International Society for Photogrammetry and Remote Sensing

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- Commission IV: Spatial Information Systems and Digital Mapping
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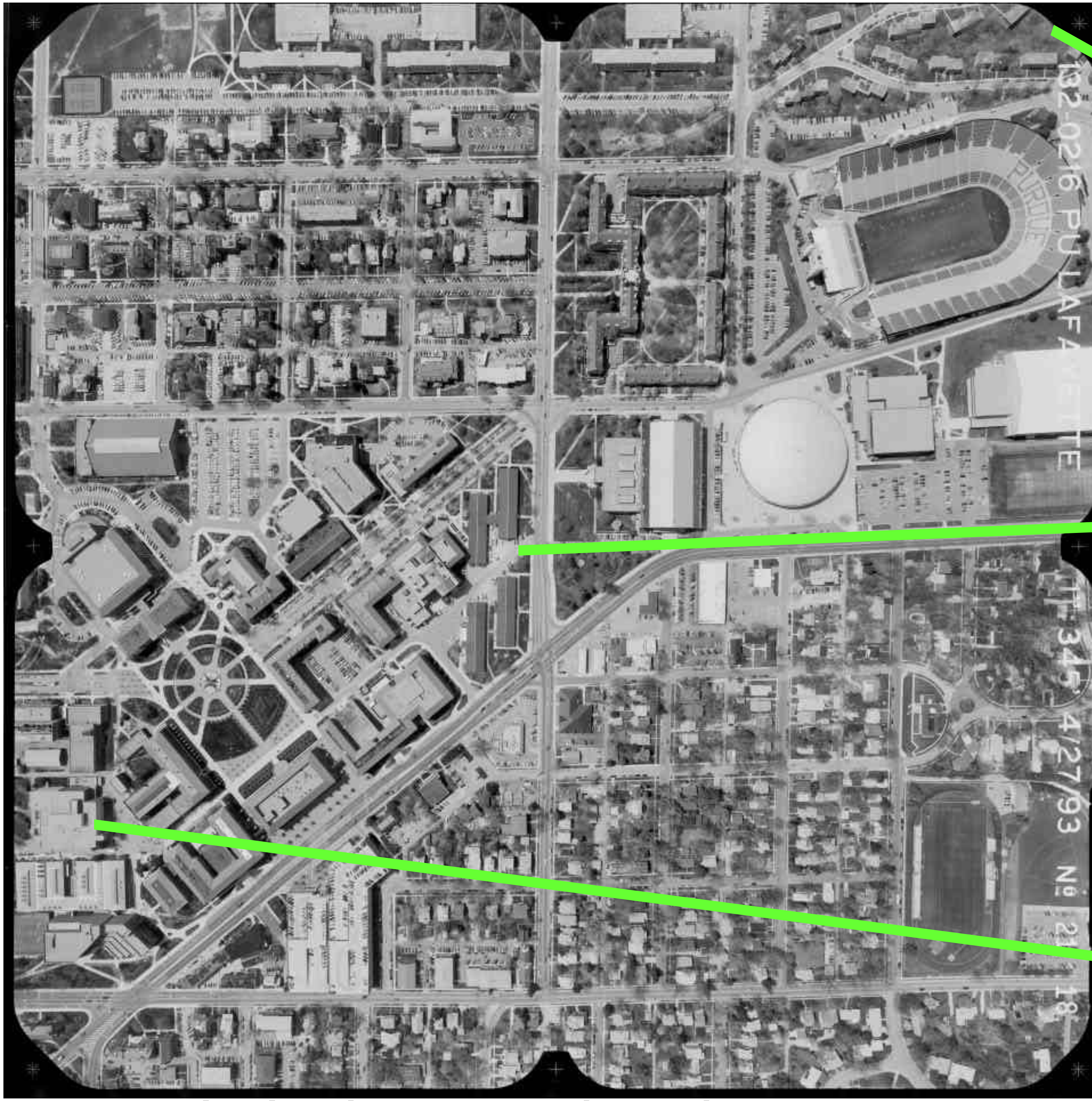
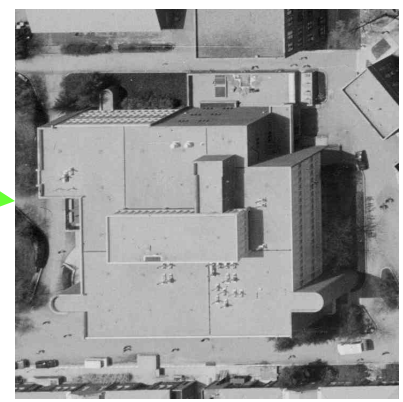
Commission III Symposium 2002 Graz, Austria

