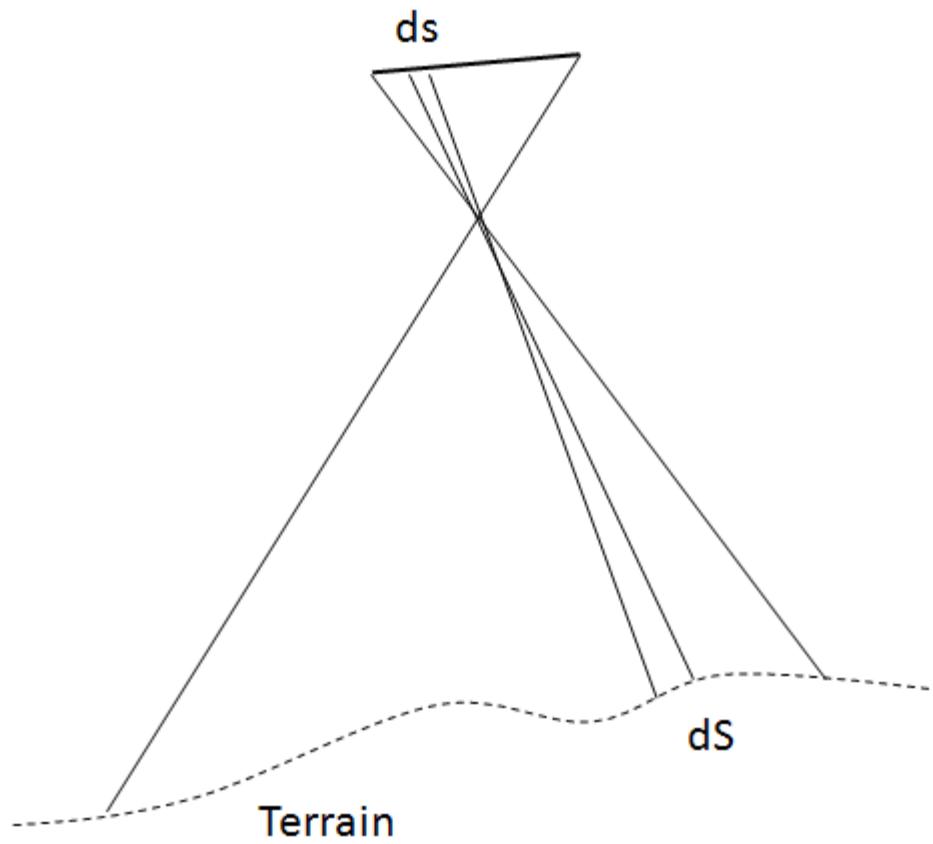


▶ Low-oblique image

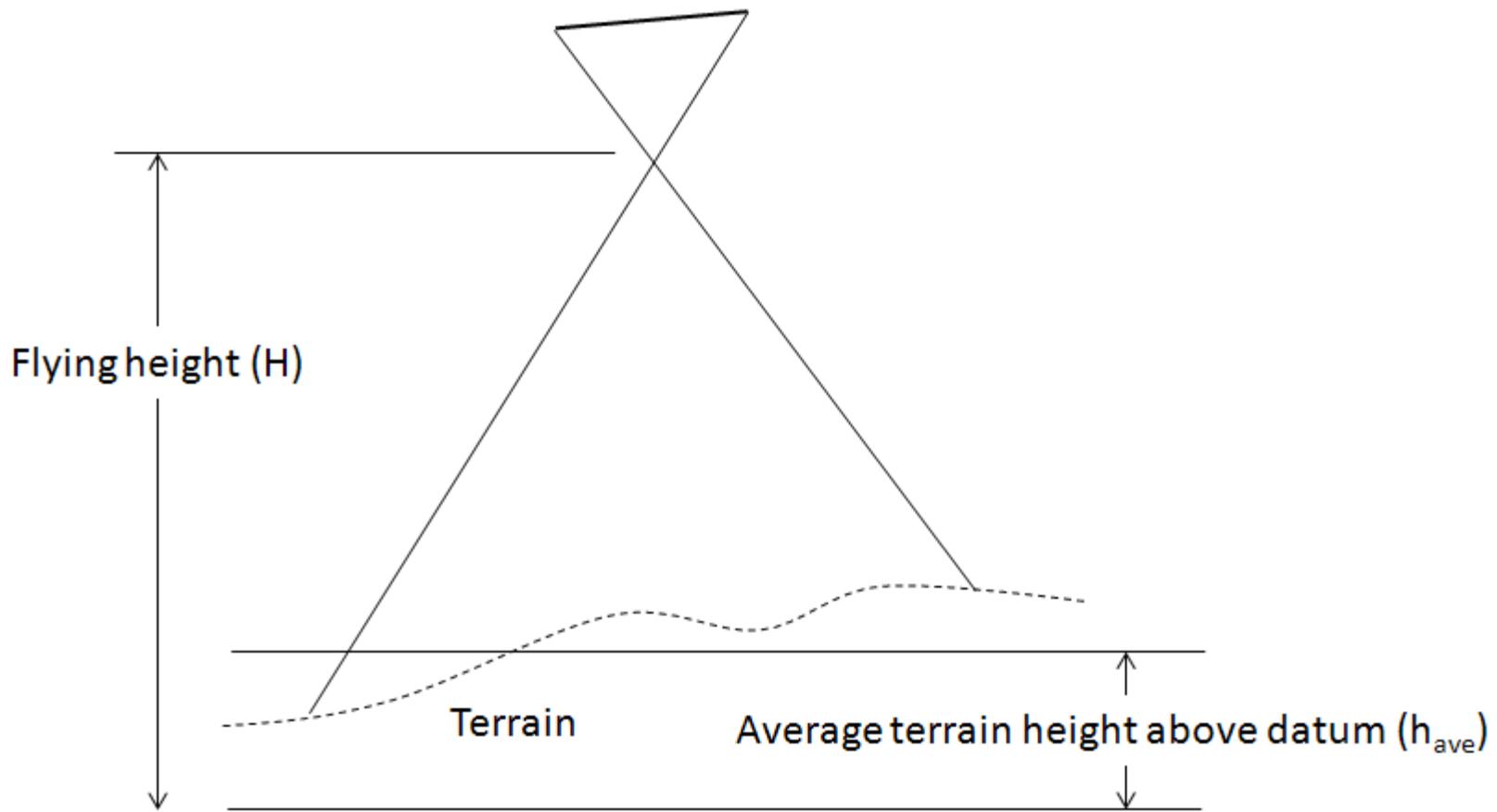


# Image Scale—Differential