SMALL-FORMAT AERIAL PHOTOGRAPHY AND UAS IMAGERY

Principles, Techniques, and Geoscience Applications

SECOND EDITION

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ELSEVIER

Elsevier
Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-12-812942-5

Publisher: Candice Janco
Acquisition Editor: Laura S Kelleher
Editorial Project Manager: Emily Thomson
Production Project Manager: Vignesh Tamil
Cover Designer: Mark Rogers

Typeset by SPi Global, India

CHAPTER

1

Introduction to Small-Format Aerial Photography

Small is beautiful. E. Schumacher 1973, quoted by Mack (2007)

1-1 OVERVIEW

People have acquired aerial photographs ever since the means have existed to lift cameras above the Earth's surface, beginning in the mid-nineteenth century. Human desire to see the Earth "as the birds do" is strong for many practical and aesthetic reasons. From rather limited use in the nineteenth century, the scope and technical means of aerial photography expanded throughout the twentieth century. Now well into the 21st century, the technique is utilized for all manners of earth-resources applications from small and simple to large and sophisticated.

Aerial photographs are taken normally from manned airplanes or helicopters, but many other platforms may be used, including tethered balloons and blimps, drones, gliders, rockets, model airplanes, kites, and even birds (Tielkes 2003). Recent innovations for cameras and platforms have led to new scientific, commercial, and artistic possibilities for acquiring dramatic aerial photographs (Fig. 1-1).

The emphasis of this book is small-format aerial photography (SFAP) utilizing consumer-grade and small professional digital cameras as well as analog 35-mm film cameras in the visual and near-infrared spectral range. Such cameras may be employed from manned or unmanned platforms ranging in height from just 10s of meters above the ground to 100 s of kilometers into space. Platforms may be as simple as a fiberglass rod to lift up a point-and-shoot camera, as technical as unmanned aerial systems (UAS) for GPS-controlled photomosaic imagery, or as complex as the International Space Station.

SFAP became a distinct niche within remote sensing during the 1990s (Warner et al. 1996; Bauer et al. 1997), and it has been employed in recent years for documenting all manner of natural and human resources. The field is ripe with experimentation and innovation of equipment and techniques applied to diverse situations. Recent development and popularity of UAS demonstrate the human desire for low-height, large-scale aerial imagery for hobby, artistic, and professional applications.

In the past, most aerial photography was conducted from manned platforms, as the presence of a human photographer looking through the camera viewfinder was thought to be essential for acquiring useful imagery. For example, Henrard developed an aerial camera in the 1930s, and he photographed Paris from small aircrafts for the next four decades compiling a remarkable aerial survey of the city (Cohen 2006).

Fig. 1-1 Vertical view of abandoned agricultural land dissected by erosion channels near Freila, Province of Granada (Spain) during a photographic survey taken with a hot-air blimp (left of center) at low flying heights. The blimp is navigated by tether lines from the ground, camera functions are remotely controlled. Its picture was taken from a fixed-wing UAV following GoogleEarth-digitized flightlines at ~200 m height. The blimp takeoff pad at right is 12×8 m in size. *Photo by JBR with C. Claussen and M. Niesen.*

Small-Format Aerial Photography and UAS Imagery
https://doi.org/10.1016/B978-0-12-812942-5.00001-X

This is still true for many missions and applications today. Perhaps the most famous modern aerial artist-photographer, Y. Arthus-Bertrand, produced his *Earth from above* masterpiece by simply flying in a helicopter using handheld cameras (Arthus-Bertrand 2017). Likewise, G. Gerster has spent a lifetime acquiring superb photographs of archaeological ruins and natural landscapes throughout the world from the open door of a small airplane or helicopter (Gerster 2004).

The most widely available and commonly utilized manned platform nowadays is the conventional fixed-wing small airplane, employed by many SFAPs (Caulfield 1987). Among recent examples, archaeological sites were documented for many years by O. Braasch in Germany (Braasch and Planck 2005), and by Eriksen and Olesen in northwestern Denmark (2002). In central Europe, Markowski and Markowski (2001) adopted this approach for aerial views of Polish castles. Bárta and Barta (2007), a father and son team, produced stunning pictures of landscapes, villages, and urban scenes in Slovakia.