Congress 2004 Istanbul, Turkey

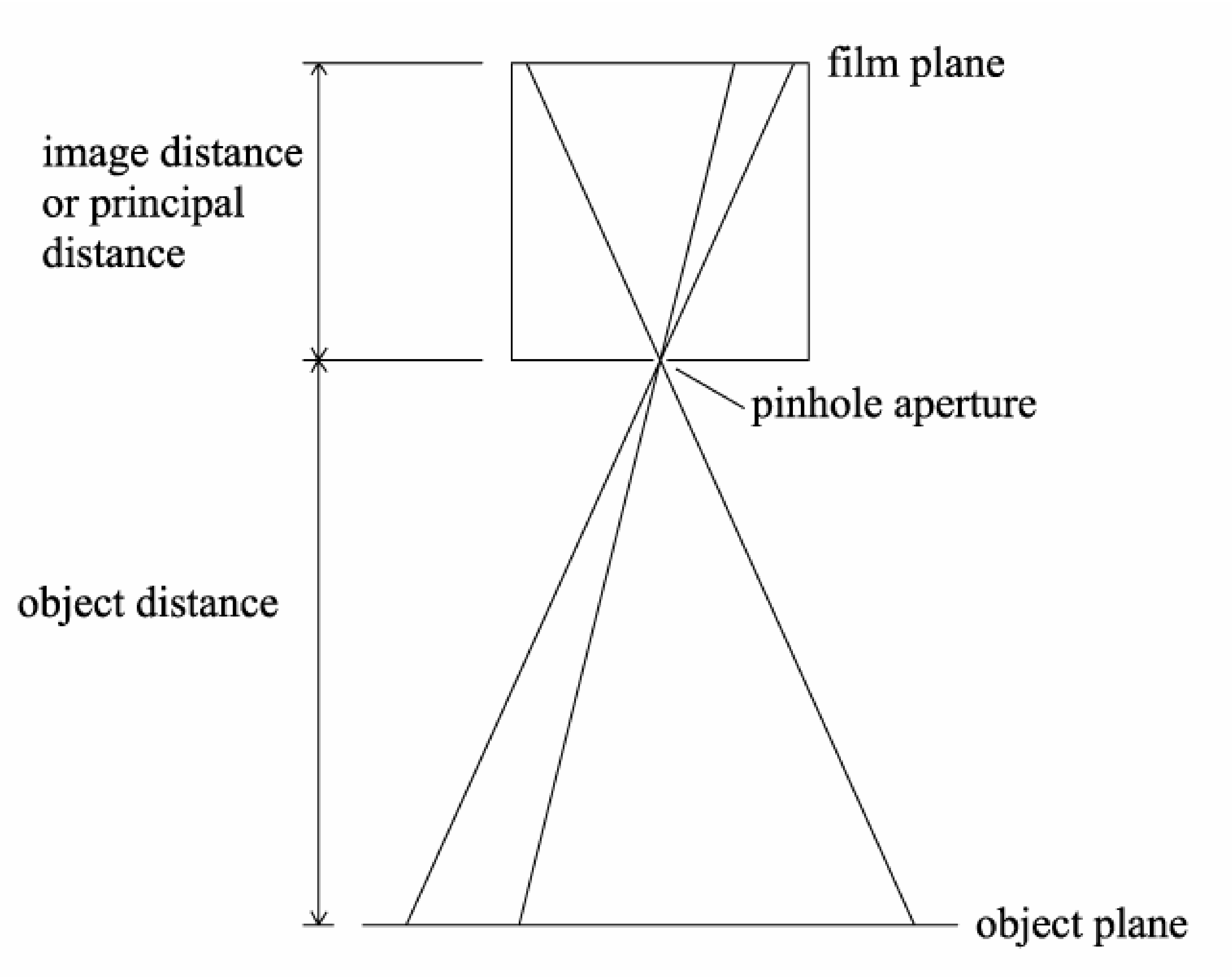
Relief Displacement



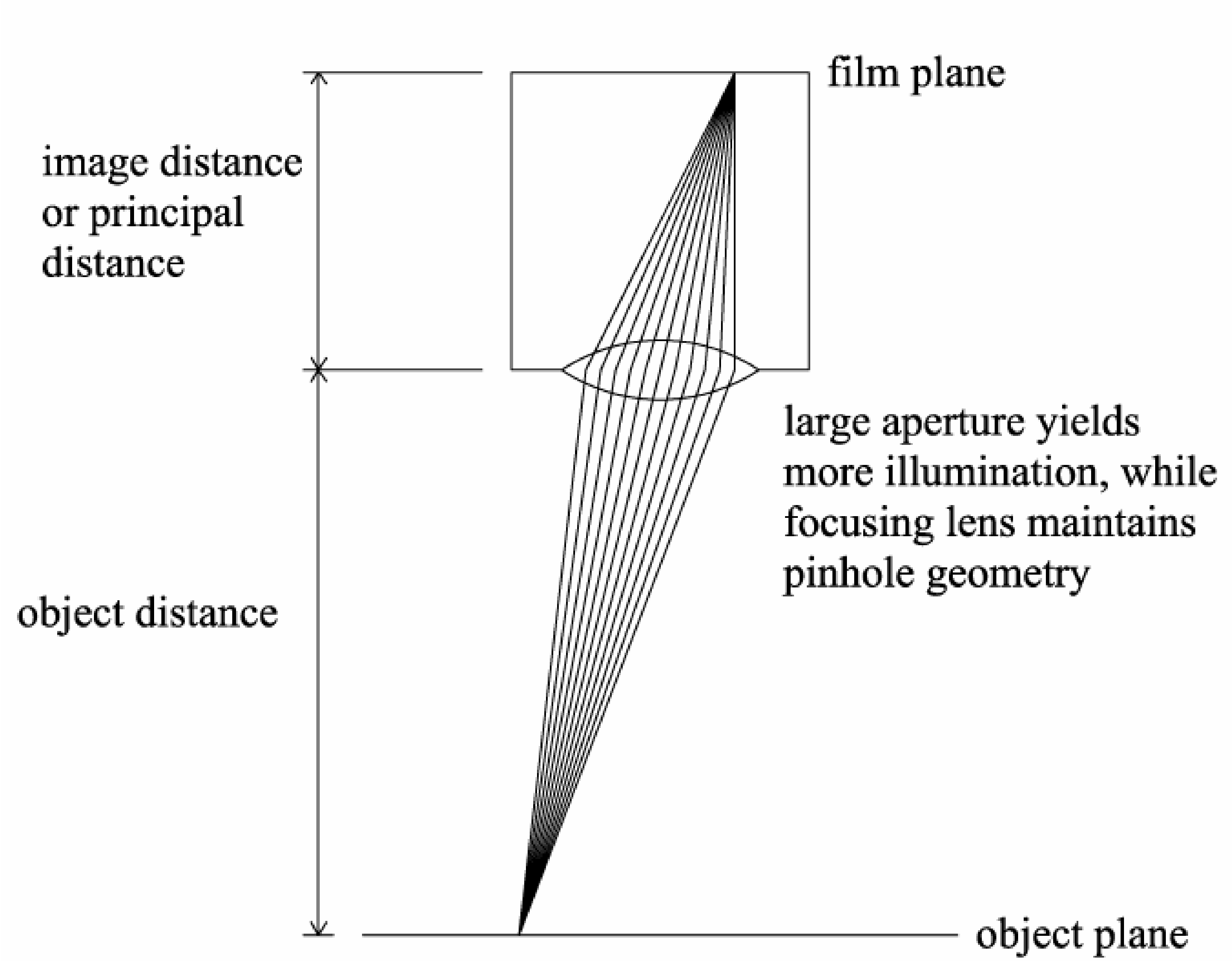


Note: nominal scale is the same everywhere in the image

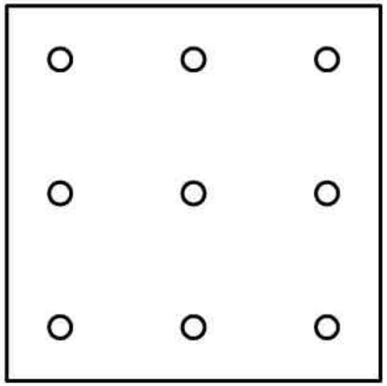
Frame Geometry



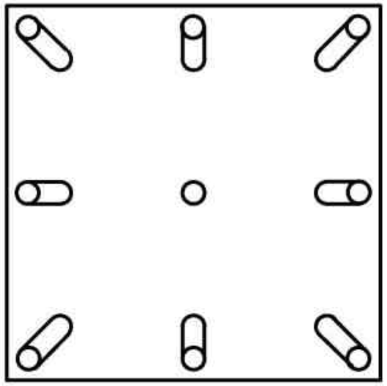
Frame Geometry with Lens for Large Aperture



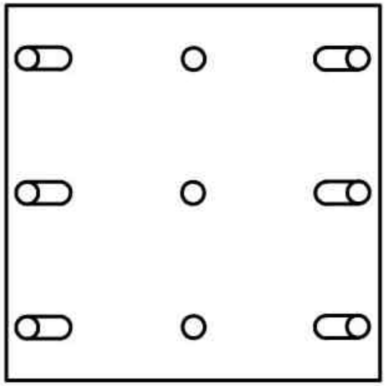
Relief Displacement



Layout of vertically extended objects within an image



Relief displacement as found in *frame* imagery, entire image captured at same instant, relief displacement is always *radial* with respect to the *nadir point*



