AERIAL PHOTOGRAPHY

Cameras and photographic films used for aerial photography are sensitive to the visible and the near infrared. Aerial photography is a passive technique since it detects existing radiation (from the Sun) and gives a two-dimensional representation (image) of the radiance of the target area.
Surprisingly, film-based photography is still preferred to digital photography because it allows for a better resolution.

The traditional photographic process is based on a chemical reaction: the conversion of a salt of silver into metallic silver by the absorption of a photon. Photographic film consists of very many small crystals of a salt (for instance, silver bromide AgBr) embedded in gelatin and supported on a plastic base. The gelatin layer is typically about 10 μm thick and the crystals (grains) are typically 0.1 to 5 μm in size. Absorption of a sufficiently energetic photon converts a grain into metallic silver, which is opaque, and unexposed grains are later removed by a chemical process.
The result is called negative, because if it is viewed by passing light through it, areas that received light during the exposure stage will appear dark, and those that did not will appear light.

Black and white (panchromatic) films ⇒ Visible photography: 0.3-0.7 μm
True infrared photography: 0.7-0.9 μm

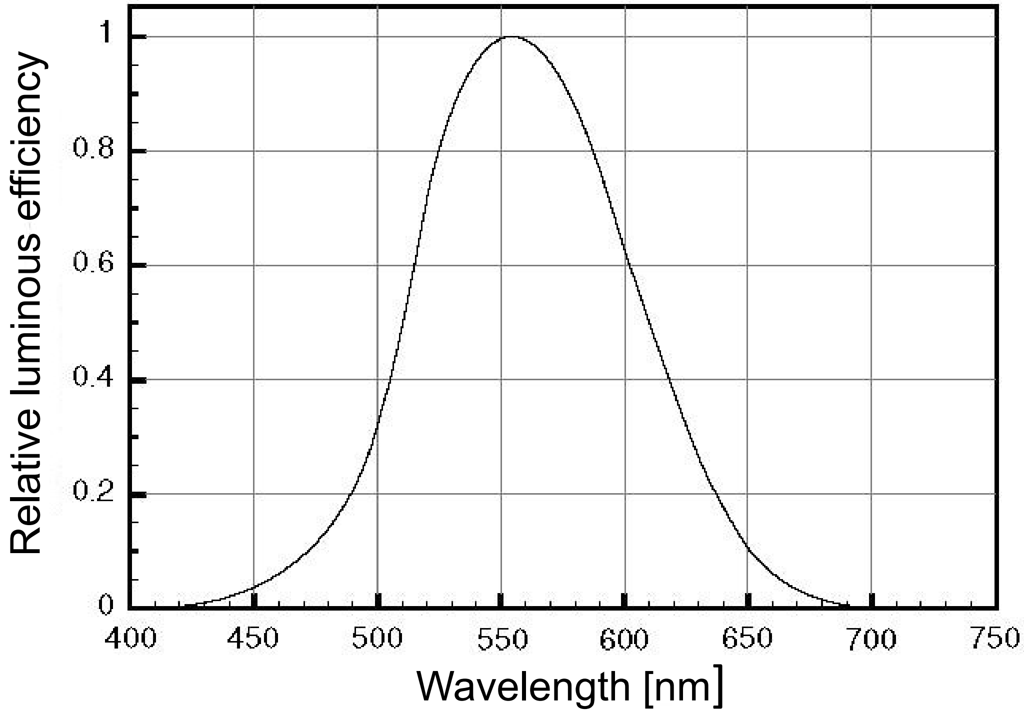
The response of a photographic film is normally defined in terms of photometric units which are weighted with respect to the nominal spectral sensitivity of the human eye.
The photometric unit corresponding to irradiance is called the illuminance.

$$E_v = K \int_0^{\infty} E_\lambda V(\lambda)\, d\lambda$$

E_v **illuminance**

E_λ spectral irradiance

K it is a constant factor (not important)



$V(\lambda)$

nominal sensitivity of the light adapted human eye, its maximum value is reached in the **green** region

Speed of a film

It refers to the time duration for which it must be exposed to light of a given illuminance in order to achieve a significant change of opacity after processing. The speed is usually quantified by an ASA, ISO or DIN number, for films intended for aerial photography the AFS (Aerial Film Speed) index is used. Larger numbers correspond to faster films and hence shorter exposure times.

