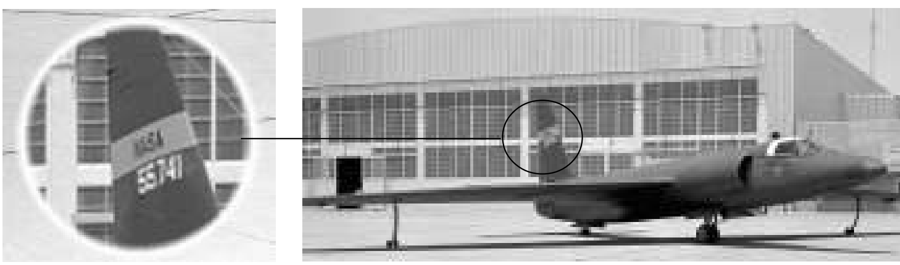
Electromagnetic Surveillance

9

Aerial



1. Introduction

Aerial surveillance is not technically an electromagnetic technology, but rather a category that encompasses any surveillance technology that can be used from above the Earth's surface. However, since about 90% of the surveillance technologies currently in use for aerial purposes rely on electromagnetic phenomena, it was appropriate to include this chapter in this section. The Aerial Surveillance chapter extends many aspects of the Infrared and Visual Surveillance chapters and cross-referencing all three (or reading the other two first) is recommended.

Aerial surveillance began when humans climbed trees and cliffs to get a better view of food, shelter, fuel sources, predators, and the activities of other people. When great fleets of ships began to sail the seas, telescopes were used from atop crow's nests to site lands and other ships. Not long after humans first flew in hot air balloons, they realized they could use telescopes, binoculars, and photographic equipment from better vantage points, to extend their ability to see and record from unprecedented heights and soon they began developing devices especially made for use on planes, helicopters and spacecraft.

When U-2 pilot Francis Gary Powers was shot down on a spying mission over Soviet territory in 1960, the United States hastily applied NASA markings to a U-2 aircraft (enlargement), issued coverup news releases that the plane was a stray weather research craft, and invited the press to view and photograph the plane. The Soviet Premier later completely disproved the story by presenting the pilot, the recovered wreckage, and the incriminating surveillance tape. The history of spy planes is described further on page 9-20. [NASA/ Goddard 6 May 1960 news photo, released.]

Aerial surveillance is one of the most important political and scientific developments in our history. Viewing our solar system from above has changed our perception of ourselves and has provided dramatic new ways to explore every corner of the Earth and its people. In the context of aerial surveillance, flight has stimulated the development of faster, higher-resolution imaging technologies and, in the last few decades, aerial photography has became routine.

Most aerial surveillance is intended to surveil surface features and vessels, but aircraft are sometimes also used to visually surveil marine environments and to use acoustic devices such as towed sonar. Aerial surveillance is not a specific technology, bur rather a means of deploying a variety of technologies with applications sufficiently diverse and important to warrant a separate chapter.

Taking still or moving photos from great heights or at great speeds is a difficult technological challenge that scientists have tackled with a remarkable degree of success. Many aerial imaging devices are being adapted for space surveillance as well. Orbiting satellites and space probes provide not only a view of near and distant parts of the universe, but also information on how the universe began.

The Shift in Power

The capability to unobtrusively observe other people's business is power. With that power comes responsibility, whether or not it is mandated by law. Until the mid-1990s, the power of surveillance was mainly in the hands of local and federal government agents and, to a lesser extent, private detectives. This is no longer true. It is now possible to purchase an aerial picture of your neighbor's backyard for less than $20 that is sufficiently detailed for you to distinguish between a large dog house and a small hot tub. You can purchase an equally detailed picture of government buildings in foreign nations, a refugee tanker, a controversial logging site, or the production yard of your chief business competitor on the other side of town. Sources of these images are discussed later in this chapter.

Technology changes faster than laws can be drafted to protect the vulnerable. Currently, private citizens don't need any special permission to purchase or own most types of images. You can download them off the Internet. Satellites and network distribution channels have put access to information in the hands of ordinary people in most of the democratic developed nations. More than half the American populace now has access to the Net. While military entities are still the only ones who can get the highest resolution imagery, sometimes accessible in realtime, the gap between the information available to civilians and those in traditional positions of power (e.g., national defense) has narrowed dramatically. Now this shift of access is putting a great deal of power and responsibility in the hands of a largely unregulated public which, in free societies, is bound to result in some unethical and unscrupulous behavior on the part of a percentage of individuals willing or eager to take advantage of others.

To resolve these issues we must either evolve as a society to take more personal responsibility to respect the rights of others, or we must give up a portion of our freedoms and more stringently regulate access to and use of the new forms of personal and business information that are becoming available. Either way, society must change and adapt, because it may only be five years before satellites and unpiloted air vehicles can recognize and track not just backyard hot tubs, but individual people, without their knowledge. It might only be a decade before every move you make can be recorded in realtime by satellites and intelligent software. (See the chapter on Visual Surveillance for significant improvements in software that allow a video camera to select and recognize individual faces on a crowd and track their movements automatically.)

Aerial Photography in the Context of Progress

The technology to surveil from higher vantage points has evolved dramatically since our ancestral days, but before we call it progress, it is prudent to note that our motives don't seem to have changed over the centuries. It is sobering to acknowledge that most aerial surveillance is used to monitor predators (primarily other humans), food (esp. crops and herds), shelter and fuel (esp. oil and forests), and the activities of other people, essentially the same reasons we spied from clifftops 100,000 years ago.

This chapter surveys a variety of interesting airborne and spaceborne aerial technologies, including highlights in the history of the technology, applications, and device deployment. The basic physics of the specific spectra that are used in aerial surveillance are described in more detail in other chapters.

2. Types and Variations

Aircraft and spacecraft can be loosely differentiated as those which fly through the Earth's atmosphere and those which fly primarily in space (first passing through the Earth's atmosphere). Some, like the NASA space shuttles, are designed to travel in both air and space. Some craft are dependent on wind or 'loft' to stay airborne (parachutes, gliders, kites), some on lighter-than-air gases like hydrogen and helium, and some are self-powered (planes, ultralights, rockets). Most spacecraft are launched through the atmosphere to a distance above Earth where they can achieve a more-or-less stable orbit for a period of time (usually a few years), while some are launched far into space, where they can travel for long distances until they come within the gravitational influence of other bodies.