Relief displacement as found in *pushbroom* imagery, the image is built up *over time* by the platform motion, relief displacement only exists *within a line.* It is still radial with respect to the nadir point, but there is a different nadir point *for every line.* Therefore the only component of relief displacement is *cross-track,* there is no *along-track* component. (platform motion is up/down)

Relief Displacement for Nadir Imagery

Ideal geometry: nadir imagery, flat terrain

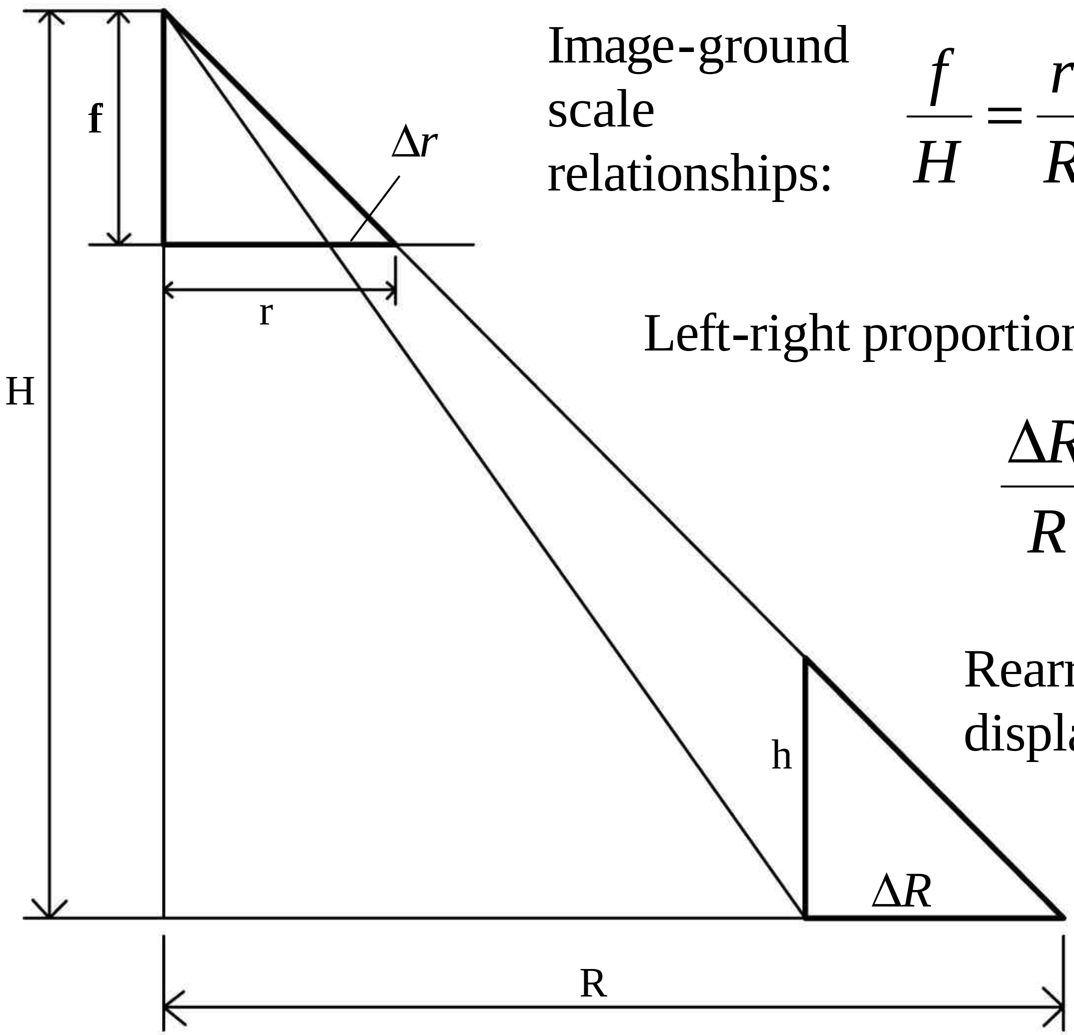


Image-ground scale relationships:

$$\frac{f}{H} = \frac{r}{R} = \frac{\Delta r}{\Delta R} = \text{scale}$$

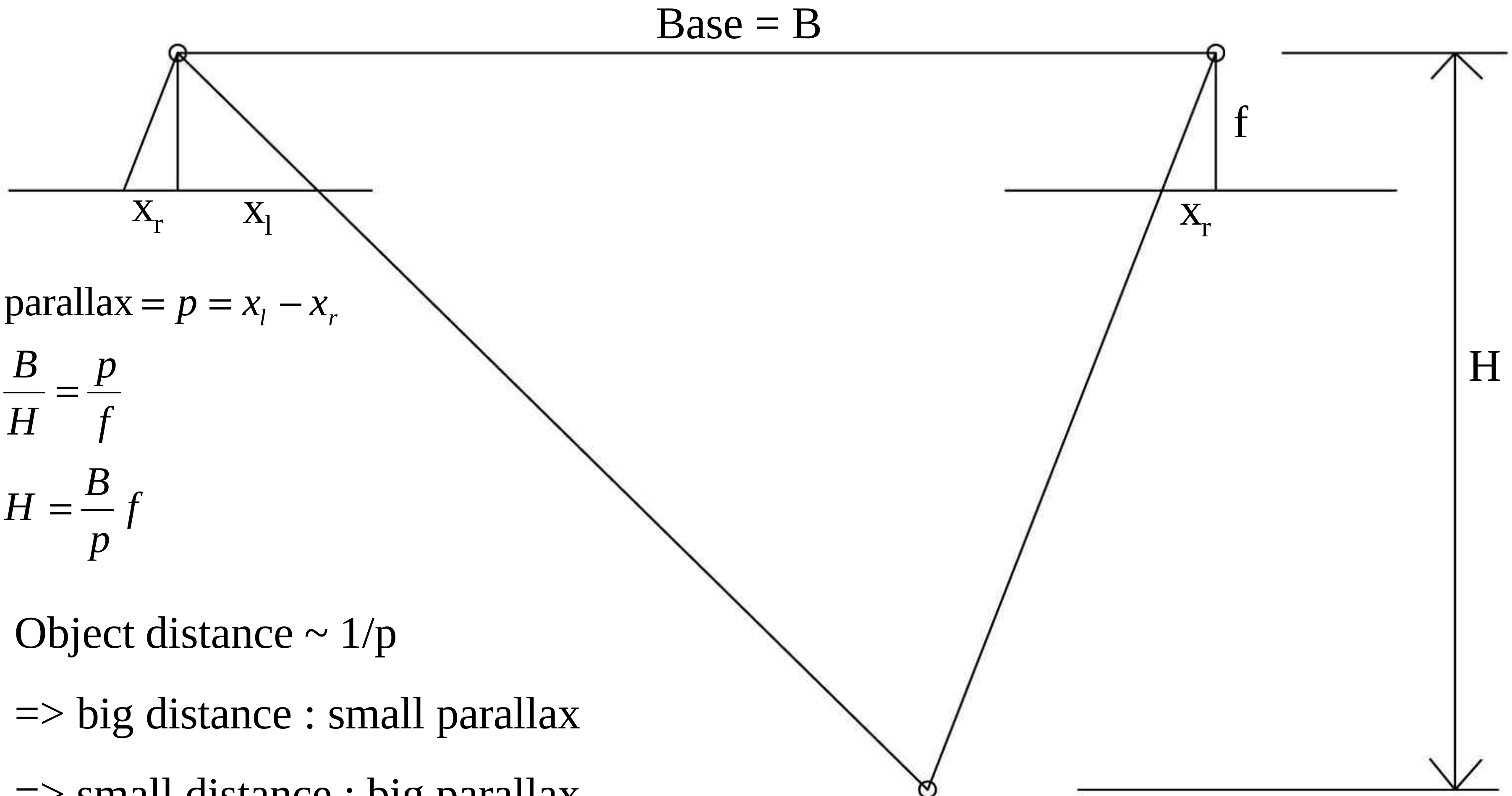
Left-right proportionalities:

$$\frac{\Delta R}{R} = \frac{\Delta r}{r} = \frac{h}{H}$$

Rearrange for classic relief displacement formula:

$$h = \frac{\Delta r}{r} H$$

Parallax: *apparent change in position due to change in view location (sometimes called disparity)*



$$\text{parallax} = p = x_l - x_r$$

$$\frac{B}{H} = \frac{p}{f}$$

$$H = \frac{B}{p} f$$

Object distance ~ 1/p

=> big distance : small parallax

=> small distance : big parallax

$$\frac{dp}{dH} = -fBH^{-2} = -\left(\frac{f}{H}\right)\frac{B}{H} = -(scale)\frac{B}{H}$$