Form

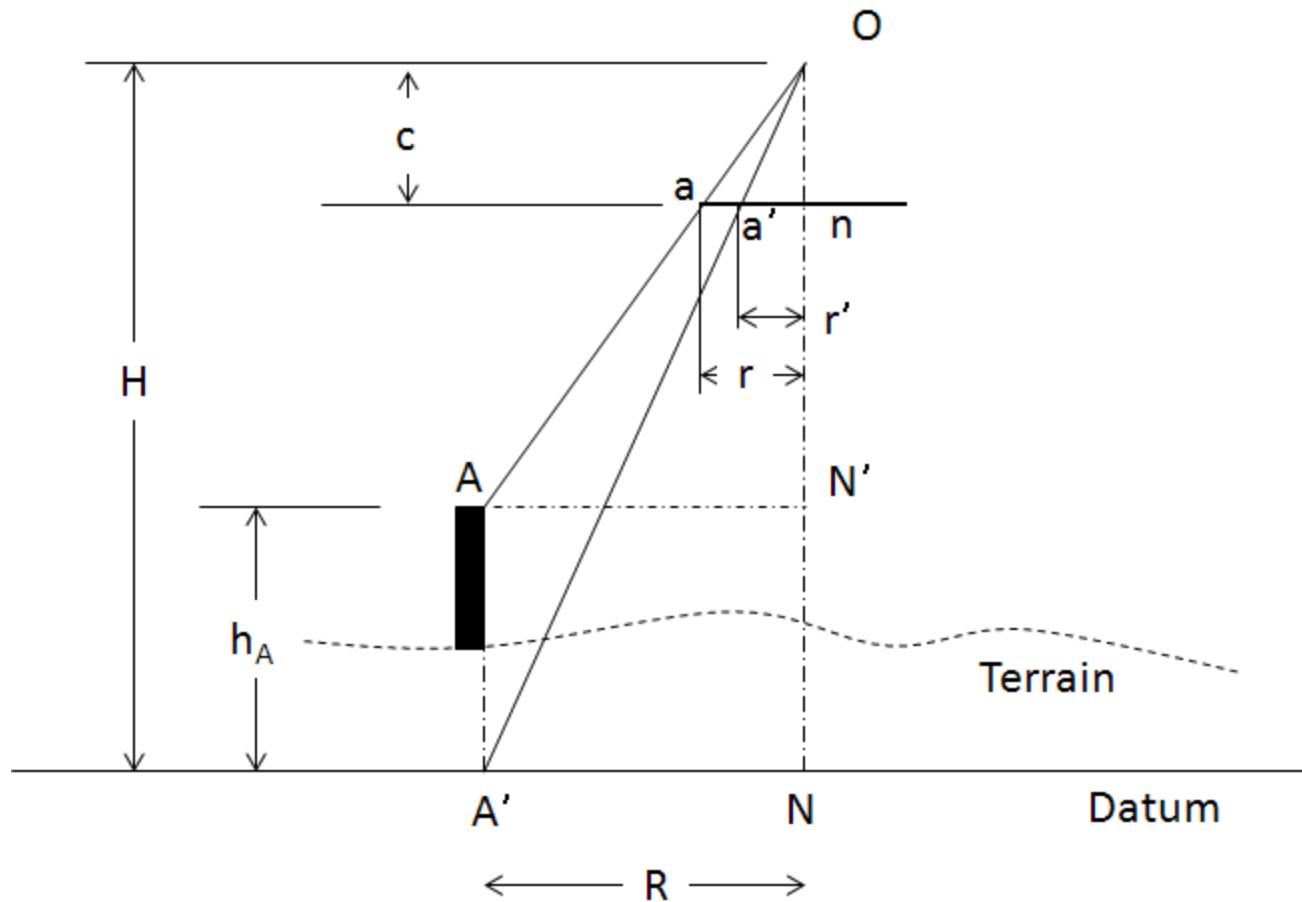
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# Average Image Scale