In the early days of the air travel industry, balloons and dirigibles were known as airships and fixed wing craft were commonly known as 'flying machines.' For a few decades this terminology was sufficient to describe most of the vessels that were developed and used for civilian and military purposes. In the last 20 years or so, it has become more difficult to describe the great variety of airborne craft that are used to view the world. Aircraft and the more recent spacecraft come in many shapes and sizes. Recently, we've added radio-controlled planes and helicopters, rocket ships, shuttle craft, autonomous and remote-controlled air vessels, and orbiting space stations and satellites. All of these craft, small and large, fast and slow, can be used in one way or another for surveillance. Their prices range from about $500 to hundreds of millions of dollars. Most of them can be fitted with a variety of passive and active remote-sensing technologies, including radar, infrared, ultraviolet, radio, photographic, and tape recording devices.

2.a. General Categories of Aerial Surveillance Craft

The type of sensing technologies that can be used with a particular type of airborne craft will depend on the size and weight of the craft, its visibility, the flying or orbiting altitude, cost, maneuverability, and ability to carry equipment. Some of the basic categories of air- and spaceborne vessels that can be used to observe and record include wind-lofted, light-than-air, and self-powered craft.

Wind-Lofted Craft

Typical wind-powered aerial craft include parachutes, kites, and gliders. These craft are dependent on differences in air pressure between their upper and lower surfaces and, in the case of parachutes and some gliders, may need to be towed, dropped, or launched to have sufficient loft.

Parachutes, kites, and gliders have all been used at various times to carry surveillance devices or to allow people to surveil territory from above. Sometimes radio gear is dropped in by parachute for scientific and military surveillance missions. Here, a U.S. Marine Corps captain pulls in a parachute in a Kuwait drop zone as part of Exercise Eager Mace 98. Capt. Rick Uribe dropped 1,250 feet from a cargo plane in 1997 as part of a joint training exercise with U.S. and Kuwaiti armed forces. [U.S. DoD 1998 news photo by Mike Wentzel, released.]

The practical weight limit for most wind-dependent craft is a few hundred pounds, and their steering capabilities are often limited as well. Yet they still have characteristics that are important in surveillance. They are quiet and easier to transport than larger, heavier craft and can be quite inexpensive. Helmets for use with parachutes and gliders can now be purchased with mounting brackets for cameras (skydivers often use these) and some even have small video cameras built in. It is also possible to get harnesses that allow a camera to be securely fastened to a person's chest. Smaller autonomous or remote-controlled versions of wind-dependent craft can be equipped with remote-controlled cameras or cameras designed to take pictures at predetermined intervals

Lighter-Than-Air Craft

Air is made of a variety of elements and the lighter ones tend to rise to the top. Hence, the air on mountain tops is 'thinner' than at lower altitudes; in other words, there is less oxygen as you move up away from the Earth. Mountain climbers, high-altitude flyers, and skydivers need oxygen supplementation or they risk confusion, brain damage, or cerebral edema. The characteristic of lighter elements rising makes it possible to launch hot-air balloons and dirigibles ('steerables') that contain lighter-than-air hydrogen or, more commonly, helium (which is less flammable). There are both rigid and nonrigid dirigibles.

Balloons and dirigibles have been used for surveillance since the earliest flights and even now, some are being constructed to carry cameras and radar systems. Their carrying-capacity is related to the size of the vessel but can be many hundreds of pounds, indeed, in the past, dirigibles were used for commercial travel.

Self-Powered Craft

There are many types of self-powered aircraft, ranging from a few ounces to hundreds of tons, so it is difficult to make generalizations about their carrying capacity or suitability for specific types of surveillance. These versatile devices, which comprise the majority used for aerial surveillance, include

- remote-controlled planes, helicopters, and air vessels
- autonomous, unpiloted air vessels (autonomous UAVs)
- piloted aircraft, helicopters, and space shuttles (return trip)

In addition to the basic categories of Earth-based aerial surveillance craft, there are also a number of spacecraft and projectiles that are used to mount surveillance devices.

Launched Probes and Orbital Craft

Looking beyond our current frontiers is an important aspect of surveillance. During the seafaring years, one would climb a mast to the Crow's Nest and surveil with a telescope. However primitive it might be, the telescope was essential to survival; finding land after a two-month journey on the sea could mean the difference between life and death. It could also reveal the temptation of great wealth from the exploitation of new and abundant lands. Now that all the land on the planet has been discovered, space is seen as the next frontier. Astronomers now look to the heavens for new understanding of our universe and what we learn in the process may mean the difference between life and death for the entire human race in a future where the increasing population continues to consume the planet's finite resources. If we can find water, land, medicine, and other resources outside of Earth's boundaries, it may contribute to our survival as well as our knowledge. Even in the 1960s, when the population was only half of what it is now, space pioneers felt a sense of urgency when the Russian Federation was the first to publicly put a satellite into orbit. The U.S. immediately responded and the resulting developments came to be known as the "Space Race."

Launched space probes or orbital craft include space shuttles (partially self-powered), rockets, satellites, and specialized planetary and interplanetary space probes. Air and spaceborne telescopes also fall within the category of aerial surveillance.

Projectiles

Almost any sort of projectile that travels a reasonable distance in the air can be equipped with a small camera. Wireless pinhole cameras are now so tiny that it's even reasonable to consider attaching one to the shaft of an arrow. Other projectiles that have been outfitted with surveillance devices include missiles, rockets, and fireworks (which are essentially a type of rocket designed to 'self-destruct').

2.b. Reconnaissance and Surveillance

Reconnaissance is a preliminary or exploratory survey. It accounts for a large proportion of military aerial surveillance. Assessing a situation before sending in troops or weapons is considered an important aspect of military strategy.

Military Reconnaissance

Aerial reconnaissance was already in use soon after the airplane and airships were invented and played an important part in World War I, but the technology itself was crude and as yet undeveloped. For the most part, military aerial reconnaissance in the modern sense came of age during World War II.