In the United States, Evans and Worster (1998) were among the first to explore the aesthetic aspects of prairie aerial photography from a small manned airplane, and Wark (2004) published hundreds of dramatic landscape pictures taken from a small plane across the country. Hamblin (2004) focused on panoramic images of geologic scenery in Utah, and Morton (2017) displayed spectacular geologic features throughout North America.

D. Maisel has sought out provocative images of strip mines, dry lake beds, and other unusual landscape patterns in the western United States (Gambino 2008). In one of the most unusual manned vehicles, C. Feil pilots a small autogyro for landscape photography in New York and New England (Feil et al. 2005). An ultralight aircraft is utilized for archaeological and landscape scenes in the Southwest by A. Heisey (Heisey and Kawano 2001; Heisey 2007).

Unmanned, tethered, or remotely flown platforms have come into increasingly widespread use during the last two decades. This book highlights such unmanned systems for low-height SFAP, including kites, blimps, and UAS (drones). While the focus of the book is on the use and potential of SFAP for geoscientific research and applications, the merits and attraction of the bird's-eye view from low heights have become of general interest for a far greater range of topics and motifs. Representative recent kite aerial photography, for example, includes Wilson's (2006) beautiful views of Wisconsin in the United States, Tielkes's (2003) work in Africa, and N. Chorier's magnificent pictures of India (Chorier 2016).

Drone photography has already become a subdiscipline of photography, and photo-sharing communities such as *Dronestagram* testify to the fascination of SFAP felt by photographers around the world. Many professional photographers, with or without previous experience in aerial photography from manned aircraft, are now utilizing drones for their art (Gear 2016). Such imagery has large-scale and exceptionally high spatial resolution that depict ground features in surprising detail from unique vantage points difficult to achieve by other means (Fig. 1-2). These photographic views bridge the gap between ground observations and conventional airphotos and satellite images.

Fig. 1-2 Close-up vertical view of the elephant seal rookery on the beach at Piedras Blancas, California, United States. These juvenile seals are ~2–2½m long, and most are sleeping on a bank of seaweed. People are not allowed to approach the seals on the ground, but the seals were not aware of the silent kite and camera overhead. The spatial detail depicted in such images is extraordinary; individual pebbles are clearly visible on the beach. Special permission was necessary to conduct kite aerial photography at this site; image acquired with a compact digital camera.

1-2 BRIEF HISTORY

Since ancient times, people have yearned to see the landscape as the birds do, and artists have depicted scenes of the Earth as they imagined from above. Early maps of major cities often were presented as aerial views, showing streets, buildings, and indeed people from a perspective which only could be visualized by the artist. Good examples may be found in Frans Hogenberg's *Civitates Orbis Terrarum* (Cologne, 1572–1617). Seventeenth-century artists such as Wenceslaus Hollar engraved remarkable urban panoramas that showed cities from an oblique bird's-eye view.

George Catlin was another leading practitioner of aerial vantages in the early 1800s (Fig. 1-3). It was not until the mid-1800s, however, that two innovations combined, namely manned flight and photochemical imagery, to make true aerial photography possible. Since then, photography and flight have developed in myriad ways

Fig. 1-3 Bird's-eye view of Niagara Falls, Canada and the United States. George Catlin, 1827, gouache, ~45×39 cm. *Adapted from Dippie et al. (2002, p. 36).*

leading to many manned and unmanned methods for documenting the Earth from above.

1-2.1 Nineteenth Century

Louis-Jacques-Mandé Daguerre invented photography based on silver-coated copper plates in the 1830s, and this process was published by the French government in 1839 (Romer 2007). The earliest known attempt to take aerial photographs was made by Colonel Aimé Laussedat of the French Army Corps of Engineers (Wolf et al. 2014). In 1849, he experimented with kites and balloons, but was unsuccessful. The first documented aerial photograph was taken from a balloon in 1858 by Gaspard Félix Tournachon, later known as "Nadar" (Colwell 1997). He ascended in a tethered balloon to a height of several hundred meters and photographed the village of Petit Bicêtre, France. Later that same year, Laussedat again tried to use a glass-plate camera lifted by several kites (Colwell 1997), but it is uncertain if he was successful. The oldest surviving airphoto was taken by S.A. King and J.W. Black from a balloon in 1860 over Boston, Massachusetts (Jensen 2007).