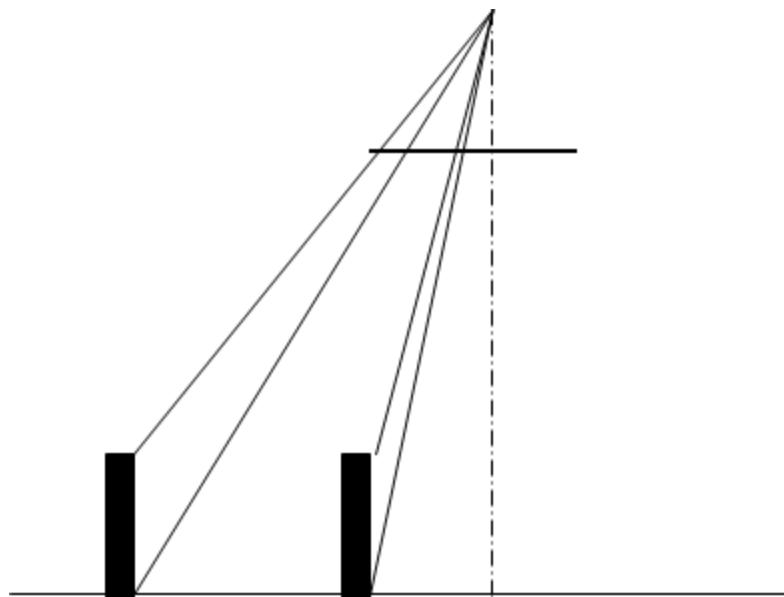


# Relief Displacement



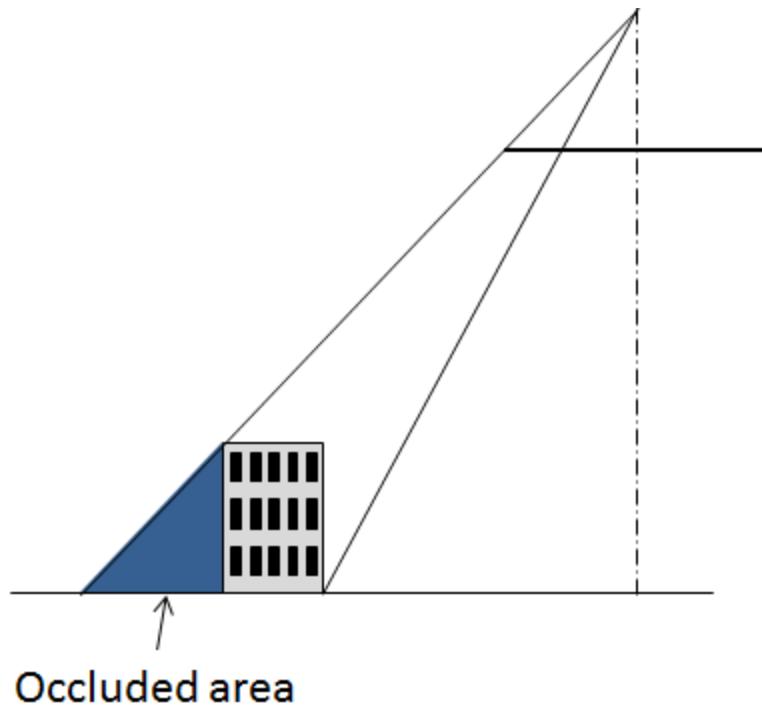
# Relief Displacement (cont'd)