Aviation reconnaissance was subdivided during World War II into two general categories:

strategic long-range operations

tactical visual and photographic missions (installation recording, target imaging, and mapping, etc.) for the Tactical Air Force, the Tactical Air Division, and associated ground forces

Military reconnaissance holds a prominent role in our present society. Considerable funding and personnel are involved in maintaining early warning systems and in monitoring global activities. Military applications of technologies such as satellite sensing and Global Positioning Systems (GPSs) often are funded by military interests before they came into use as civilian commercial products. As a consequence of this dynamic, many of the examples in this chapter are of military aerial reconnaissance systems and activities.

Commercial and Law Enforcement Surveillance

A variety of aerial craft are used in civilian and aviation surveillance including light planes, helicopters, and remote-controlled aircraft. TV producers looking for 'reality programming' for their broadcasts often travel along with law enforcement agents and news crews, sometimes supplying the aircraft and sometimes using those available. Military operations involve a great number of different aerial craft including planes, satellites, dirigibles, gliders, and unpiloted aerial vehicles. Environmentalists often track plant and animal resources and monitor the legal and responsible use of these resources using aerial craft and photos.

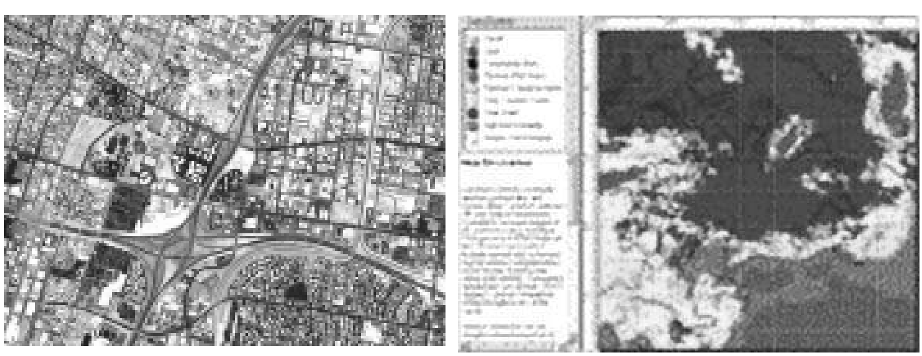
Local law enforcement agents now also make regular use of aircraft to monitor fugitives, accidents, natural disasters, and crime scenes. Individuals who run from crime scenes or speed to avoid arrest have a far more difficult time evading arrest when a helicopter or other aerial surveillance craft is radioing his or her position to police on the ground.

3. Context

High-resolution aerial imaging as a technology is less than forty years old. At first the images were crude, costly, and classified. When aerial images were expensive and low-resolution, they were primarily sold to researchers, large corporations, and military analysts. Even a few years ago, it was not unusual for an image to cost over $4,000. Now that high-resolution satellite images can be purchased for under $25 per square mile, a dramatic shift is occurring in the applications for which these images are used and the people who use them.

Scientific Inquiry

Aerial surveillance technologies, especially those related to imagery, are useful for almost every type of scientific inquiry including ecosystems monitoring (weather, pollution, climate change), geology, archaeology, wildlife monitoring, etc.

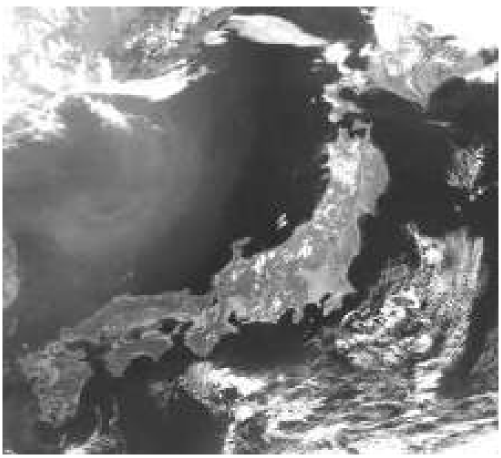


Left: A portion of an image of New Mexico from the Department of Energy's R&D Multispectral Thermal Imager (MTI) satellite launched March 2000. The project was led by Sandia Labs. It senses 3 visible and 12 infrared spectral bands, collects pictures of volunteer ground sites, and compares the images with other data. Right: A sample fish map generated from satellite data. [Sandia news photo, released; OrbImage ©2000 news photo, www.orbimage.com, used as per copyright guidelines.]

The data from multispectral imaging satellites can potentially be used for hazardous waste site characterization, climate research, and treaty monitoring applications. Fish maps can be used for charting fish stocks and migration patterns and managing marine resources.

Government Applications

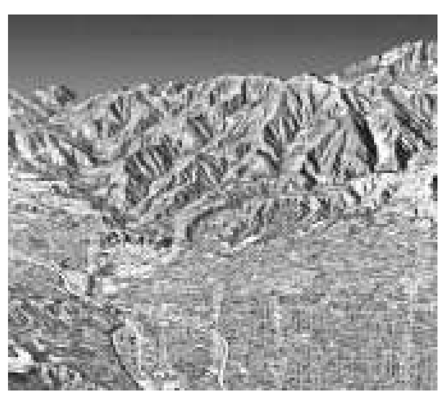
Aerial surveillance is used in many government and commercial activities, including national defense, local law enforcement, disaster assessment and relief, community planning, building permit issuance and compliance monitoring, resource exploration, wildlife monitoring, property tax assessment, border patrol, search and rescue, camouflage detection, treaty negotiation and verification.



Left: The islands of Japan, 9 May 1998. Right: Egypt, Saudi Arabia and the Middle East, 3 April 1998. [OrbImage ©1998, www.orbimage.com, used as per copyright instructions.]

Commercial Applications

There are thousands of ways in which aerial surveillance, particularly satellite images, are useful in commercial applications.



Left: A NASA aerial photograph of the *Stennis Visitors Center and Administrative Complex.* Stennis is a lead center for commercial remote sensing. Right: A composite aerial perspective radar photo of Pasadena, Ca., with a Landsat image overlay. The detail is supplied by USGS digital photography. [NASA 1990 news photo, NASA/JPL 2000 news photo.]