The grain size controls speed: high speed films are obtained by using large grains.

Contrast of a film

It refers to the effect of changing the exposure time (or the illuminance). If a small change of illuminance produces a large change of opacity of the processed film, the film is said to have a high contrast.

The grain size controls contrast: high contrast films have a specific range of grain sizes.

Spatial resolution

It is the ability of a remote sensing system to distinguish two points. For photographic systems the resolution is normally expressed in line-pairs (lp) per unit length: it is the greatest number of line-pairs per unit length that can be resolved on a negative.

The resolution r has the dimensions of 1/length: for instance, r = 10 lp/mm=10^4 m^{-1}

$$\boxed{\delta x = \frac{1}{2r}}$$

r resolution

δx smallest distance between two points that can be resolved

The highest spatial resolutions available for aerial photographic films are typically 200 lp/mm, with corresponding low film speeds of about 10 AFS units.
A fast mapping film might have a spatial resolution of about 20 lp/mm and a film speed of 1000 AFS units.

Traditional film-based photography offers a better spatial resolution than digital photography; we explain this by means of an example with realistic numbers.
A typical mapping film has a spatial resolution of 50 lp/mm, assumed to be equivalent to resolve an object 0.01 mm wide on the negative. A 230-mm square negative can resolve $(230/0.01)^2 \approx 530$ million point-like objects: we might describe this as a 530-megapixel system.
Aerial digital mapping cameras achieve a resolution around only 100-200 megapixels.

Let us consider a system with a single lens of focal length f; the image distance v can be obtained from the object distance u by means of the thin lens equation

$$\boxed{\frac{1}{u}+\frac{1}{v}=\frac{1}{f}}$$

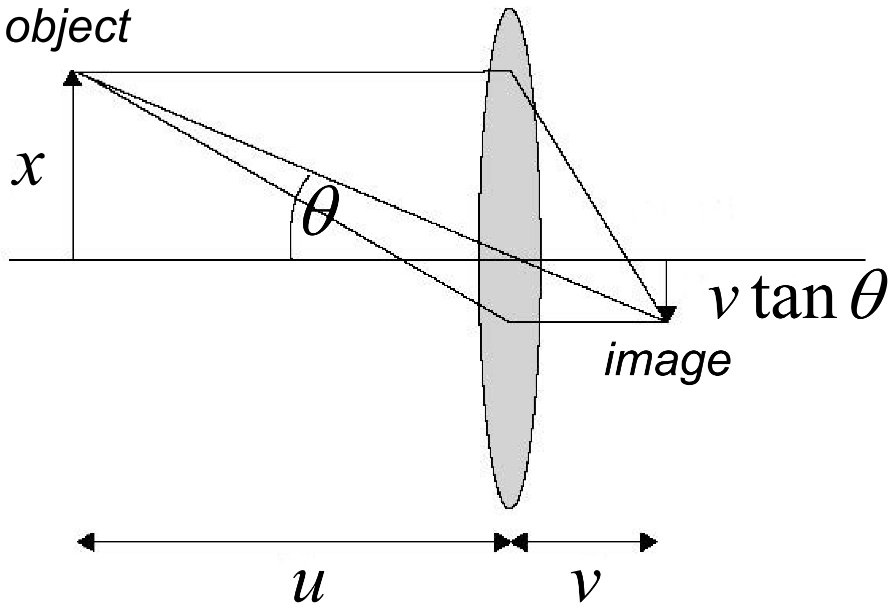


image height $h = v\tan\theta$

if the object distance is much larger than the focal length

$$h = f\frac{x}{u} \approx f\theta$$

Let us suppose that the object has a uniform exitance, such that the luminance incident at the lens is L. If the object subtends a small solid angle Ω, the irradiance at the lens is LΩ.

