Concepts of Aerial Photography

What is an aerial photograph?

An aerial photograph, in broad terms, is any photograph taken from the air. Normally, air photos are taken vertically from an aircraft using a highly-accurate camera. There are several things you can look for to determine what makes one photograph different from another of the same area including type of film, scale, and overlap. Other important concepts used in aerial photography are stereoscopic coverage, fiducial marks, focal length, roll and frame numbers, and flight lines and index maps. The following material will help you understand the fundamentals of aerial photography by explaining these basic technical concepts.

Basic Concepts of Aerial Photography

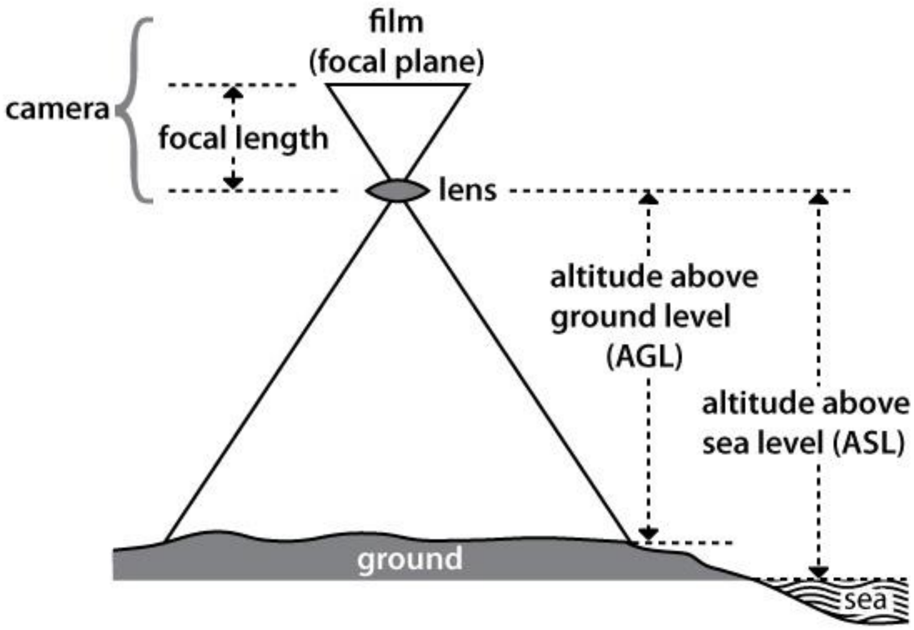
Film: most air photo missions are flown using black and white film, however colour, infrared, and false-colour infrared film are sometimes used for special projects.

Focal length: the distance from the middle of the camera lens to the focal plane (i.e. the film). As focal length increases, image distortion decreases. The focal length is precisely measured when the camera is calibrated.

Scale: the ratio of the distance between two points on a photo to the actual distance between the same two points on the ground (i.e. 1 unit on the photo equals "x" units on the ground). If a 1 km stretch of highway covers 4 cm on an air photo, the scale is calculated as follows:

$$\frac{\text{PHOTO DISTANCE}}{\text{GROUND DISTANCE}} = \frac{4\ \text{cm}}{1\ \text{km}} = \frac{4\ \text{cm}}{100\ 000\ \text{cm}} = \frac{1}{25\ 000} \quad \text{SCALE: } 1/25\ 000$$

Another method used to determine the scale of a photo is to find the ratio between the camera's focal length and the plane's altitude above the ground being photographed.