Hydrogen-filled balloons were utilized for observations of enemy positions during the American Civil War (1861–65); photographs reputedly were taken, although none have survived (Jensen 2007). Meanwhile, Tournachon continued his experiments with balloons and aerial photography in France with limited success. In 1887, a German forester obtained airphotos from a balloon for the purpose of identifying and measuring stands of forest trees (Colwell 1997).

Already in the 1850s, stereophotography was practiced, and new types of glass led to modern anastigmatic camera lenses by 1890 (Zahorcak 2007). Three-color photography was first practiced by Louis Ducos du Hauron, who obtained a French patent for the method in 1868 (Šechtl and Voseček Museum of Photography 2006), and experimental color photography was conducted by F.E. Ives in the 1890s (Romer 2007).

Considerable debate and uncertainty surround the question of who was first to take aerial photographs from a kite. By some accounts, the first person was the British meteorologist E.D. Archibald, as early as 1882 (Colwell 1997). He is credited with taking kite aerial photographs in 1887 by using a small explosive charge to release the camera shutter (Hart 1982). At about the same time, the Tissandier brothers, Gaston and Albert, also conducted kite and balloon aerial photography in France (Cohen 2006). Others maintain that kite aerial photography was invented in France in 1888 by A. Batut, who built a lightweight camera using a 9×12-cm glass plate for the photographic emulsion (Beauffort and Dusariez 1995). Later he built a panoramic system that included six cameras in a hexagonal arrangement for 360° views (Tielkes 2003).

In 1890, Batut published the first book on kite aerial photography entitled *La photographie aérienne par cerf-volant*—Aerial photography by kite (Batut 1890; translated and reprinted in Beauffort and Dusariez 1995). In that same year, another Frenchman, Emile Wenz, began practicing kite aerial photography. Batut and Wenz developed a close working relationship that lasted many years. They quickly gave up the technique of attaching the camera directly to the kite frame in favor of suspension from the tether line some 10s of meters below the kite. The activities of Batut and Wenz gained considerable attention in the press, and the method moved across the Atlantic. The first kite aerial photographs were taken in the United States in 1895 (Beauffort and Dusariez 1995). Thereafter the practice of taking photographs from kites advanced rapidly with many technological innovations.

1-2.2 Twentieth Century

The early twentieth century may be considered the golden age of kite aerial photography. At the beginning of the century, kites were the most widely available means for lifting a camera into the sky. Aerial photographs had been acquired from balloons since the mid-1800s, but this was a costly and highly dangerous undertaking and, so, was not widely practiced. Meanwhile powered flight in airplanes had just begun, but it also was a risky way to take aerial photographs. Kites were the "democratic means" for obtaining pictures from above the ground. In the first decade of the twentieth century, kite aerial photography was a utilitarian method for scientific surveys, military applications, and general viewing of the Earth's surface. Its reliability and superiority over other methods were well known (Beauffort and Dusariez 1995).

In the United States, G.R. Lawrence (1869–1938) became a photographic innovator in the 1890s. He built his own large, panoramic cameras that he mounted on towers or ladders. He tried ascending in balloons, but had a near fatal accident when he fell >60 m. Thereafter, he took remarkable aerial photographs with kites. His best-known photograph was the panoramic view of *San Francisco in Ruins* taken in May 1906 a few weeks after a devastating earthquake and fire had destroyed much of the city (Fig. 1-4).

Some controversy has surrounded Lawrence's camera rig, which he called a *captive airship*. Some have interpreted this to mean he used a balloon (Beauffort and Dusariez 1995). However, strong historical documentation exists for kites as the lifting means (Baker 1989, 1997). Lawrence utilized a train with up to 17 delta-conyne kites that flew up to 2000 ft (~600 m) above the ground (Rizzo 2014). For his most famous picture, the kite train and camera were lifted from a naval ship in San Francisco Bay. The panoramic camera took photographs with a wide field of view around 160°. The remarkable quality of this photograph was due to a series of mishaps that delayed the picture until late in the day, when the combination of clouds and low sun position provided dramatic lighting of the scene.