Total power intercepted by a lens of diameter D

$$\boxed{P_{tot} = \pi \frac{D^2}{4} \Omega L}$$

The power is distributed on an area $f^2 \Omega$ of the film, thus the illuminance at the film plane is

$$E_{film} = \pi \frac{D^2}{4} \frac{L}{f^2}$$

The ratio of the illuminance at the film to the luminance at the lens is given by

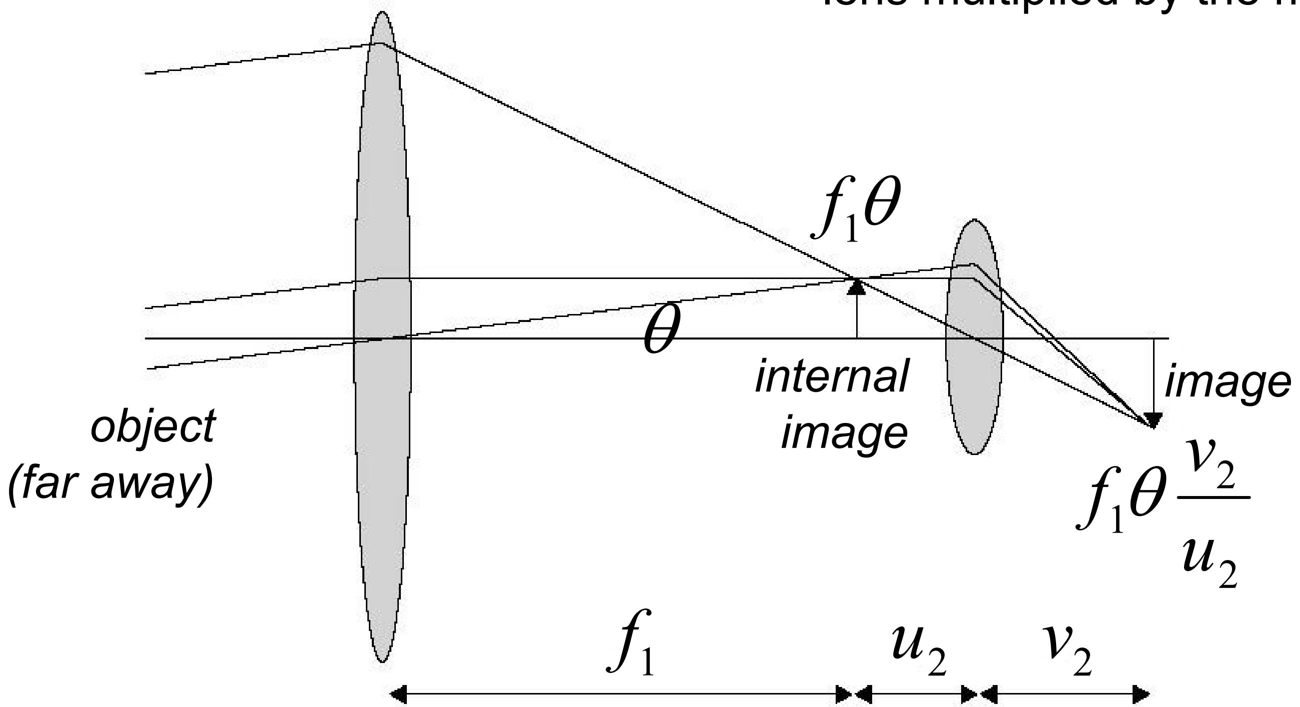
$$\boxed{\frac{E_{film}}{L} = \frac{\pi}{4} \left(\frac{D}{f} \right)^2}$$

$$\frac{f}{D}$$

f/number of a lens
the smaller the f/number, the larger the lens and the brighter the image
Lenses can be constructed with f/numbers as small as 1, but most lenses used in aerial mapping have f/numbers in the range 5 to 10.

Most aerial photographic systems use compound lenses, which have the advantage of giving increased focal length without making the lens assembly physically larger.