Commercial applications include, but are not limited to, weather reporting, property value and damage assessment, marketing and promotion, travel planning, contractor planning, city planning, architectural planning, investigative journalism, ranching and livestock monitoring, surveying, fish finding, crop yield assessment, forestry, firefighting, and managing livestock on large ranches.

Detailed weather images, which are just one kind of image, are of commercial interest to newscasters, boaters, commercial fishers, firefighters, production companies, homeowners and businesses in the path of the hurricane, insurance adjusters, and others.

Nonprofit and Public Welfare Applications

Charitable, nonprofit, and other public welfare organizations use aerial imagery for environmental, pollution, human rights, refugee, public safety, and public resources monitoring.

Personal Applications

Satellite imagery is now inexpensive enough to allow people to purchase photos of home and hearth, hobby farms, and land investments. They can also be useful for trip planning, genealogical publications, and home-schooling.

4. Origins and Evolution

While people have undoubtedly been spying from trees and cliffs for tens of thousands of years, the history of aerial surveillance technology is very recent, less than 300 years old. Most of the significant inventions, air vehicles, portable cameras, and practical telescopes, didn't emerge until the late 1700s and early 1800s. Dramatic improvements did not come about until the mid-20th century, and satellite imagery is less than 40 years old. This section charts some of the significant inventions and inter-relations between flight and photography, the two most important technological aspects of modern aerial surveillance.*

Aerial surveillance involves the evolution of two main aspects of technology, devices to help us fly and devices to help us record images.

The Late 1700s - Pioneer Aviation and Emerging Photography

The first attempts to put cargo into the air probably started with birds and kites thousands of years ago. The first successful attempts to put people in the air were with kites and balloons; the first significant hot air balloon flight took place in France on 5 June 1783. Later that year, on 21st November 1783, humans traveled over Paris in a balloon constructed by the brothers Joseph and Etienne Montgolfier. It reached a height of almost 6,000 feet and traveled nearly a mile. This achievement was sufficient to inspire inventors worldwide to seek additional ways to put people in the air. As a result, in the next several decades, many experimental flying technologies were developed, most of which still exist in one form or another today.

The other key aspect of aerial surveillance, photography, was also emerging. Pinhole cameras (camera obscura) and sun paintings (heliotropes) were being developed around this time.*

The Early 1800s - Pioneer Photography and Aerial Photography

Aerial photography appears to have begun almost at the same time as photography itself. In fact, the first acknowledged photograph by Joseph Nicéphore Niépce (1765-1833), taken in 1826, was shot from above the ground, looking down over the roof of an outbuilding.

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*Earlier examples of *camera obscura* (pinhole cameras) lacked the ability to record or 'fix' the images and so are not covered here.

This historic photograph, by J. N. Niépce, was shot from an upper story window, providing an elevated vantage point of his estate. One of the most significant limitations of early photography was that exposures like this took many hours. [Copy print of the original 1826 heliograph, from the Permanent Exhibitions at the Harry Ransom Center at the University of Texas, Austin, copyright expired by date.]

As soon as cameras were available, inventors and entrepreneurs began trying to rig them to trees, cliffs, birds, masts, kites, and balloons. Many of these early attempts at aerial photography were unsuccessful and occasionally disastrous, yet they suggest that the desire to obtain images from the air is a basic impulse, waiting only for the technology to provide a better way to take advantage of the opportunities.

The development of equipment for taking aerial pictures fueled the invention of timers, image and camera stabilizers, automatic shutters, smaller cameras, and automatic film advance mechanisms. The development of photography is intrinsically linked with the human impulse to witness and record unusual scenes, events, or covert activities. Many of the most sophisticated cameras are those which have been developed for use on reconnaissance planes that fly very high and very fast, with the advanced technology gradually filtering down into consumer products.

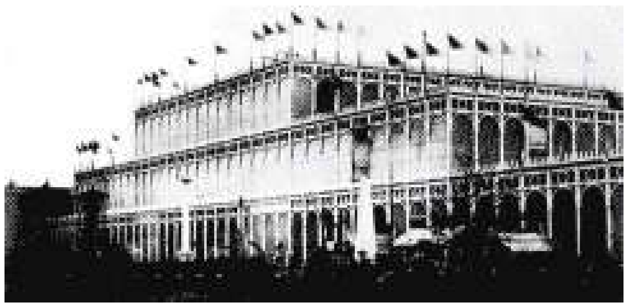
Early photographs weren't recorded on paper. The earliest photographic negatives were imaged on materials that were difficult to handle and had to be manually placed and removed. Many of the earliest pictures were temporary, and the permanent ones were usually printed on ceramic or metal, which made them durable but also somewhat awkward and expensive to process. These early systems were too cumbersome for most surveillance tasks.

Louis Jacques Mandé Daguerre (1789-1851) made a significant contribution to photography by developing a process for imaging on a copper plate so that reproductions could be made commercially, resulting in the *daguerreotype*. This was an important milestone in photography, but there were still some hurdles to overcome before photography became an intrinsic tool of surveillance. At the time of Daguerre, exposures could last almost an hour, which was faster than Niépce's process, but still too long for recording normal human activities or anything else that moved.

In spite of its limitations, the world was quick to embrace the new technology. In the mid-1800s, daguerreotypes were introduced to Japan through trade with The Netherlands.

Gradually, film negatives and paper prints were developed and automatic features including film advance, shutters, and focusing features were added to cameras to at least partially automate photography. The feature film industry, in which long reels and animated frames were used, also provided key technology for aerial photography. With planes flying at high speeds, fast frame rates and long reels of film were needed, and the special problems of stability, registration, and drag on the reels had to be solved. At the same time, inventors were experimenting with different types of film, including those which were more sensitive in the infrared spectrum. (For further details on the history of photography, see the history sections of the Infrared and Visual Surveillance chapters, as well.)

The Mid-1800s - Rise of Photography and Airships



The Crystal Palace, built for the 1851 Great Exhibition, was photographed in detail by pioneer photographer Philip Henry Delamotte, thus initiating a new age of documentary photography. Aerial surveillance photography has become an important aspect of modern documentary news photography and is also increasingly used to monitor vehicular traffic. [Photo by Philip Henry Delamotte, public domain by date.]