=> Rate of change of parallax with respect to distance ~ scale and B/H

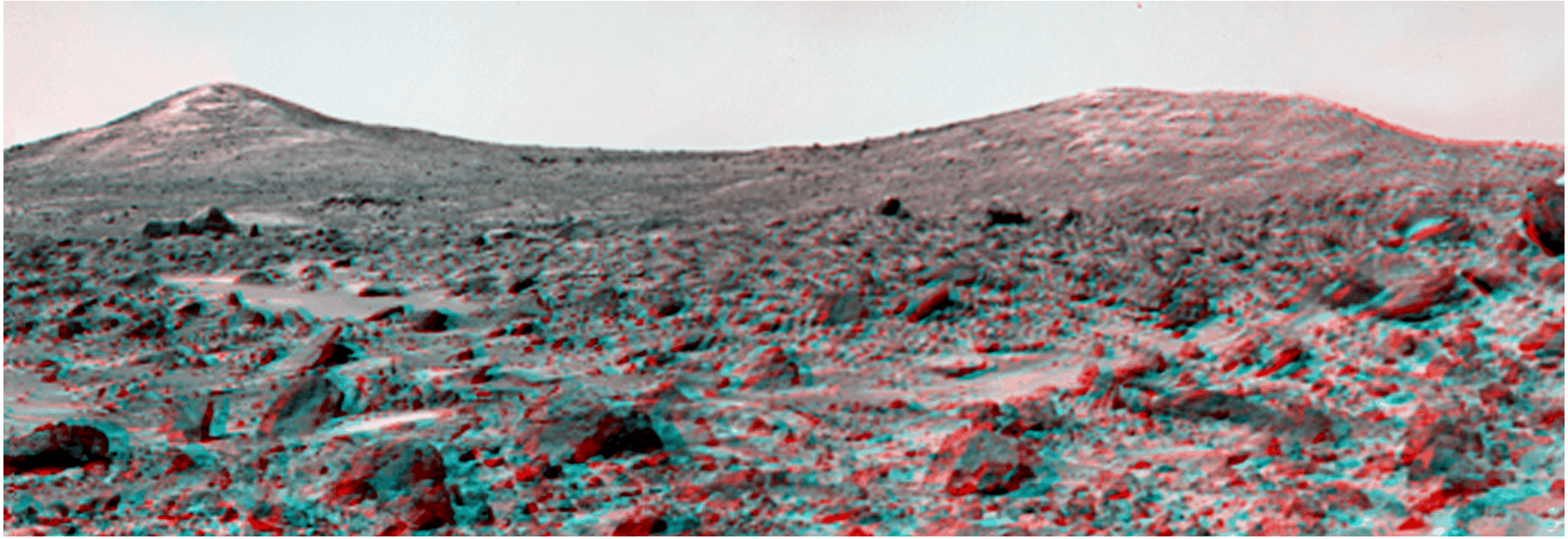
L

R

R

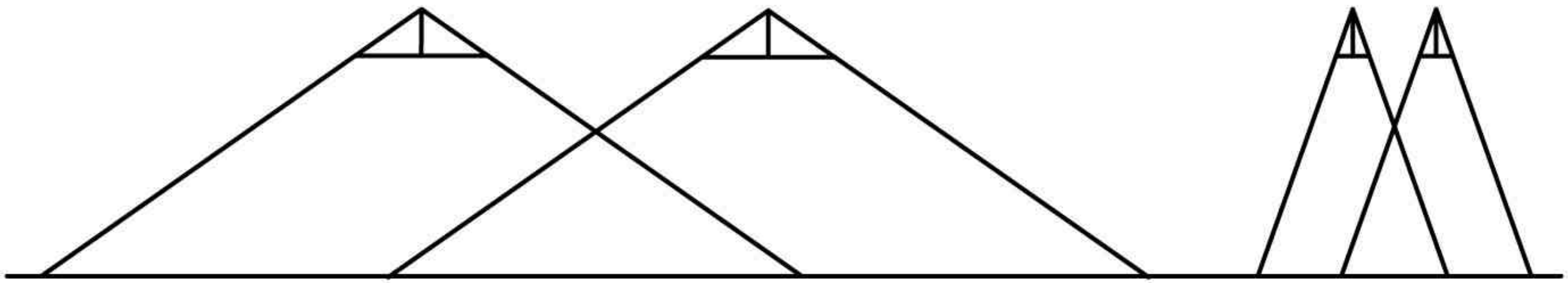
Near point (top of tank) makes a larger excursion between the left and right exposure, compared to the base of the tank (larger parallax or larger disparity). This disparity can be processed by our eyes to sense depth. A stereo cursor can be placed on an object to measure 3D coordinates delineate 3D features. If image B/H is greater than our eye's b/h, then we sense *vertical exaggeration.* This changes the appearance, but does not hurt measurement accuracy (in fact it helps).