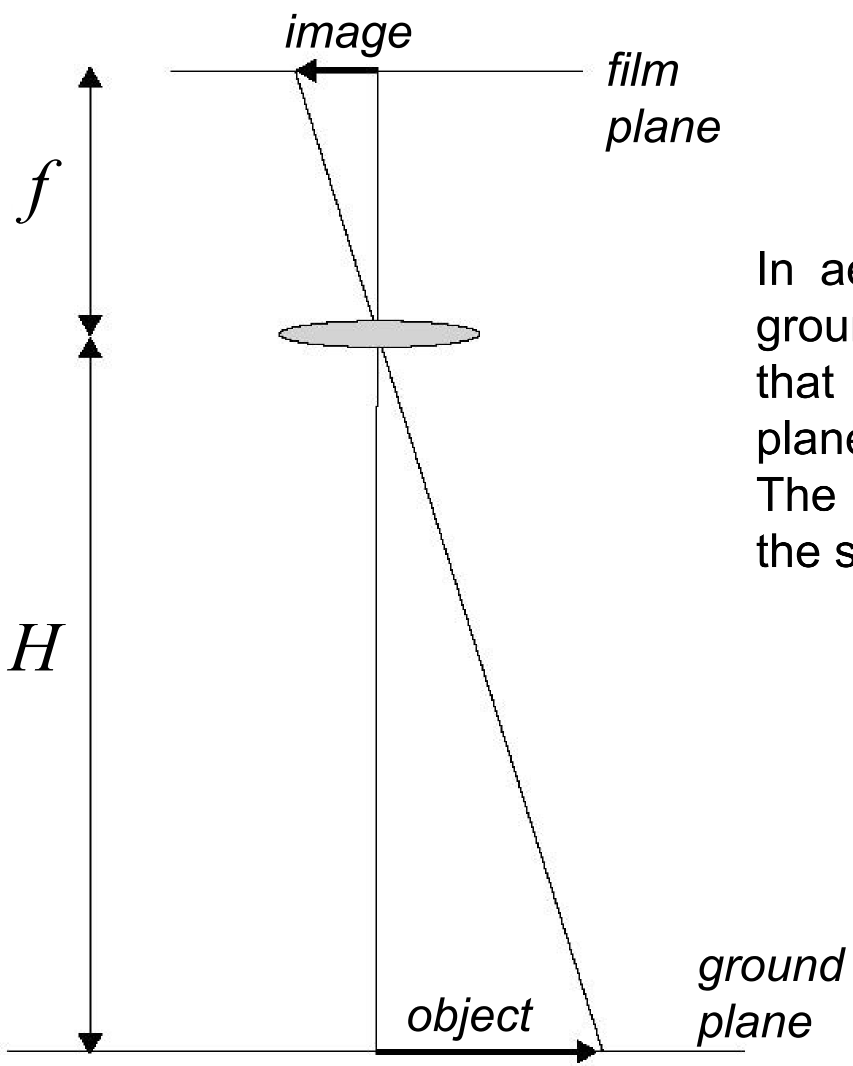
Example: two converging lenses are equivalent to a single lens whose focal length f_e is the focal of the first lens multiplied by the magnification of the second lens.



equivalent focal length $$f_e = f_1 \frac{v_2}{u_2}$$

SCALE OF VERTICAL AERIAL PHOTOGRAPHY

The scale of a map is the number (less than unity) that expresses the ratio of the size of the representation of an object on the map to the size of the real object.



In aerial photography, the distance from the ground is much larger than the focal length, so that the distance from the lens to the film plane can be taken as the focal length.
The scale of the image at the film plane (i.e the scale of the negative) is readily obtained.

scale of the image $\boxed{s = \frac{f}{H}}$

If the negative has a width w the corresponding region on the ground (coverage of the aerial photography) is w_g.