In the mid-1850s, the commercial value of photography was acknowledged through some of the first photographic exhibitions, and photography for documentary use was pioneered by Philip Henry Delamotte (1820-1889), who meticulously recorded the Crystal Palace in London, England. Newscasters, investigative journalists, and political documentors now rely heavily on aerial photography.

In the mid-1850s another important aspect of the aerial photography industry was being introduced. *Aerostats*, which included balloons and airships, were getting a lot of attention from inventors and the public. Henri Giffard (1825-1882) created a coal-gas-powered airship that is remembered for achieving the first powered, controlled flight in 1852. *Dirigibles* (literally 'steerables') were distinguished from balloons by their propulsion and control systems, allowing them to be navigated horizontally without dependence on the direction of the wind.

In the late 1850s, the idea of transatlantic flight had taken hold of the imaginations of a number of pioneer balloonists, including John Wise, who oversaw the construction of a huge balloon with a passenger gondola that he optimistically christened the Atlantic. Unfortunately, on an inaugural flight in 1859, the balloon encountered a storm and the balloonists were treated to the discomfort and indignity of landing in an elm grove, much to their disappointment. They did succeed, however, in establishing a long-distance record of 809 miles that remained unbroken for half a century.

An Official Balloon Reconnaissance Corps

In April 1861, Thaddeus S. C. Lowe (1832-1913) touched down in South Carolina after traveling more than 500 miles in a balloon. Like Wise, Lowe's original intention was to establish transatlantic balloon travel, but political unrest caused him to change his priorities and he began to promote the idea of an aerial reconnaissance corps to support the northern armies. In June, he demonstrated to President Lincoln that a balloon could be used for aerial reconnaissance by going aloft and sending a message through a War Department telegraph system mounted in the balloon to the ground through a tethered cable. He also took along a camera and shot one of the first aerial photographs. The *Balloon Corps* was established by Lincoln as a civilian corps under the Union Bureau of Topographical Engineers and Lowe served as the head of the Union Army aeronautics service during the American Civil War.

Lowe wasn't the only ballooning pioneer to envision a military air corps. John LaMountain, who had accompanied John Wise on his historic 1859 trip, was also promoting the idea of using balloons to surveil enemy troops from the air. While Lowe got the early favor of the politicians, LaMountain nevertheless made reconnaissance trips later in 1861, surveying Confederate troops near Newmarket Bridge, Virginia, thus being the first to actually deliver enemy intelligence obtained from an airborne balloon.

Left: Thaddeus S. Lowe viewing the battle from the aerial balloon, the "Intrepid," on 1 May 1862 during the Civil War Peninsular Campaign. Right: The Federal observation balloon being inflated during the period of the Battle of Fair Oaks, Virginia, 1862. [Library of Congress compiled by Milhollen and Mugridge, photos public domain by date.]

Concerned about the northern forces' Balloon Corps, Capt. John Randolph Bryan of the Confederate Army volunteered to supervise the construction and deployment of a surveillance balloon. In April 1862, he was launched over Yorktown, Virginia in a hot air balloon in the Peninsular Campaign. He communicated with ground forces through semaphore. When safely out of shooting range of Union troops, he created a map of Union positions. The same month, General Fitz John Porter was borne into enemy territory in a balloon that strayed, but managed to return to base. The die had been cast and further balloons followed, with the popular story being that southern belles donated their finest silk dresses for the making of balloons for the War effort. In actual fact, it is more likely that the silk balloons were constructed out of silk dress fabric than of actual silk dresses.

Commercialization

Many of the balloonists offering their services to the Civil War effort had begun with ideas of establishing commercial balloon travel services, particularly trips across the Atlantic. Once the War ended, commercialization efforts were renewed. By 1874, passenger balloon flights were being offered over San Francisco, and within thirty years, the Thomas A. Edison, Inc. company was creating animated aerial moving pictures from on board balloons.

The Late-1800s - New Technologies and Chemistries

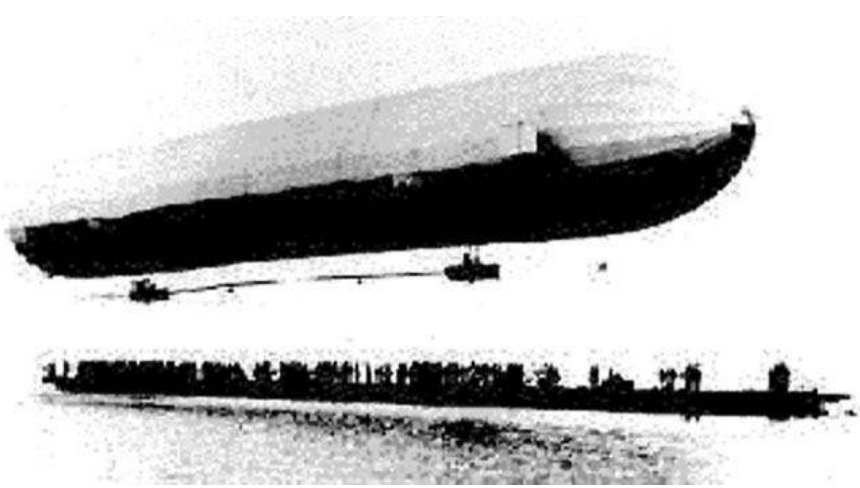
Toward the end of the century, helium was discovered. It was lighter than air and without the explosive nature of hydrogen, so that it was eventually preferred over hydrogen for filling aerial balloons (especially following the tragic explosion of the Hindenburg in 1937).

In 1894, Octave Chanute (1832-1910), an American immigrant from France, contributed to the acceptance of flying as a field by publishing “Progress in Flying Machines,” a history of human attempts at flight up to that time. Over the next several years, Chanute applied his engineering knowledge to the design of gliders and later served as a flight consultant to the famous Wright brothers.

In 1899 in America, Orville and Wilbur Wright were experimenting with kites, with the goal of putting a man in the air while overseas, in Europe, a different type of craft was being developed by German entrepreneur and intelligence agent Graf (Count) von Zeppelin.