On the same trip to California, Lawrence photographed many other locations in a similar manner, including Pacific Grove (Fig. 1-5). On the centennial of this event, we attempted to recreate Lawrence's panoramic view using modern kite aerial photography techniques. With a single, large rokkaku kite, we lifted a small digital camera rig from a position near Point Pinos, and we achieved a similar height, direction, and field of view (Fig. 1-6). At the top of his fame and fortune in kite aerial photography, Lawrence left the field in 1910 and pursued a career in aviation design.

The most daring method of this era was manned kite aerial photography undertaken by S.F. Cody and his sons

Fig. 1-4 Panoramic kite aerial photograph of San Francisco by George R. Lawrence (1906). Caption on the image reads: Photograph of San Francisco in ruins from Lawrence "captive airship" 2000 ft above San Francisco Bay overlooking waterfront. Sunset over Golden Gate. *Image adapted from the collection of panoramic photographs, U.S. Library of Congress, Digital ID: pan 6a34514.*

Fig. 1-5 Panoramic kite aerial photograph of Pacific Grove and Monterey Bay, California by G.R. Lawrence (1906). View from near Point Pinos looking toward the southeast at scene center. *Image adapted from the collection of panoramic photographs, U.S. Library of Congress, Digital ID: pan 6a34645.*

Fig. 1-6 Panoramic kite aerial photograph of Pacific Grove and Monterey Bay, California. Two wide-angle photos were stitched together to create this picture. Award-winning image by JSA and SWA, Oct. 2006.

in the early 1900s (Robinson 2003b). Cody experimented with kites and patented his "Cody kite" in 1901. He eventually succeeded in interesting the British military in man-lifting kites, and a demonstration was conducted at Whale Island, Portsmouth, England in 1903. Further trials were undertaken in 1904–05, and Cody achieved a record height of 800 m for manned kite flight. However, few others followed Cody, because of the cost and enormous risk involved.

During the period 1910–39, René Desclée became the preeminent European kite aerial photographer of his day (Beauffort and Dusariez 1995). His main subjects were the city of Tournai (Belgium) and its cathedral. Over a period of three decades he produced >100 superb aerial photographs, among the best kite aerial photography portfolios prior to World War II. Desclée's career marked the end of kite aerial photography's golden age. Rapid progress in military and commercial photography from airplanes reduced kites to a marginal role (Hart 1982), and kite aerial photography nearly became a lost art during the mid-twentieth century.

The first photograph from a powered flight was taken by L.P. Bonvillain in an airplane piloted by W. Wright in 1908 (Jensen 2007). They shot motion picture film over Camp d'Auvours near Le Mans, France. The original film is lost, but one still frame was published that same year in a French magazine. Aerial photography from manned airplanes gained prominence for military reconnaissance during World War I. Aerial cameras and photographic methods were developed rapidly, and stereo imagery came into common usage. A typical mission consisted of a pilot and photographer who flew behind enemy lines at low height and relatively slow speed. Tens of 1000s of aerial photographs were acquired by Allied and German forces, and the intelligence gained from these images had decisive importance for military operations (Colwell 1997).

At the beginning of the twentieth century, German professors H.W. Vogel and A. Miethe made improvements for three-color photography, and the Russian S.M. Prokudin-Gorsky perfected the technique for *Dreifarbenphotographie* based on triple-color gray-tone negatives (Šechtl and Voseček Museum of Photography 2006). The first near-infrared and near-ultraviolet photographs were published by R.W. Wood in 1910 (Finney 2007). Practical black-and-white infrared film was perfected and made available commercially in the late 1930s, and early types of color film were developed then.

Following World War I, civilian and commercial use of aerial photography expanded for cartography, engineering, forestry, soil studies, and other applications. Many branches of the U.S. federal government employed aerial photography beginning in the 1920s (Weems 2015) and routinely during the 1930s, including the Agricultural Adjustment Administration, Forest Service, Geological Survey, and Navy, as well as regional and local agencies such as the Tennessee Valley Authority and Chicago Planning Commission (Colwell 1997). In his landmark paper on the potential of aerial photography for such applications, and especially for studies of what he termed landscape ecology, the German geographer Carl Troll (1939) highlighted the potential of aerial photographs for viewing the landscape as a spatial and visual entity and strongly advocated their use in scientific studies.