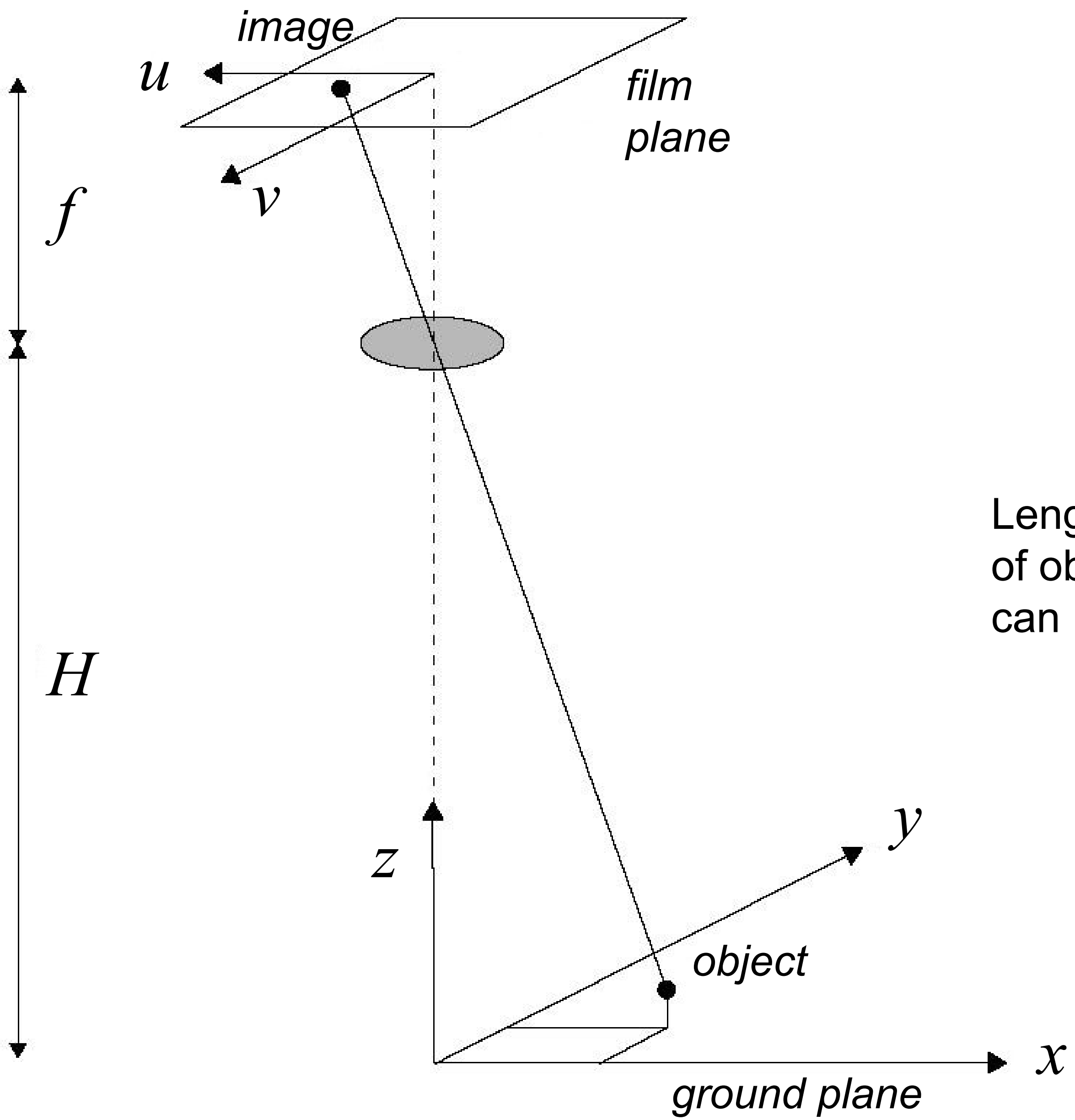
$$w_g = \frac{w}{s} = w\frac{H}{f}$$

The spatial resolution r_g on the ground is determined by the imaging geometry and the film resolution r.

$$r_g = \frac{\delta x}{s} = \frac{1}{2r}\frac{H}{f}$$

If we consider a constant value of the camera distance from the ground H, higher spatial resolution (smaller r_g) requires a longer focal length f, but will give a smaller coverage w_g.

Diffraction can limit the resolution of the image only if the diffration-limited resolution is smaller than the imaging system resolution.



$$u = \frac{f}{H - z} x$$

$$v = \frac{f}{H - z} y$$

Lengths, areas and orientation of objects on horizontal ground can be determined from photos.