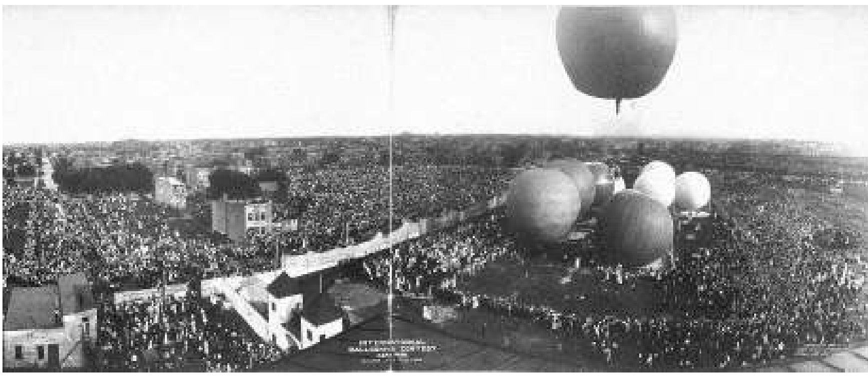
The 1900s - The New Age of Flight

The invention of dirigibles and balloons provided new ways for people to view the world from aloft, even if it wasn’t for any significant distance or period of time.



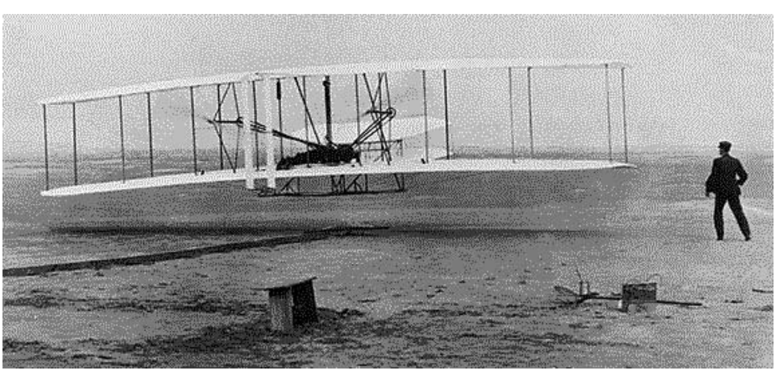
Top left: Graf von Zeppelin in 1866, about four years before he led a reconnaissance mission for Germany in the war against France. By 1874 he was recording ideas for airship design. Top right: Graf von Zeppelin in the early 1900s, sporting simple surveillance equipment, a set of miniature binoculars. Bottom: The LZ1 Zeppelin at Lake Constance, created and constructed by Graf von Zeppelin and Theodor Kober. [Zeppelin Museum Friedrichshafen photos, public domain by date.]

At the turn of the century Ferdinand Adolf August Heinrich Graf von Zeppelin (1838-1917) was perfecting his Zeppelin airship. He was seeking ways to improve the technology to make flying more efficient and comfortable. The first flight of the Graf Zeppelin in south Germany on 2 July 1900 extended to almost four miles. In 1908, von Zeppelin established the Zeppelin Foundation for the development of aerial navigation and airships. The Zeppelin airship was put into service as a commercial craft in 1910.



Ballooning captured the popular imagination in the early 1900s and soon competitions were being held. This picture shows the International Ballooning Contest held at Aero Park, Chicago, on 4 July 1908, with thousands of spectators enjoying the sight. Since there were no highrises from which this photo could have been taken, it's probably reasonable to assume that it may be an aerial photograph taken from a nearby balloon. [Library of Congress, George R. Lawrence Company, public domain by date.]

The inventive Wright brothers went from building kites to creating a new form of fixed-wing flying machine. The main stumbling block to aerial photography at this time was not so much the ability to get into the air, which was improving by the day, but rather the bulky nature of cameras at the time. They were not only awkward to handle, but were limited in their applications by long exposure times that required the camera (and the subject) to remain completely still. As cameras improved, however, so did aeronautical science.

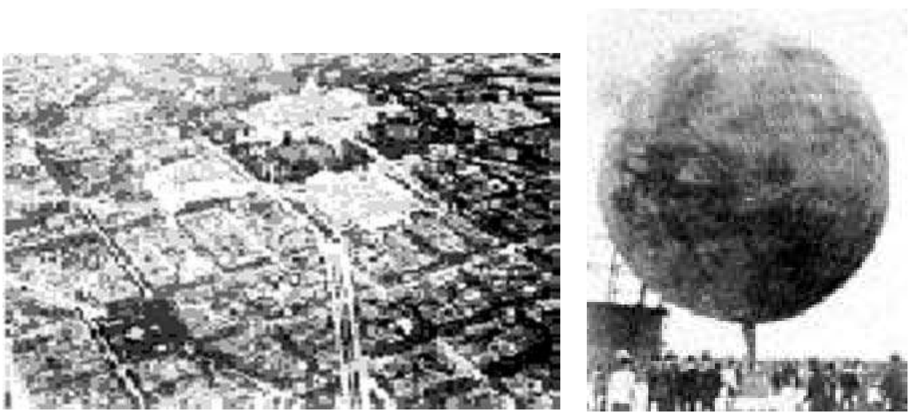


The historic first piloted airplane to sustain flight. It was flown by Orville Wright and later that day in a longer flight by his brother, Wilbur Wright, 17 Dec. 1903. The plane had a wing span of just over 12 meters and was powered by a 12-horsepower gasoline engine. [The Smithsonian National Air and Space Museum collection. The original negative was imaged on glass, public domain by date.]

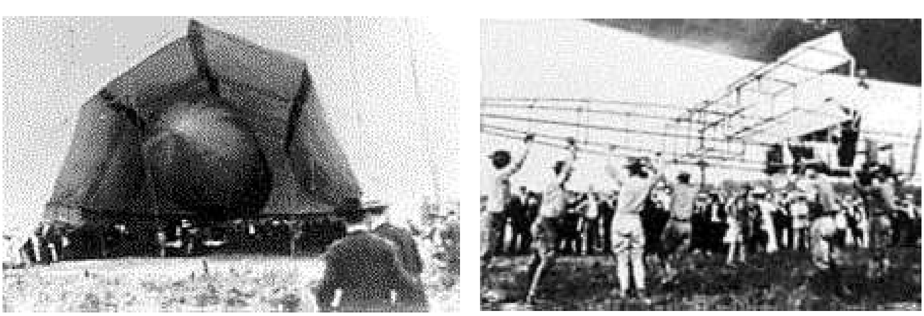
On 17 December 1903, Orville Wright piloted the first sustained powered airplane flight from Kitty Hawk, North Carolina. Within two years the brothers had improved on the technology enough to develop a practical model. Meanwhile others continued to research balloon flight in parallel with the development of planes.

