CHAPTER 3: MAPPING CAMERAS
Remote sensing as a technology can be said to have started with the appearance of the first photographs.

The so-called aerial photo - emerged in the 1840s with pictures taken from balloons.

By the First World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance.

From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the earth surface.
EVOLUTION OF AERIAL CAMERAS
FIGURE 3.1. Schematic diagram of an aerial camera, cross-sectional view.
CROSS-SECTIONAL VIEW OF AN IMAGE FORMED BY A SIMPLE LENS

(a)

NODAL POINT

FOCAL PLANE

FOCAL POINT

CHIEF RAY

OPTICAL AXIS

APERTURE STOP

FOCAL LENGTH

IMAGE PRINCIPAL PLANE
Energy of different wavelengths is brought to a focus at varying distances from the lens. More complex lenses are corrected to bring all wavelengths to a common focal point.
**DIAPHRAGM APERTURE STOP**

Relative Aperture ($f$) = Focal length / Aperture size

- **(a)**: Bright
- **(b)**: Dim
- **(c)**: Dimmer

<table>
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<th>Aperture Size</th>
<th>f stop</th>
<th>Relative Brightness</th>
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<td>6%</td>
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<td></td>
<td>$f \ 32$</td>
<td>0.7%</td>
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Aerial photographs can be classified according to the orientation of the camera in relation to the ground at the time of exposure.

FIGURE 3.4. Oblique and vertical aerial photographs. Oblique perspectives provide a more intuitive perspective for visual interpretation but present large variation in image scale. Vertical photography presents a much more coherent image geometry, although objects are presented from unfamiliar perspectives and thus it can be more challenging to interpret.
FIGURE 3.5. High oblique aerial photograph. From authors’ photographs.
The principal point, defined as the intersection of the optical axis with the focal plane, which forms the optical center of the image.

![Diagram of principal point and fiducial marks]

**La Parguera, P.R.**

**FIGURE 3.7.** Fiducial marks and principal point.
ERRORS

The most important positional, or geometric, errors in the vertical aerial photograph are:

1. Optical distortions
2. Tilt
3. Relief displacement

FIGURE 3.8. Schematic representation of terms to describe geometry of vertical aerial photographs.
FIGURE 3.9. Relief displacement. The diagram depicts a vertical aerial photograph of an idealized flat terrain with five towers of equal height located at different positions with respect to the principal point. Images of the tops of towers are displaced away from the principal point along lines that radiate from the nadir, as discussed in the text.
A charged-coupled device (CCD) is formed from light-sensitive material embedded in a silicon chip. The potential well receives photons from the scene through an optical system designed to collect, filter, and focus radiation.
DIGITAL IMAGING

Picture Elements
PIXELS
CCD-based linear arrays have been used for remote sensing instruments that acquire imagery line by line as the motions of the aircraft or satellite carry the field of view forward along the flight track.

**FIGURE 3.12.** Schematic diagram of a linear array.
“In the digital realm, there are several alternative strategies for acquiring images, each representing a different strategy for forming digital images that are roughly equivalent to the 9 in. × 9 in. size of analog aerial photographs that became a commonly accepted standard in the United States after the 1930s.”

**FIGURE 3.13.** DMC area array. A single composite image is composed of two separate images acquired by independent lens systems with overlapping fields of view. From Intergraph.
FIGURE 3.15. Schematic diagram of a linear array applied for digital aerial photography. The nadir-viewing red linear array acquires imagery in the red region; two aft-viewing arrays acquire green and panchromatic data in the blue and panchromatic channels, and forward-viewing arrays acquire imagery in the green and NIR. Because of the camera’s continuous forward motion, each field of view acquires a strip of imagery of the flight line. See Figure 3.16. From Leica Geosystems.
Specialized high-quality scanners provide large scanning surfaces, large CCD arrays, and sophisticated software to preserve information recorded in the original.
Advantages of digital systems