The advent of World War II once again spurred rapid research, testing, and development of improved capabilities for aerial photography. Cameras, lenses, films, film handling, and camera mounting systems developed quickly for acquiring higher and faster aerial photography. Large-format aerial mapping cameras were built for 9-in. (23 cm) format film (Malin and Light 2007). A most important innovation was color-infrared photography designed for camouflage detection.

The global extent of this war led to ever-increasing types of terrain, climate, vegetation, urban and rural settlement, military installations, and other exotic features to confuse photointerpreters. From Finland to the South Pacific, all major combatants utilized aerial photography extensively to prosecute their military campaigns on the ground and at sea. In the end, the forces with the best airphoto reconnaissance and photointerpretation proved victorious in the war, a lesson that was taken quite seriously during the subsequent Cold War (Colwell 1997).

The art and science of aerial photography benefited substantially immediately after World War II in the United States and other countries involved in the war, as military photographers and photointerpreters returned to civilian life (Colwell 1997), and surplus photographic equipment was sold off. Many of these individuals had been drawn from professions in which aerial photography held great promise for further development, and it is not surprising that aerial photography expanded significantly in the post-war years for non-military commercial, governmental, and scientific applications.

Meanwhile, as the Cold War heated up, military aerial photography moved to yet higher and faster platforms, such as the manned U-2 and SR-71 US aircrafts. Unmanned, rocket-launched satellite photographic systems, such as *Corona* (US) and *Zenit* (Soviet), were operated from orbital altitudes during the 1960s and 1970s (Jensen 2007).

Closer to ground, renewed interest in kites began in the United States following World War II. Aeronautical engineering was applied to kites, parachutes, hang gliders, and other flying devices. For example, the *Flexi-Kite* designed and built by F. and G. Rogallo in the late 1940s was the inspiration for many modern kites as well as hang gliders and ultralight aircraft (Robinson 2003a). At the hobby level, Roy (1954) used a home-made camera mounted directly to the frame of a delta-conyne kite. The *Sutton Flowform*, a soft airfoil kite, was invented as a byproduct of experiments to create a better parachute during the 1970s (Sutton 1999). This kite has become a popular choice for lifting camera rigs.

Non-military uses of aerial photography continued to expand apace. As an example, the US *Skylab* missions in the early 1970s demonstrated the potential for manned, space-based, small-format photography of the Earth (Fig. 1-7). *Skylab* 4 was most successful; about 2000 photographs were collected of >850 features and phenomena (Wilmarth 1977). The lessons learned during *Skylab* missions formed the basis for the program of US space-shuttle photography in the 1980s and '90s. These trends culminated early in the 21st century with astronaut photography of the Earth from the *International Space Station* for scientific and environmental purposes.

SFAP began to make a slow but definite comeback during the 1970s and 80s, particularly in the United States, Japan, and western Europe. Unmanned purpose-built platforms for off-the-shelf cameras in particular were taken up again for archaeology and cultural heritage studies, and also in forestry, agriculture, vegetation studies, and geo-ecology. Since the 1990s, SFAP has become quite widely utilized for diverse applications around the world, from Novaya Zemlya (arctic Russia) to Antarctica. The late twentieth century saw rapid development in methods and popularity for unconventional manned flight, including unpowered hot-air balloons, gliders, and sailplanes, as well as powered ultralight aircraft of various types. All these platforms have been utilized for SFAP (Fig. 1-8).

Developments in computer hardware and software have encouraged the use of small-format, non-metric photography for applications hitherto reserved to large-format metric cameras, particularly photogrammetric and GIS techniques, and SFAP has expanded from mostly scientific studies into the service sector. UAS, also known commonly as drones, have become quite popular in recent years for hobby and professional uses. Both fixed-wing and multirotor platforms have undergone rapid development (Fig. 1-9). SFAP applications range from inspecting bridge structures to evaluating agricultural crop conditions.

1-3 PHOTOGRAPHY AND IMAGERY

The word *photograph* means literally "something written by light," in other words an image created from light. For the first century of its existence, photography referred exclusively to images made using the light-sensitive reaction of silver halide crystals, which undergo a chemical change when exposed to near-ultraviolet, visible, or near-infrared radiation. This photochemical change may be "developed" into a visible picture. All types of film are based on this phenomenon.