- ▶ Relief displacement increases with radial distance

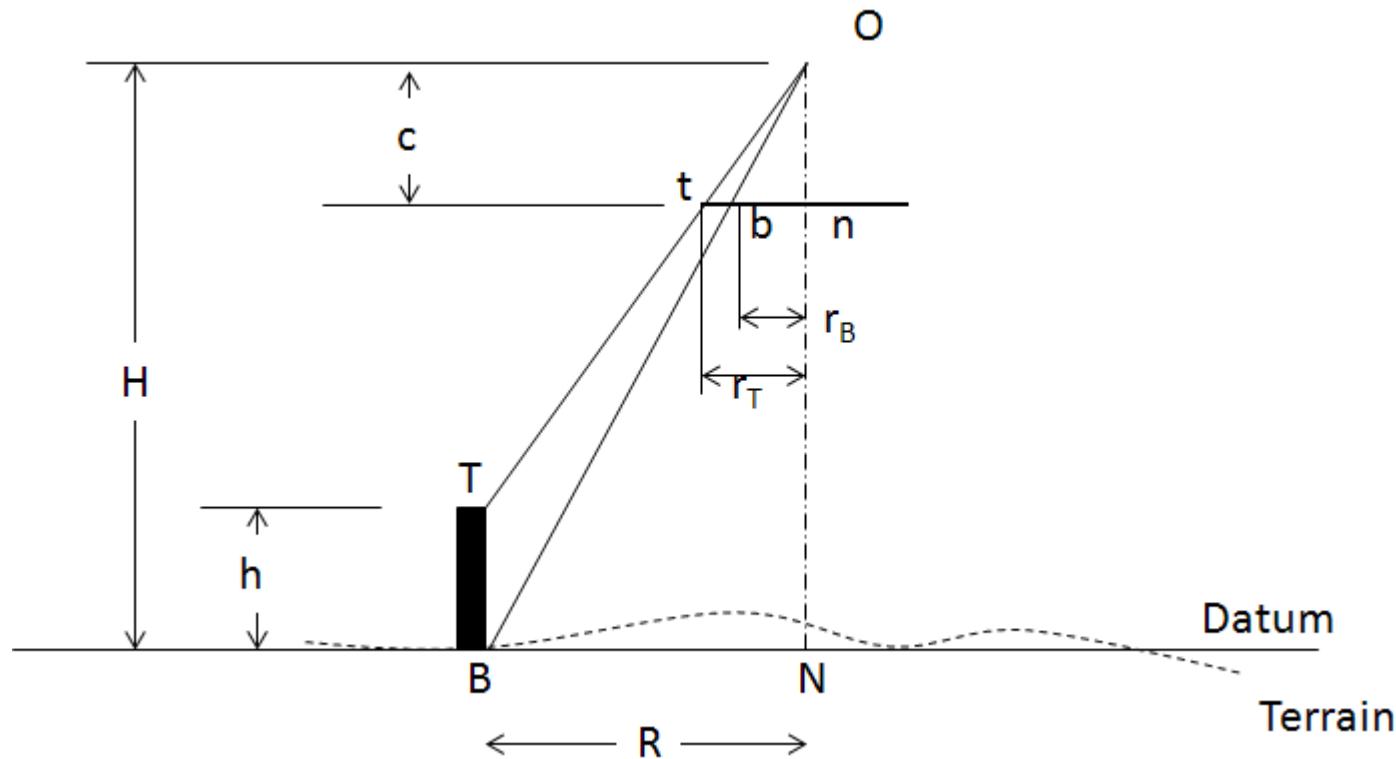


# Relief Displacement (cont'd)

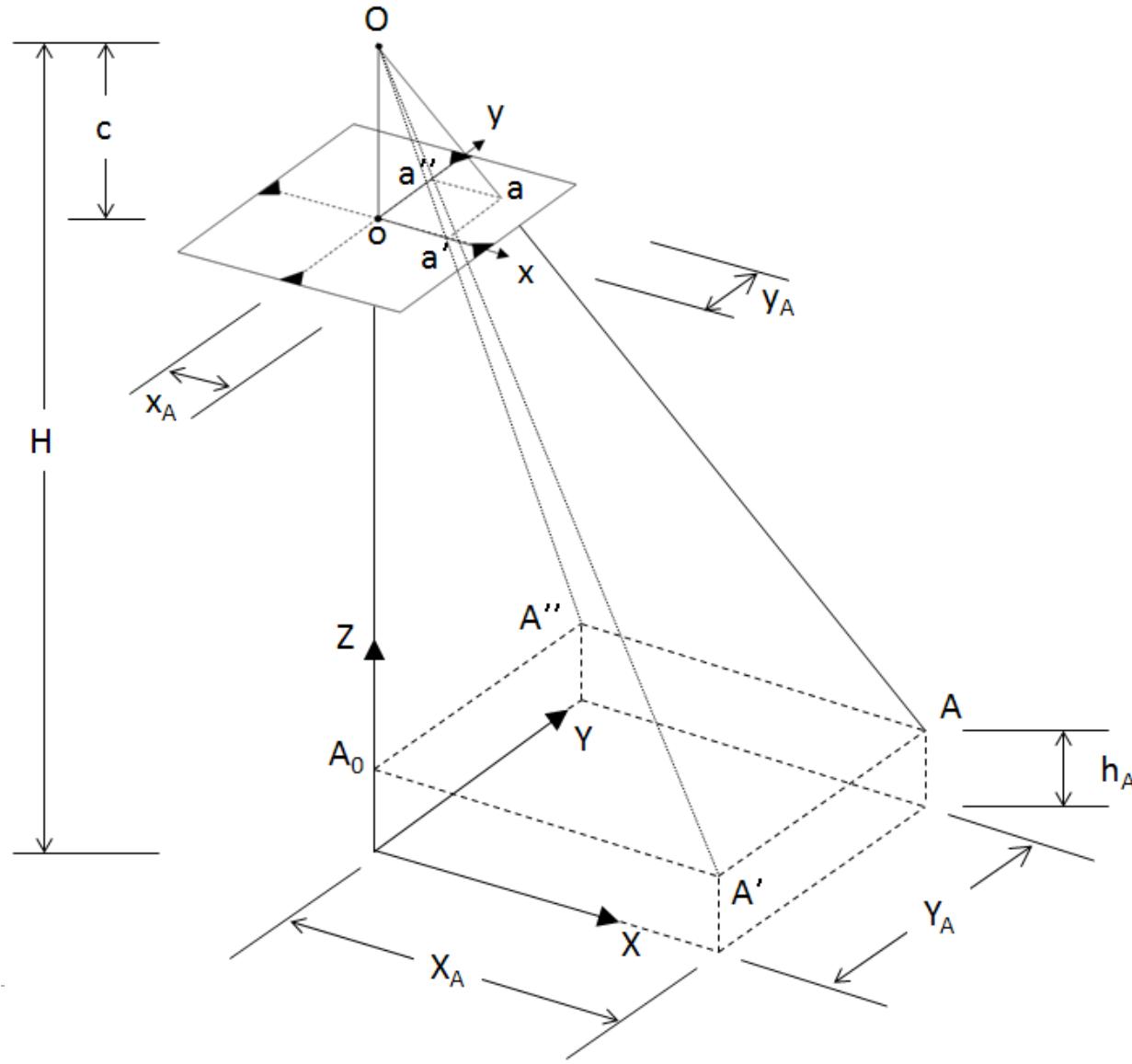
- ▶ Relief displacement causes occlusions