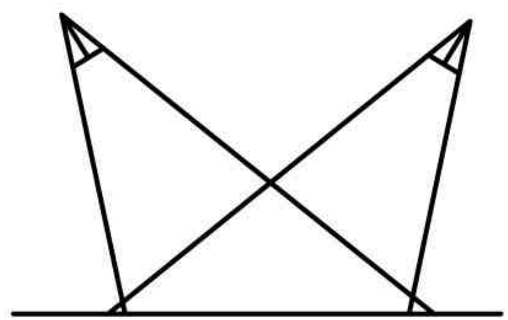
Anaglyph Stereo of Mars scene shows greater disparity or parallax in foreground and less in the background or far distance



Wide angle and given overlap
yields large B/H ratio

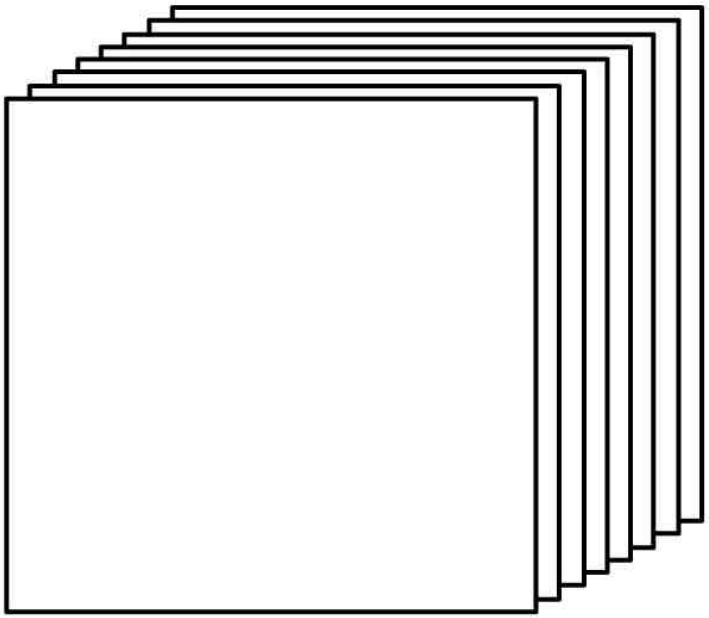
Narrow angle and same overlap
yields small B/H ratio





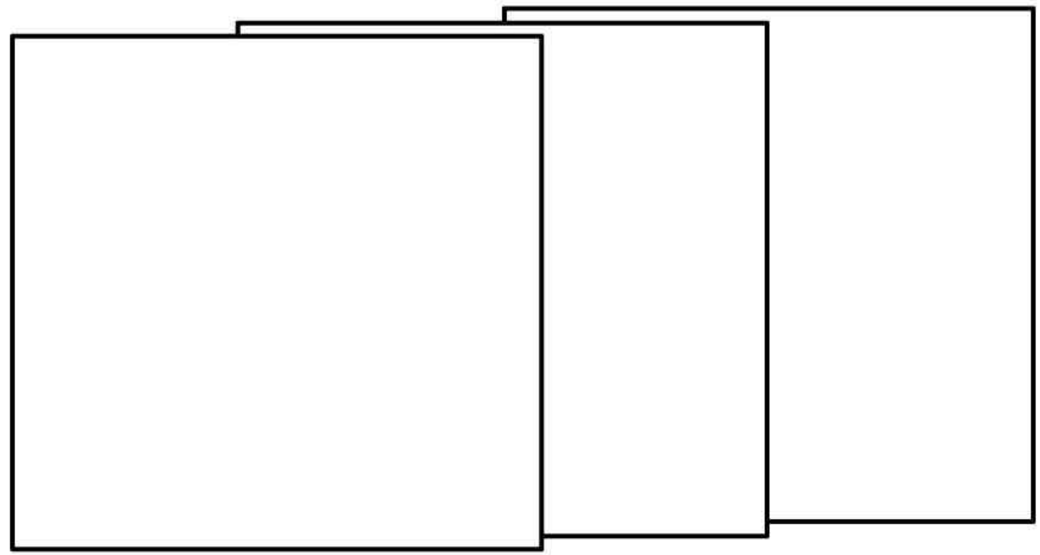
Can compensate for narrow angle camera by introducing strong convergence angle thus restoring favorable B/H ratio

High frame rate motion imagery = short baseline or small B/H (between adjacent images)