If a camera's focal length is 152 mm, and the plane's altitude Above Ground Level (AGL) is 7 600 m, using the same equation as above, the scale would be:

$$\frac{\text{FOCAL LENGTH}}{\text{ALTITUDE (AGL)}} = \frac{152\text{ mm}}{7\,600\text{ m}} = \frac{152\text{ mm}}{7\,600\,000\text{ mm}} = \frac{1}{50\,000} \quad \text{SCALE: 1/50 000}$$

Scale may be expressed three ways:

- Unit Equivalent
- Representative Fraction
- Ratio

A photographic scale of 1 millimetre on the photograph represents 25 metres on the ground would be expressed as follows:

- Unit Equivalent - 1 mm = 25 m
- Representative Fraction - 1/25 000
- Ratio - 1:25 000

Two terms that are normally mentioned when discussing scale are:

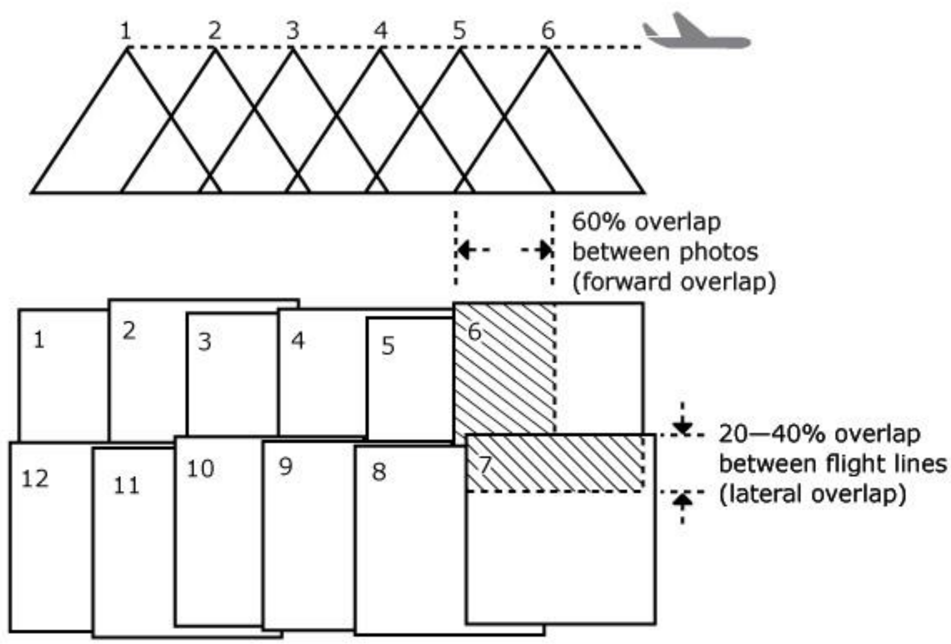
Large Scale - Larger-scale photos (e.g. 1:25 000) cover small areas in greater detail. A large scale photo simply means that ground features are at a larger, more detailed size. The area of ground coverage that is seen on the photo is less than at smaller scales.

Small Scale - Smaller-scale photos (e.g. 1:50 000) cover large areas in less detail. A small scale photo simply means that ground features are at a smaller, less detailed size. The area of ground coverage that is seen on the photo is greater than at larger scales.

The National Air Photo Library has a variety of photographic scales available, such as 1:3 000 (large scale) of selected areas, and 1:50 000 (small scale).

Fiducial marks: small registration marks exposed on the edges of a photograph. The distances between fiducial marks are precisely measured when a camera is calibrated, and this information is used by cartographers when compiling a topographic map.

Overlap: is the amount by which one photograph includes the area covered by another photograph, and is expressed as a percentage. The photo survey is designed to acquire 60% forward overlap (between photos along the same flight line) and 30% lateral overlap (between photos on adjacent flight lines).