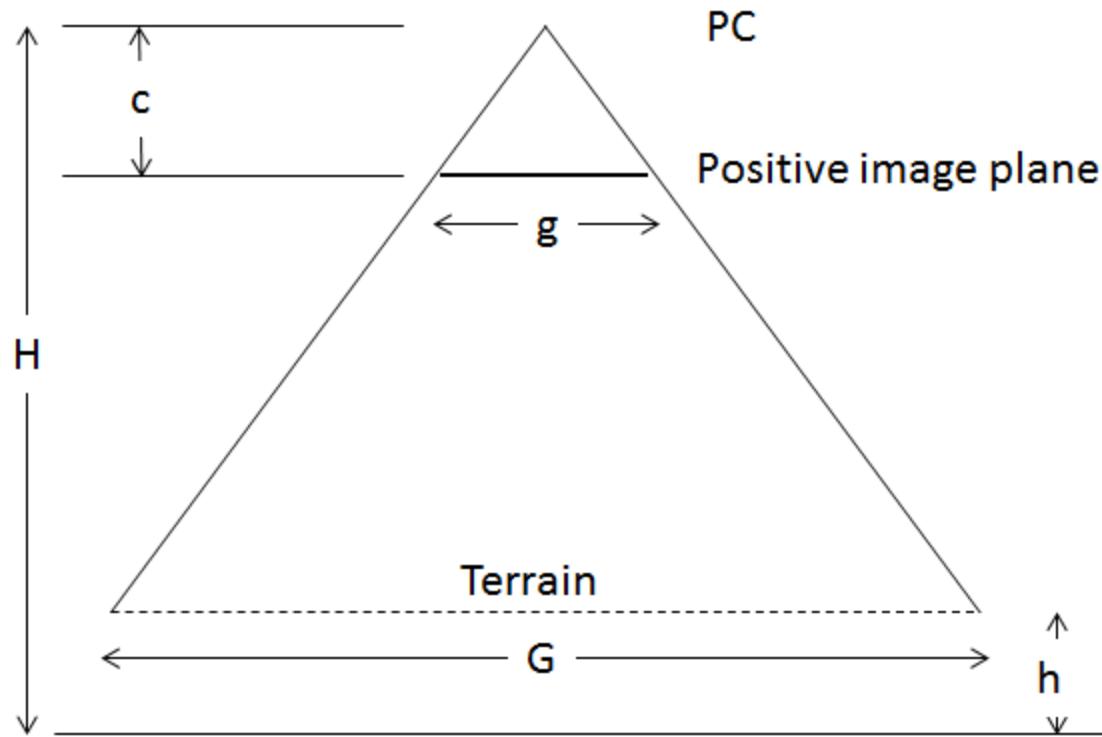
# Building Height



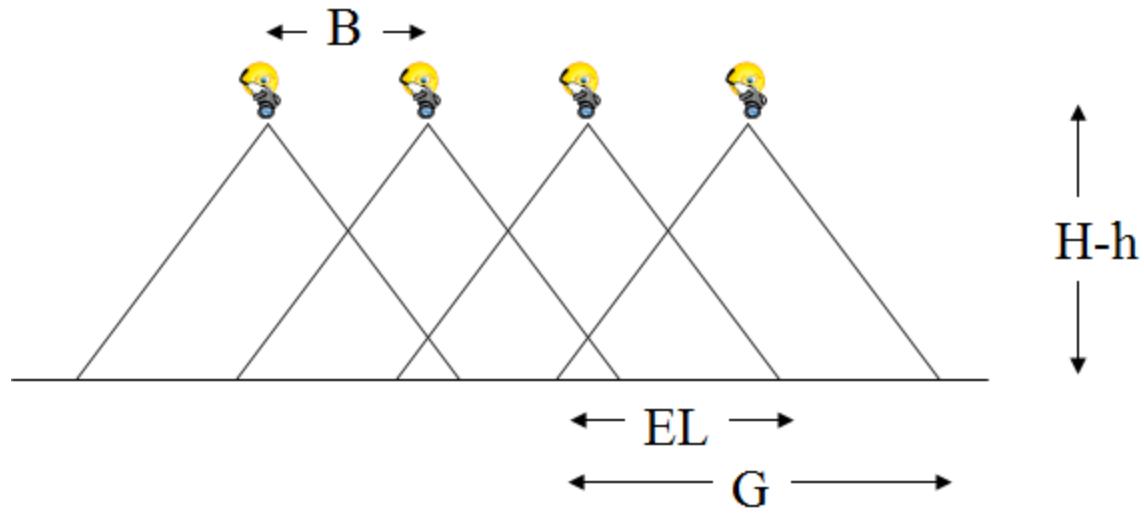
# Ground Co-ordinates from Image Co-ordinates