Beginning in the mid-twentieth century, however, new electronic means of creating aerial images came into existence. As electronic imagery became more common, many restricted use of the term *photograph* to those pictures exposed originally in film and developed via photochemical

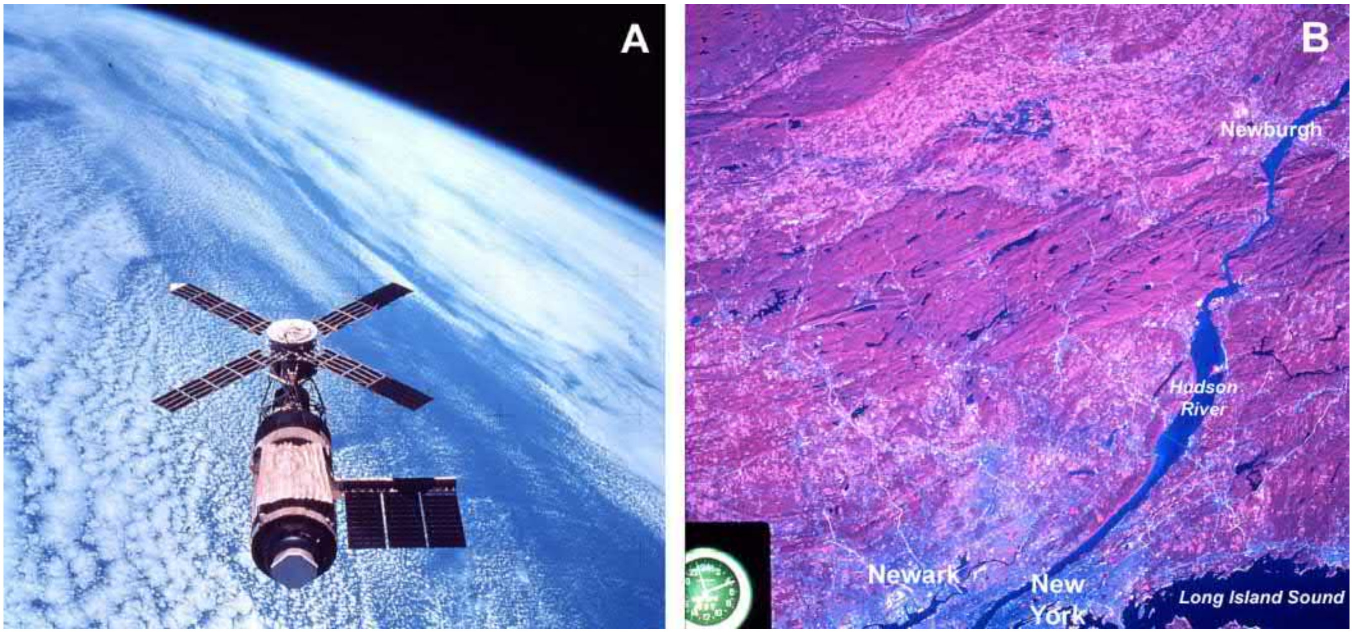

Fig. 1-7 (A) Photograph of *Skylab* in orbit around the Earth taken from the manned rendezvous module. NASA photo SL4-143-4706, January 1974. (B) Near-vertical view of New York City and surroundings. Color-infrared, 70-mm film, Hasselblad camera; active vegetation appears in red and pink colors. NASA photo SL3-87-299, August 1973. *Both images courtesy of K. Lulla, NASA Johnson Space Center.*

Fig. 1-8 Airport at the National Soaring Museum at Harris Hill, near Elmira, New York, United States. Several gliders are visible on and next to the runway. Photo taken with a compact digital camera through the open window of the copilot's seat in an unpowered, two-person glider several 100 m above the ground, an example of an unconventional platform utilized for SFAP.

Fig. 1-9 Small UAV, *DJI Phantom*, a quadcopter that has become quite popular. Note the red and green signal lights that aid the pilot in flying the drone. Flown by D. Van der Merwe.

processing. Thus, aerial imagery was classed as photographic or non-photographic; the latter included all other types of pictures made through electronic means.

Traditional film-based photographs are referred to as *analog* images, because each silver halide crystal in the film emulsion records a light level within a continuous range from pure white to pure black. The spatial resolution of a photograph is determined by the size of minute silver halide crystals. In contrast, electronic imagery is typically recorded as *digital* values, for example 0–255 (2^8) from minimum to maximum levels, for each picture element (cell or pixel) in the scene. Spatial resolution is given by pixel size (linear dimension).