The armed forces were now giving the new aerostats and flying machines some serious consideration as tactical military vessels. Thomas Scott Baldwin, an associate of the Wright brothers and Alexander Graham Bell, was appointed by the U.S. Army to oversee the construction of balloons and dirigibles for military use, beginning with an airship similar to the Zeppelin, in 1908.

R. F. Collier, of Collier's Magazine, purchased a Wright brothers plane in 1910, which he turned around and offered to the U.S. Army. The plane was demonstrated for possible use as a courier craft for travel among military stations.



A pioneer aerial image, this photo of Washington, D.C. (left), was apparently taken from a hydrogen balloon on 4 June 1907, possibly from the U.S. Army balloon, or one like it, that is depicted on the right. [U.S. Army historic archives, public domain.]

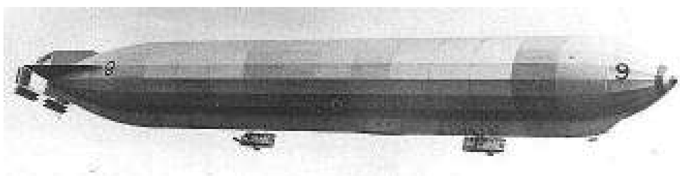


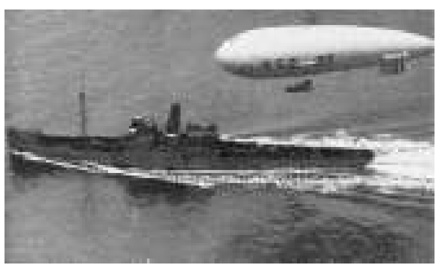
U.S. Signal Corps Dirigible No. 1 in the hangar (left) and being launched (right). Originally the Baldwin dirigible, it was first tested in the summer of 1908 and formally accepted into the Signal Corps fleet in August. [U.S. Air Force historic archives, public domain.]

The 1910s - Flying Machines and Consumer Cameras

Many covert photographic assignments require smaller cameras, so they can be packed, hidden, or attached to balloons, remote-controlled planes, or other airborne craft. Surveillance cameras also often require wider aperture capabilities, so pictures can be taken in lower light conditions. Both these problems were addressed by Oscar Barnack, a German designer with the Leitz optical company, who developed a prototype of the Leica camera by about 1913. However, the first World War interfered somewhat with Barnack's realization of his finished model. Nevertheless, when the new 35 mm available-light Leica was introduced, news photographers and celebrity hunters quickly began to make use of the new capabilities of the camera and the photographic medium for surveillance purposes.

The development of the Zeppelin airship in Germany spurred the British Admiralty to construct a rigid airship of similar design. By 1910, both Germany and Britain had acknowledged the surveillance and weapons-carrying capacity of airships. Several prototypes were submitted and some were developed, but the first to actually fly was the "HMA. No. 9," originally designed in 1913, but delayed in construction and flight until 1916, due to an interim emphasis on non-rigid airships.





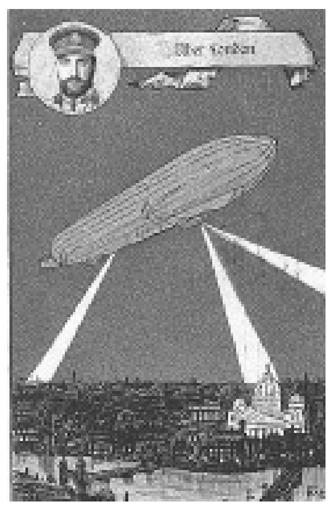
The development of the Zeppelin in Germany spurred the creation of an airship fleet in Britain. Top: The British HMA No. 9, the first rigid British airship to fly successfully. Bottom: A British 'submarine scout' (designated "S.S.") non-rigid reconnaissance airship. [Airship Heritage Trust historical photos, copyrights expired by date.]

When the Mayfly, the first of the rigid British airships, was destroyed, the Royal Navy chose to develop a fleet of over 200 non-rigid airships for submarine, coast, and ocean surveillance, including the NS No. 10 North Sea class vessel shown here. NS vessels were equipped with separate command cabins and engine rooms slung under the bellies of the airships, as is shown. These were often joined by a walkway for braver souls. The ships could stay aloft for about 24 hours. [Airship Heritage Trust historical photo, copyright expired by date.]

World War I was the first significant war fought both in the air and on the ground. The Germans, the British and, to a lesser extent, other Europeans and Americans, used rigid and non-rigid airships and equipped their crews with binoculars and telescopes for various surveillance activities, including submarine-spotting, coastal patrol, and target assessment.

In America, the U.S. Signal Corps officially formed a new Aviation Section on 18 July 1914, thus recognizing the role of aviation in military activities. The Section was small at first, consisting of just a single squadron and the Aviation School.

In 1916, Brigadier General John Pershing began to make extensive use of innovative technologies including mobile Radio Tractor units and aerial reconnaissance systems. Captain Benjamin Foulois commanded the 1st Aero Squadron, using several Curtiss JN-3 aircraft, when Pershing ordered troops into New Mexico to respond to the raid of Pancho Villa. Pancho Villa wasn't found, but the events served to demonstrate the value of aerial reconnaissance and radio devices in military reconnaissance.



Lothar von Wallingsfurt (the Sepia Baron) had a fertile imagination and a fervor for air transportation and is perhaps best known for an unsuccessful attempt to fit out Parseval-Sigsfeld observation balloons for use as fighter interceptors, in 1915. He later persuaded the German Naval Airship Service to use Zeppelins in warfare. On its first raid in 1917, the L.49 airship crashed over London. Wallingsfurt then served with the German Secret Service in Zürich where he continued to advocate the use of airships for warfare and transport. [Janus Museum photo and poster, copyrights expired by date.]