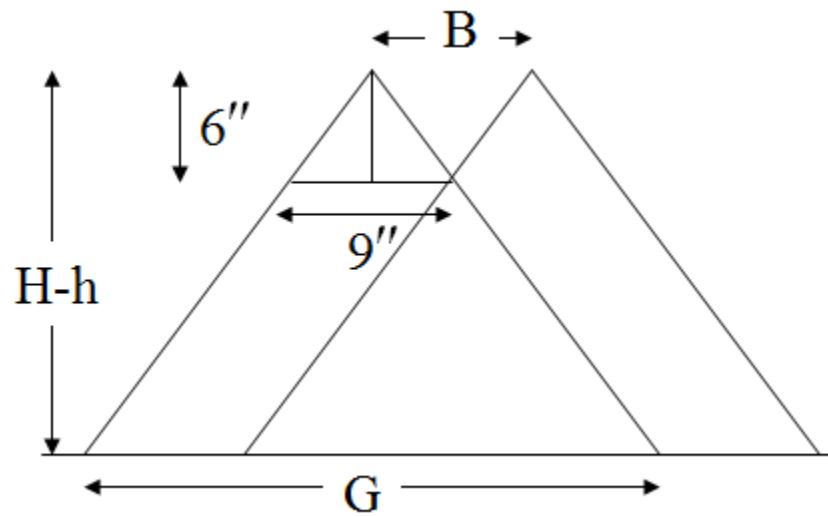
# Ground Coverage



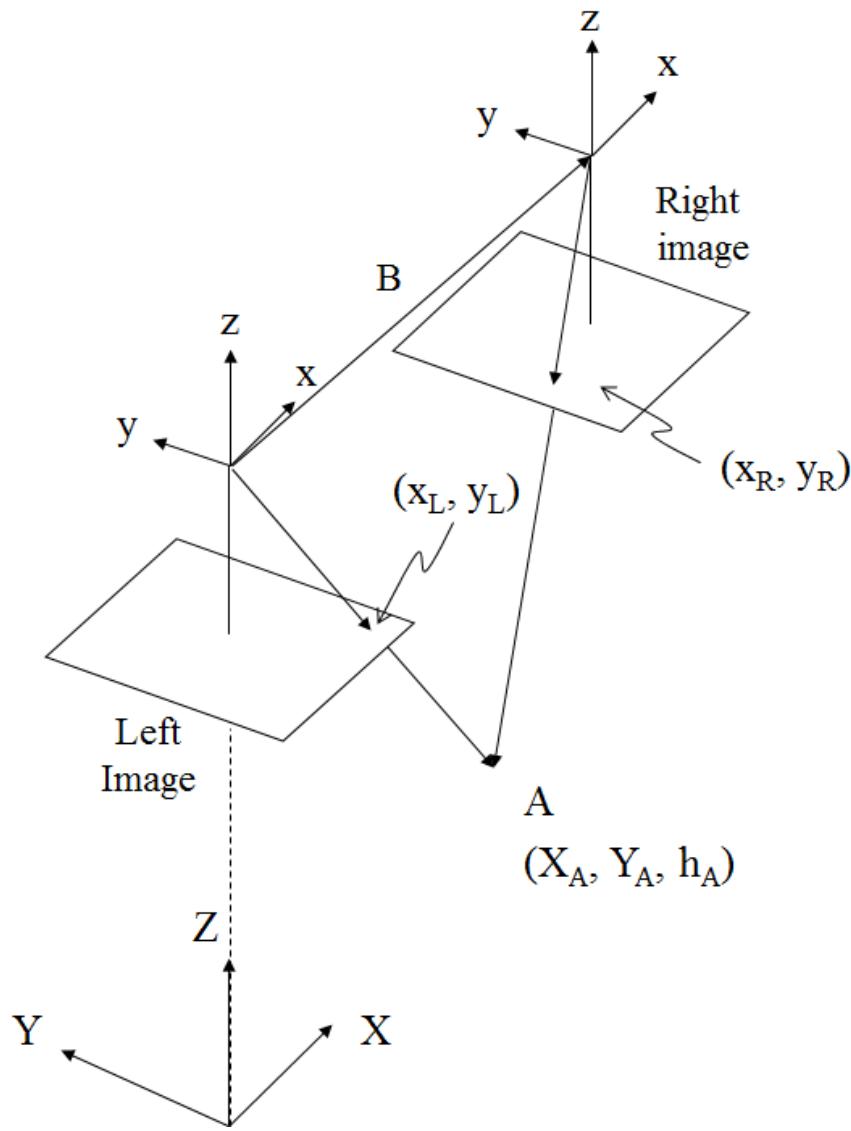
# Overlapping Ground Coverage



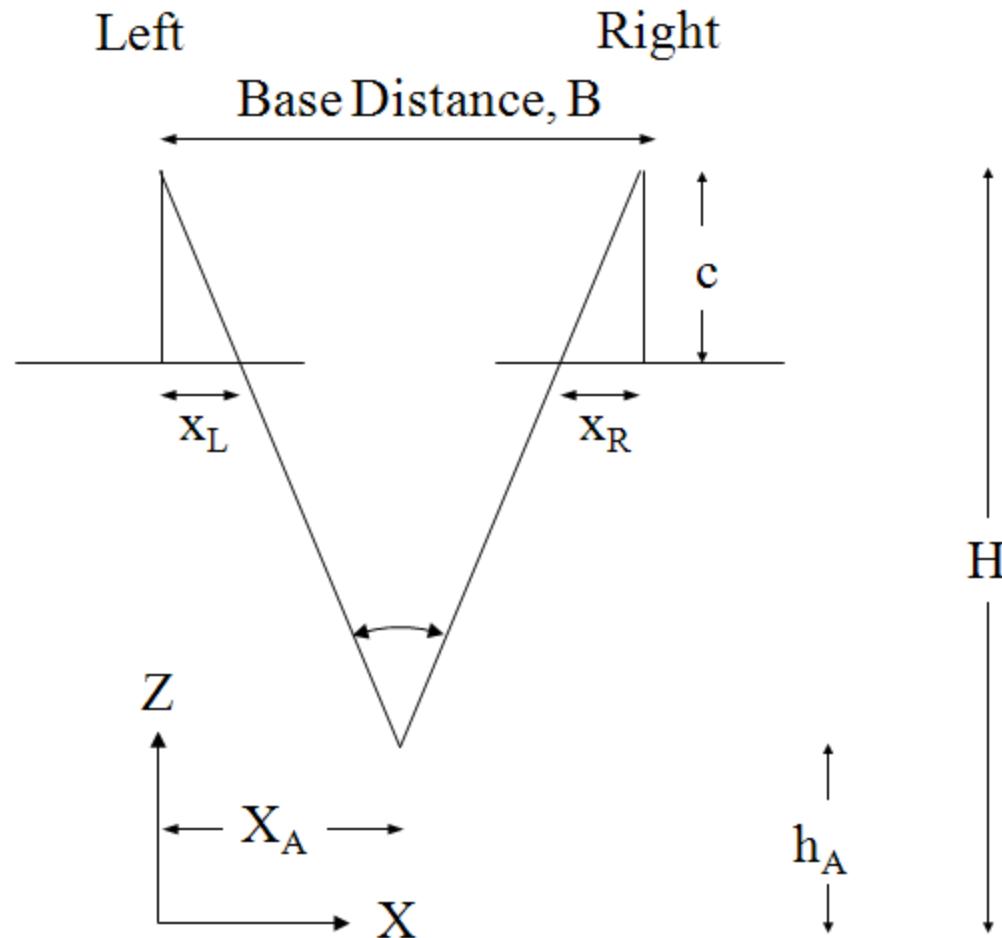
# Base-to-Height Ratio (B/H)



# Stereo Image Geometry



# Stereo Image Geometry (cont'd)

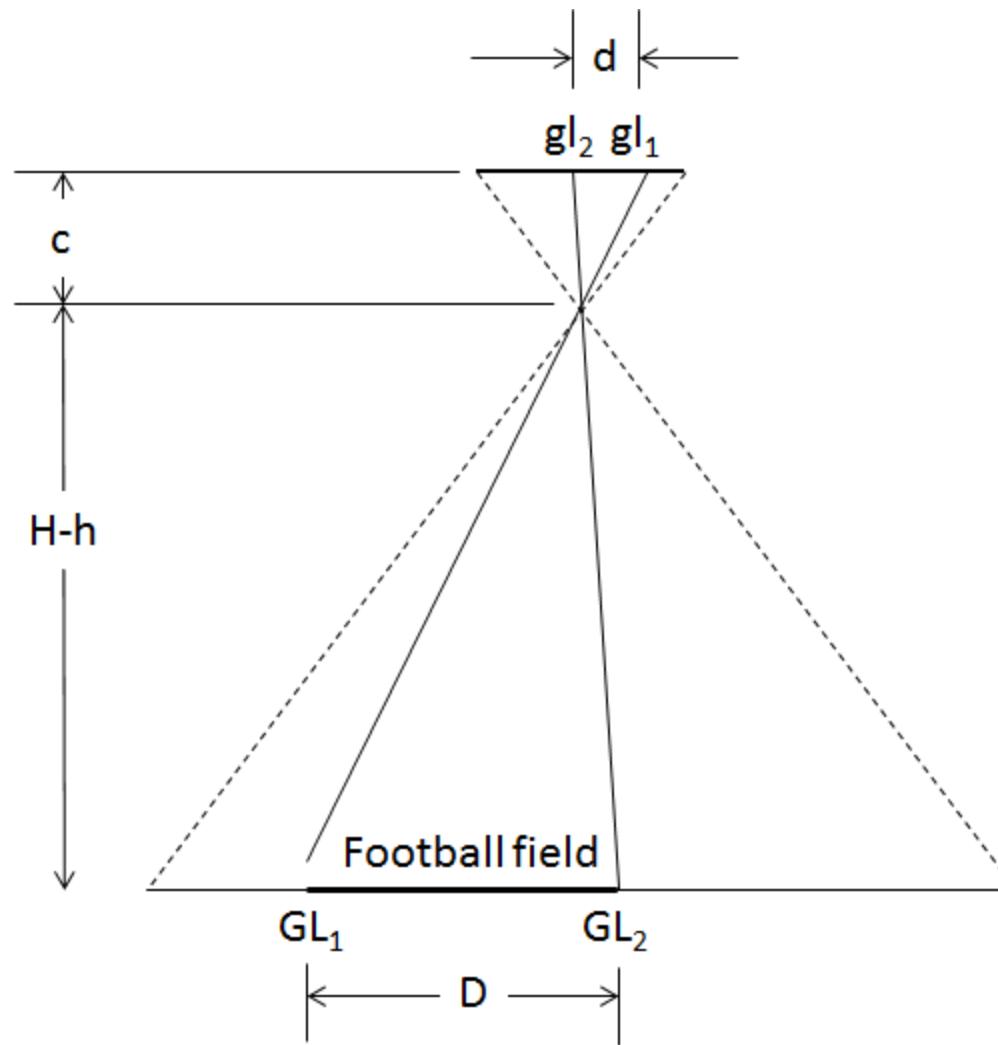


# Question 1

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- ▶ A vertical image of a football stadium has been acquired with a 6" focal length lens at 1000 m above the playing surface
- ▶ What is the image distance between goal lines of the football field?
- ▶ What is the scale of the image?