In the late twentieth century, a basic distinction grew up between analog photographs exposed in film and digital images recorded electronically. Analog photographs generally had superior spatial resolution but limited spectral range—panchromatic, color visible, color infrared, etc. Digital imagery lacked the fine spatial resolution of photographs, but had a much broader spectral range and enhanced multispectral capability.

The dichotomy between analog and digital imagery faded quickly in the first decade of the 21st century for several reasons. The advantages of digital image storage, processing, enhancement, analysis, and reproduction are major factors promoting adoption by users at all levels—amateur to professional. Analog airphotos are routinely scanned and converted into digital images nowadays. Digital cameras have achieved equality with film cameras in terms of spatial resolution and geometric fidelity (Malin and Light 2007).

Film photography is rapidly becoming obsolete, in fact, except for certain artistic and technical uses, and where the lower cost of film remains attractive. For most people today, nonetheless, the word *photograph* is applied equally to images produced from film or electronic sensors. We follow this practice, in which we place primary emphasis on digital photography regardless of how the original image was recorded.

1-4 CONVENTIONAL AERIAL PHOTOGRAPHY

Since World War I, aerial photography has evolved in two directions: larger formats for accurate mapping and cartographic purposes, and smaller formats for reconnaissance usage (Warner et al. 1996). The former became standardized with large, geometrically precise cameras designed for resource mapping and military use. The science of photogrammetry developed for transforming airphotos into accurate cartographic measurements and maps (Wolf et al. 2014). Standard, analog aerial photography today is based on the following:

- Large-format film—panchromatic, color-visible, infrared, or color-infrared film that is 9 in. (23 cm) wide. This format is the largest film in production and common use nowadays.
- Large cameras—bulky cameras weighing 100 s of kg with large film magazines. Film rolls contain several hundred frames. Standard lenses are 6- or 12-in. (152- or 304-mm) focal length.
- Substantial aircraft—twin-engine airplanes are utilized to carry the large camera and heavy support equipment necessary for aerial photography. Moderate (3000 m) to high (12,000 m) altitudes are typical for airphoto missions.
- Taking photographs is usually controlled by computer programming in combination with a global navigation satellite system (GNSS) such as GPS to acquire nadir (vertical) shots in a predetermined grid pattern that provides complete stereoscopic coverage of the mapping area.

Large-format aerial photography is expensive—$10s to $100s of thousands to acquire airphoto coverage. This cost may be justified for major engineering projects and extensive regional mapping of the type often undertaken by provincial or national governments—soil survey, environmental monitoring, resource evaluation, property assessment and taxation, topographic mapping, and basic cartography.

Analog aerial photography is mature with many cameras, films, airplanes, and other equipment readily available worldwide. Large-format digital cameras are relatively new, and several types of optical and sensor systems are in use. For example, the *Leica ADS100* airborne digital sensor is a linear array with a swath width of 20,000 pixels in red, green, blue, and near-infrared (RGBN) with forward, nadir, and backward capability (Ribeiro 2013). The *Z/I DMC II 250* camera is another example, which is based on a RGBN 250 MB detector array (GISCafé 2011). Large-format digital cameras, thus, have achieved technical parity with analog cameras, and large-format digital cameras now dominate the market for conventional aerial photography.

1-5 SMALL-FORMAT AERIAL PHOTOGRAPHY

SFAP, in contrast, employs much smaller lightweight cameras—previously with 35- or 70-mm film, and now predominantly with digital sensors. For the most part, these are popular cameras designed for handheld or tripod use by amateur and professional photographers. Such cameras lack the geometric fidelity and exceptional spatial resolution of aerial mapping cameras. However, the case for SFAP depends on cost and accessibility.

- Low cost—SFAP cameras are relatively inexpensive, few $100 to several $1000, compared with large-format aerial cameras at several $100,000. The cost of SFAP platforms ranges from only a few $100 for kites to tens of $1000 for larger and more sophisticated aircraft. These costs put SFAP within the financial means for many individuals and organizations that could otherwise not afford to acquire conventional aerial photography suitable for their needs.
- Feasibility—low-height, large-scale imagery is possible with various manned or unmanned platforms in diverse circumstances. SFAP may be acquired in situations that would be impractical, illegal, risky, or impossible for operating larger aircraft.
- SFAP has high portability, rapid field setup and use, and limited need for highly trained personnel, all of which makes this means for aerial photography logistically possible for many applications.