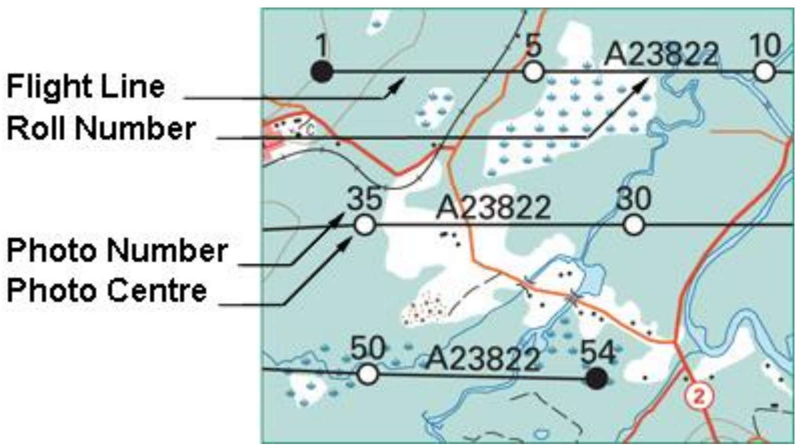


Stereoscopic Coverage: the three-dimensional view which results when two overlapping photos (called a stereo pair), are viewed using a stereoscope. Each photograph of the stereo pair provides a slightly different view of the same area, which the brain combines and interprets as a 3-D view.

Roll and Photo Numbers: each aerial photo is assigned a unique index number according to the photo's roll and frame. For example, photo A23822-35 is the 35th annotated photo on roll A23822. This identifying number allows you to find the photo in NAPL's archive, along with metadata information such as the date it was taken, the plane's altitude (above sea level), the focal length of the camera, and the weather conditions.

Flight Lines and Index Maps: at the end of a photo mission, the aerial survey contractor plots the location of the first, last, and every fifth photo centre, along with its roll and frame number, on a National Topographic System (NTS) map. Photo centres are represented by small circles, and straight lines are drawn connecting the circles to show photos on the same flight line.

This graphical representation is called an air photo index map, and it allows you to relate the photos to their geographical location. Small-scale photographs are indexed on 1:250 000 scale NTS map sheets, and larger-scale photographs are indexed on 1:50 000 scale NTS maps.



Influence of Drone Altitude, Image Overlap, and Optical Sensor Resolution

Few systematic analyses of the influence of different flight and sensor parameters on multi-view image reconstruction quality and efficiency of drone-based sensing in a forest environment. It provides novel information for drone flight planning and could in theory be upscaled to larger manned acquisition platforms and be used for photogrammetric benchmarking. The developed method for extracting images from video proved to be versatile in controlling the forward overlap and for achieving extraordinary overlaps of up to 98.8%, without a major loss in efficiency (flight time). Our study is also, to our knowledge, the first to be based on video data, instead of still images. An important finding was that the side overlap of the images was a major driver of flight time and processing time. Higher side overlaps, when combined with high forward overlaps increased the reconstruction detail but were detrimental to the reconstruction accuracy. However, altitude had a stronger effect on flight time. Drone flights at low altitudes dramatically increased the number of tie points and thus reconstruction detail. This was particularly true when low altitudes were combined with high forward overlaps. The question now arises whether similar tie point numbers could have been achieved using higher sensor resolutions at higher altitudes, which would have increased the flight efficiency. Our results indicate that it will be hard to compensate for the level of reconstruction detail with higher sensor resolutions, which we attributed to a changed image geometry at low altitudes, where more of the tree silhouettes are visible. Possible explanations for the observed nonlinear increase of identified tie points with decreasing altitude are that (i) more details can be detected with higher object resolutions, (ii) the inherent perspective distortion leads to higher tie point detection at tree silhouettes, and (iii) the lower relative flight speed (altitude-to-velocity ratio). Our results indicate that it is not merely a matter of higher object resolution. A further investigation of these effects would be desirable to better understand their impact.

Nadir , Oblique and Nadir + Oblique and its importance

Merging Oblique and Nadir Photogrammetry Steep topography often contains low-density regions or voids in nadir photogrammetry, while oblique photogrammetry, which is ideal for capturing steep to vertical surfaces, is inefficient (and ineffective) for large mapping projects in varied topography.

Fortunately, nadir and oblique imagery can often be processed together or merged after processing to produce a 32 single model with improved quality and completeness (Rossi et al., 2017). Most contemporary SfM photogrammetry software processing applications, including Pix4Dmapper, Agisoft Metashape (formerly PhotoScan), and Bentley ContextCapture, allow oblique and nadir imagery to be processed together.