# Question 1 (cont'd)



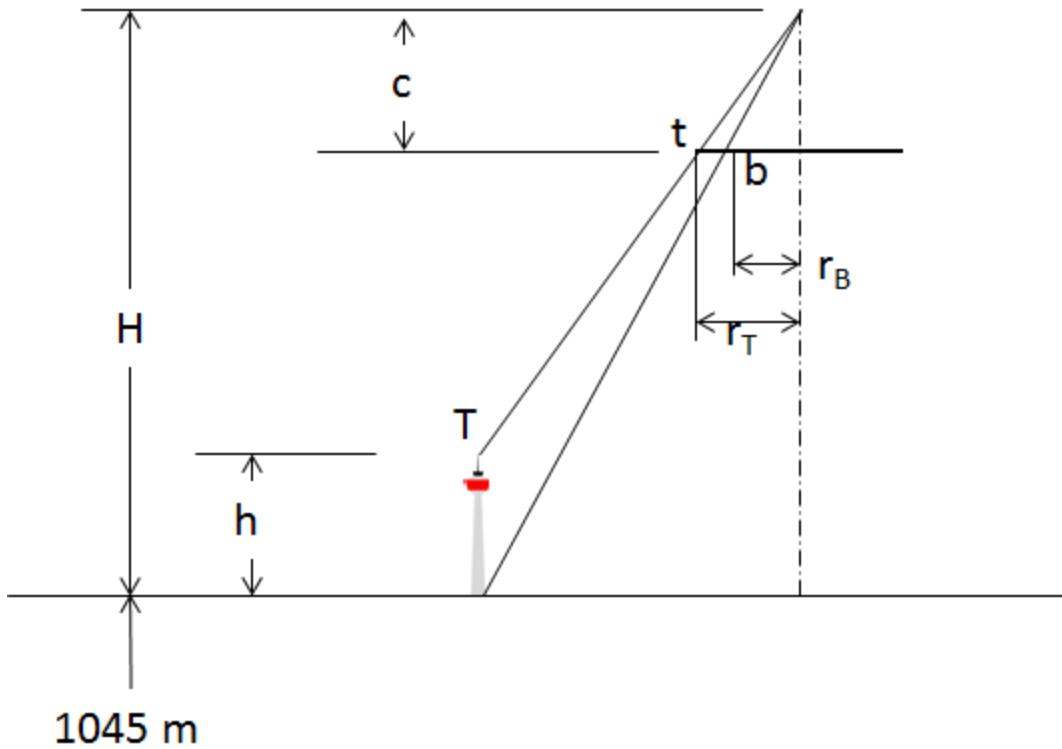
## Question 2

- ▶ A tower is imaged with a  $3\frac{1}{2}$ " focal length lens at a flying height of 900 m above the ground. The following image measurements of the top and bottom of the tower were made on a comparator such that its coordinate system was aligned with the fiducial system

point	x (mm)	y (mm)
bottom	12.176	69.847
top	15.456	88.663

- ▶ Assuming the image centre is at (0,0) mm, determine the height of the tower if the elevation of the ground at its base is 1045 m. Neglect the offset between the base of the tower from its central axis

## Question 2 (cont'd)



# Summary of Equations

- ▶ Thin lens formula

$$\frac{1}{f} = \frac{1}{c} + \frac{1}{o}$$

- ▶ Pixel to image coordinates conversion

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x' \cdot \Delta x \\ -y' \cdot \Delta y \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} (x' - N/2) \cdot \Delta x \\ -(y' - M/2) \cdot \Delta y \end{pmatrix}$$

- ▶ Image scale

$$\frac{1}{S} = \frac{ab}{AB} = \frac{c}{H-h} \quad \frac{1}{S} = \frac{ds}{dS} \quad \frac{1}{S_{ave}} = \frac{c}{H-h_{ave}}$$

- ▶ Relief displacement and building height

$$d = \frac{rh_A}{H}$$

$$h = \frac{H(r_T - r_B)}{r_T}$$

- ▶ Ground coverage

$$\frac{g}{c} = \frac{G}{H-h} \rightarrow G = Sg$$

- ▶ Ground coordinates from a stereo pair and precision

$$X_A = \frac{(H-h_A)}{c} X_L = S X_L \quad Y_A = \frac{(H-h_A)}{c} Y_L = S Y_L \quad h_A = H - \frac{Bc}{p_x}$$

$$\sigma_{X_A} = S \sigma_x \quad \sigma_{Y_A} = S \sigma_y$$
$$\sigma_{h_A} = \frac{\sqrt{2}S}{B/H} \sigma_x$$