Low-cost availability of cameras and lifting platforms is a combination that renders SFAP desirable for many people and organizations (Malin and Light 2007). SFAP is self-made remote sensing—system design, technical implementation, and image analysis may be in the hands of a single person, granting utmost flexibility and specialization.

Manned platforms include single-engine airplanes, helicopters, autogyros, ultralight aircraft, hot-air balloons, large blimps, and sailplanes. These are necessarily more expensive and require specialized pilot training in contrast to most unmanned platforms, such as balloons, blimps, kites, model airplanes, and unmanned aerial vehicles (UAVs). Within the field of aerial photography, much innovation is taking place nowadays with all types of platforms and imaging equipment.

As a specialty within remote sensing, SFAP fills a niche of observational scale, resolution, and height between the ground and conventional aerial photography or satellite imagery—a range that is particularly valuable for detailed site investigations of environmental conditions at the Earth's surface. SFAP is employed in various applications ranging from geoscience, to wildlife habitat monitoring, to archaeology, to crime-scene investigation, to real-estate development.

Within the past decade, commercial satellite imagery of the Earth has achieved sub-half-meter, panchromatic, spatial resolution, for example *WorldView* and *GeoEye* (Satellite Imaging 2017). Such resolution may be possible in principle; however, satellite systems must look through atmospheric haze 100 s of km thick, which degrades image quality. Operating close to the surface, SFAP provides cm-scale, multispectral imagery with insignificant atmospheric effects.

As an example, consider mapping vegetation at Kushiro wetland on Hokkaido, northern Japan. Aerial photography and expensive satellite imagery are hampered at Kushiro by persistent sea fog derived from cold offshore currents during the summer growing season when vegetation is active. Miyamoto et al. (2004) utilized two tethered helium balloons to acquire vertical airphotos of a study site in Akanuma marsh. A photomosaic was produced and used to create a detailed map of vegetation. The balloon system allowed the investigators to take quick advantage of brief fog-free conditions to acquire useful imagery. This example demonstrates the spatial, temporal, and cost advantages of SFAP to succeed in a situation where other remote-sensing techniques did not prove capable.

1-6 SUMMARY

For >150 years, aerial photography has provided the means to see the Earth from a bird's-eye perspective. During its first half-century of development, aerial photography was little used because of high cost and risk. Perhaps the most impressive early pictures were the panoramic photographs taken from kites by G.R. Lawrence in the first decade of the twentieth century. With the introduction of powered flight, aerial photography expanded tremendously throughout the 1900s based on many technological inventions for various imaging devices plus the airborne and space-based platforms to carry those devices. These innovations were accelerated by military needs, particularly during World Wars I and II as well as the Cold War.

Since World War I, aerial photography evolved in two directions—larger formats for accurate mapping and smaller formats for reconnaissance usage. During the last 30 years, technical advances in electronic devices and desktop computing have encouraged the use of SFAP with increasingly sophisticated analytical methods. Various types of electronic sensors and digital imagery progressively have taken the place of analog film photography in recent decades.

This book emphasizes SFAP based on light-weight and inexpensive digital and 35- or 70-mm film format cameras operated from platforms at relatively low height (<300 m). Photographs acquired by such means possess large scale and exceptionally high spatial resolution that portray ground features in surprising detail with minimal atmospheric effects. Within the field of remote sensing, SFAP has established a niche that bridges the scale and resolution gap between ground observations and conventional large-format airphotos or satellite images.

Both manned and unmanned platforms are utilized for SFAP. The former includes fixed-wing airplanes, helicopters, autogyros, ultralights, gliders and sailplanes, hot-air balloons, and large blimps. Unmanned platforms are balloons, blimps, kites, and UASs (drones) of various kinds. The advantages of SFAP are based primarily on lower cost and greater accessibility compared with conventional large-format aerial photography or other means of remote sensing. The combination of inexpensive cameras and lifting platforms renders SFAP desirable and feasible for many people and organizations and is particularly valuable for detailed site investigations of environmental conditions and human influence at the Earth's surface.