However, this so-called “batch processing” method was observed to produce substantial vertical offset between nadir and oblique imagery, possibly due to insufficient overlap between the sets of images. To overcome this problem, nadir and oblique imagery was processed separately and then merged into a single project using manual tie points, which were assigned to each of the brightly colored photogrammetric targets visible in the respective image sets. By forcing the software to recognize these points as common features and following the progression oblique and nadir imagery from multiple individual flights could be merged seamlessly into complete models that fully captured the varied, complex topography at each of the respective field areas. The photogrammetric reconstructions were then scaled by assigning scale constraint Photogrammetry processing workflow in Pix4Dmapper v.4.3.33. 33 tie points to the edge of each 2.0 ft x 2.0 ft photogrammetric target, marking the exact location of the corners of the target in several images, and entering the actual length of the edge of the target in the modal dialogue box.

Orientation was accomplished by assigning X, Y, and Z-axis orientations to the corresponding sides of the orientation constraint and marking the corresponding tie points in the aerial imagery. Each project was also roughly georeferenced to the Montana State Plane coordinate system (US feet) using image geotags from the onboard GPS.

Camera Fundamentals and Parameters in Photogrammetry

Here is a description of each one of these key camera characteristics:

- **Focal length.** The focal length of a lens determines the magnification and the angle of the light ray. The longer the focal length, the greater the magnification of the image, which is why long telephoto lenses are used to take pictures from far away. A long focal length will also have light rays hit the image sensor at shallower angles. Short focal length lenses cover larger areas in their field of view and are called ‘wide angle’, or ‘fish-eye’ when very wide.
- **Imaging size.** The size of the film, or the digital sensor’s imaging area determines the geometric relationship between the light ray and a point identified on the photograph. If you keep focal length constant but increase the imaging area size, you will capture more of the scene in the image. The amount of the scene captured in one image is determined by both the focal length and the imaging size. This relationship or ratio (between focal length and image format size) is more important than knowing just one or the other of the parameters. In the days of film cameras, the image size was usually 35mm, or sometimes other sizes such as 8mm, 16mm, and 70mm widths. Today’s digital image sensors vary from a couple of millimeters across in a cell phone camera, to 50mm across for very high-end sensors.
- **Sampling.** Modern photogrammetry is carried out in the digital realm by a computer. To this end, we use digital cameras with digital sensors that have pixels covering the imaging area. Each pixel picks up a bit of light from one part of the scene. Photogrammetry software uses the position of where the light ray hits the sensor’s surface to determine the light ray geometry. To get this 2D position from a digital image, one needs the relationship between the pixels in the digital image and the physical sensor size. This is given by the sampling or the pixel size. On some cameras the size of a pixel is only a few microns across – a fraction of the diameter of a human hair!
- **Principal point.** Photography takes a two-dimensional image of a three-dimensional world. The projection of your three-dimensional scene, through the lens, onto the image plane is a two-dimensional representation of the scene. The image plane is the area where the film or the digital image sensor is located. The principal point of an image is the point where a camera’s direct line of sight (called the optical axis) intersects the image plane. This is the image’s mathematical center. For high accuracy photogrammetric work, it is good to know if the lens is mounted centered over the image sensor – due to small manufacturing variances – and hence if the principal point is in the center of the image. This affects the mathematical calculation of the light ray geometry.
- **Lens distortion.** In an ideal camera (when simulating the lens as one piece), the light ray travels in a straight line from the scene to the imaging surface in the camera. Real lenses are not ideal though and will warp the light ray in interesting ways. This warp varies by the location of the light ray on the image plane. A common form of lens distortion you may have seen is barrel distortion. This distortion causes straight lines in the scene to be curved. Photogrammetry software needs to ‘undo’ lens distortion to

build up the correct internal geometry. The lens distortion has to be characterized in a mathematical formula or as a map for accurate results.