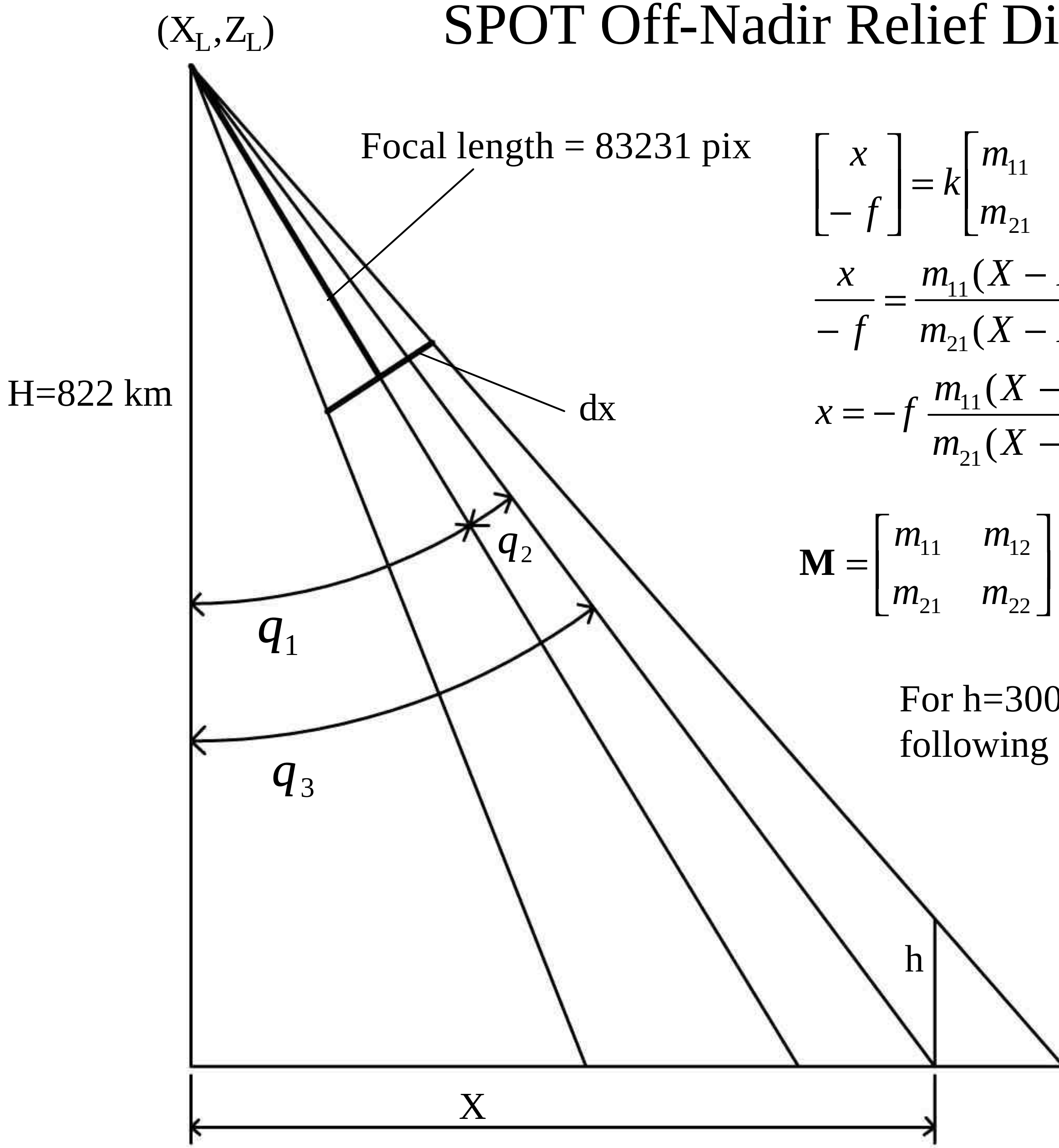
Correspondence is easy, since small displacements and parallaxes between adjacent images, for point tracking or optical flow, but determination of heights is weak (unless you extend over many frames)

Conventional aerial imagery = long baseline or large B/H



Correspondence can be a challenge if large parallaxes, but determination of heights is strong

SPOT Off-Nadir Relief Displacement



$$\begin{bmatrix} x \\ -f \end{bmatrix} = k \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \begin{bmatrix} X - X_L \\ Z - Z_L \end{bmatrix}$$

$$\frac{x}{-f} = \frac{m_{11}(X - X_L) + m_{12}(Z - Z_L)}{m_{21}(X - X_L) + m_{22}(Z - Z_L)}$$

$$x = -f \, \frac{m_{11}(X - X_L) + m_{12}(Z - Z_L)}{m_{21}(X - X_L) + m_{22}(Z - Z_L)}$$

$$\mathbf{M} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} = \begin{bmatrix} \cos q_1 & \sin q_1 \\ -\sin q_1 & \cos q_1 \end{bmatrix}$$

For h=300m, theta-2=2 deg, we have the following values for theta-1 and dx:

q_1	dx
10 deg	6.2 pix
20 deg	10.6 pix
27 deg	13.0 pix

Relief displacment for off-nadir SPOT is significant