1. Access to the advantages of digital formats without the need for film scanning, and therefore a more direct path to analytical processing.
2. Economies of storage, processing, and transmission of data.
3. Economies of operational costs.
4. Versatility in applications and in the range of products that can be derived from digital imagery.
5. The greater range of brightnesses of digital imagery, which facilitates interpretation and analysis.
6. True multispectral coverage.
Disadvantages of digital systems

1. Varied camera designs do not replicate the optical and radiometric properties of an analog framing camera and employ various processing and interpolation procedures to produce the full-frame image, to adjust brightnesses across an image, and to ensure the proper registration of the separate bands.

2. The typically smaller footprints of digital images require more stereomodels (more images) relative to analog systems.

3. Linear systems are especially dependent on high-quality airborne GPS / inertial measurement unit (AGPS / IMU) data.

4. Linear scanners also have sensor models that are less widely supported in softcopy photogrammetric software.

5. Digital systems require high initial investments.

6. There is less inherent stability than in metric film cameras (which can require reflying).

7. Component-level calibration and quality control can be difficult.
FIGURE 3.17. Bayer filter. The “B,” “G,” and “R” designations each signify cells with blue, green, and red filters, as explained in the text. Cells for each color are separately interpolated to produce individual layers for each primary.
It is the assignment of colors to represent brightnesses in different regions of the spectrum.

**Black-and-White Infrared:** Imagery acquired in the near infrared region, because it is largely free of effects of atmospheric scattering, shows vegetated regions and land–water distinctions; it is one of the most valuable regions of the spectrum.

**Panchromatic:** Panchromatic means “across the colors,” indicating that the visible spectrum is represented as a single channel (without distinguishing between the three primary colors).

**Natural-Color (True Color):** Band combinations in the same manner as our visual system.

**Color Infrared:** A three-band color image by discarding the blue band and adding the NIR band.
**FIGURE 3.18.** Diagram representing black-and-white infrared imagery. Visible radiation is filtered to isolate the near infrared radiation used to form the image.

**FIGURE 3.19.** Two forms of panchromatic imagery. Left: visible spectrum only. Right: alternative form using green, red, and NIR radiation.
Check the water! Why?

**FIGURE 3.20.** Panchromatic (left) and black-and-white infrared (right) imagery. From U.S. Geological Survey.
FIGURE 3.21. Natural-color model for color assignment.

FIGURE 3.22. Color infrared model for color assignment.
Pilots normally acquire vertical photographs by flying a series of parallel flight lines that together build up complete coverage of a specific region.

Each flight line consists of individual frames, usually numbered in sequence.

FIGURE 3.23. Aerial photographic coverage for framing cameras. (a) forward overlap, (b) drift, and (c) crab.
MOSAICS
A series of vertical aerial photographs.
STEREOSCOPIC PARALLAX
The displacement of an object caused by a change in the point of observation is called parallax.

Stereoscopic parallax is caused by taking photographs of the same object but from different points of observation.
Stereoscopic photographs and terrain data can be used to generate a corrected form of an aerial photograph known as an orthophoto that shows photographic detail without the errors caused by tilt and relief displacement.

What is the difference between an aerial photograph and an orthophoto?

1. A conventional perspective aerial photograph contains image displacements caused by the tilting of the camera and terrain relief (topography). It does not have a uniform scale. You cannot measure distances on an aerial photograph like you can on a map. It is not a map.

2. The effects of tilt and relief are removed from the aerial photograph by the rectification process to create an orthophoto.

3. An orthophoto is a uniform-scale photograph. It is a photographic map.

4. Since an orthophoto has a uniform scale, it is possible to measure directly on it like other maps.

5. An orthophoto may serve as a base map onto which other map information may be overlaid.
PHOTOGRAMMETRY is the science of making accurate measurements from photographs.
1. Read Chapter 3 and answer the review questions 1, 6, and 10 (at the end of the chapter).