On a historic day in July 1919, half a year after the declaration of the Armistice, the British R34 became the first airship to cross the Atlantic. The vessel, which had been constructed in Glasgow, Scotland, negotiated the winds of the North Atlantic for thousands of miles from East Lothian to Long Island, New York.

The 20s - Transatlantic Flight and the Lure of Outer Space

The successful flight across the Atlantic by the R34 probably inspired inventors just as much as the invention of the airplane. Human imagination quickly aspired to creating rockets that could fly into space after the Wright brothers demonstrated that piloted heavier-than-air craft were not only possible but practical. In 1926, Robert H. Goddard (1882-1945), a prolific inventor, launched a rocket on a flight that achieved a height of 41 feet with a liquid propellant. Well, 41 feet wasn't exactly outer space, but it was sufficient to convince him and other inventors, who were discovering the wonders of the heavens through new, powerful telescopes, that such a thing was possible.

It was an era of adventure and firsts in aviation history. A year after the Goddard rocket flight, Charles A. Lindbergh (1902-1974) achieved enduring international fame by completing a solo, nonstop, monoplane flight across the Atlantic in the Ryan NYP "Spirit of St. Louis" in a time of 33.5 hours at an average air speed of a little more than 100 mph. Lindbergh continued to be a goodwill ambassador and champion of commercial flight for many years, stimulating air transport design and development.

The '30s - Papparazzi, Pioneers, and Global Unrest

Erich Salomon (1886-1944) was one of the first photographers to persistently take pictures in places where cameras were not permitted, often concealing the camera in an attaché case, the archetypal 'spy' accessory. Salomon gained notoriety when he published covert photographs of a murder trial. In 1931, he published "Celebrated Contemporaries in Unguarded Moments," which included candid shots of about 150 dignitaries and celebrities of the time.

Aerial explorations of cultures, with benefits for archaeology and anthropology also began to develop. A publisher by the name of Atlantis Verlag produced a number of books in the 1930s to 1950s that showed the culture and topography of foreign nations that were otherwise rarely seen by westerners at the time. Wulf Diether Castell took some remarkable and beautiful photos of the region of Gansu, China, with a Leica camera. Over 100 of these black and white photos were published in "Chinaflug" (Flight over China) in 1938. The book, unfortunately, is out of print and difficult to find, but represents some of the earliest high quality aerial photos of places in the world that were hard to reach.

By 1933, exciting and downright dangerous efforts spurred interest in aerial and infrared photography. In an ambitious pioneer survey, cameras were mounted on two British open-cockpit biplanes, which had been converted from bombers to reconnaissance planes for the purpose of aerial surveillance. These planes had a maximum cruising speed of about 135 miles an hour. In addition to traditional black and white photos, the adventurers shot black and white Ilford infrared images [Greer, 1994]. They used gimbal-mounted Eagle III Williamson aircraft cameras which could shoot up to 125 five-inch photos. Nepal was closed at the time, so permission was needed to do a flyover, and the plane was not permitted to land in Nepalese territory. Thus, the surveys were done on a trip over Everest in which traditional and infrared photographs were taken in the vicinity of the Himalayas.

Almost everything association with the historic aerial trip was improvised. The camera was constructed of plywood by the Art Editor of the London Times newspaper. The designers had to find an effective way to attach the fully manual camera to provide a good view of the terrain. They mounted it in slings under the plane, facing forward, and tipped it down about 6°, with stuffed leather pouches as shock absorbers. The system was primitive by modern standards; the camera was aimed by aiming the plane. Double plates had to be individually mounted and removed and the shutter manually wound and released. The signal for camera readiness was a jerk on a string to the pilot. Despite the difficulties, the mission was a success and set the stage for future reconnaissance planes and aerial surveys.

A number of amateur and professional photography associations were being established around this time and some of the prominent camera companies were formed. In 1934, the American Society for Photogrammetry and Remote Sensing (ASPRS) was founded. The Japanese company now familiar as Minolta began lens production in 1937 as hostilities were gaining momentum in Europe. The global unrest resulted in many photographic technologies being put into service for wartime activities and in companies modifying consumer products to market them in the service of war. Konishiroku Co., Ltd. began constructing aerial cameras and X-ray photographic systems in 1937. Minolta created a *Rokkor* aerial camera lens in 1940, and the company was put into service by the Imperial Japanese Navy in 1942 to manufacture optical glass. Fuji Photo Film Company, which was gradually expanding into other photographic products besides film, manufactured aerial cameras and lenses during World War II as well [Ono, 1996].

War and Post-War

Not all balloons were designed for carrying people or cameras. Some were intended as defensive obstacles, for impeding the flight of foreign reconnaissance or fighting aircraft. Tethered *barrage balloons* were in use at least by the mid-1930s and occasionally they would explode in flames over the areas they were intended to protect, an event that was captured in a London newsreel in 1934. Before and during World War II, the balloons were installed to try to prevent air attacks on vulnerable areas such as major cities and important shipping lanes. The heavy tether cables could slice the wing off a low-flying aircraft that tried to fly through the barrage.

Left: U.S. Marine Corps with a barrage balloon on Parris Island, South Carolina in May 1942. The gas-filled barrage balloons and their cables were used as defensive obstacles to deter enemy reconnaissance and fighter aircraft. Right: Unfortunately, it's difficult to see them all in this small photo, but there appears to be a combination of at least a dozen airships and barrage balloons in this moving image of "D-Day" during World War II on the French beachhead in Normandy. [Library of Congress FSA/OWI photo by Alfred Palmer, public domain; U.S. Army 6 June 1944 historical archive photo by Steck, released.]

The World War II years were a strong stimulant to aircraft development and piloting technology. They were years when existing navigation devices were put into the service of the war effort, and research dollars were channeled toward these technologies. It is therefore not surprising that many advances in aircraft design and surveillance photography developed in the early 1940s.

Jet engine technology began to appear in the early 1940s and the new designs were quickly put into military service. The higher speeds and higher altitudes at which planes could now fly made it far more difficult to hang out a window with a camera to take aerial pictures, as had been done in earlier decades. It also made it necessary for the pilots and crew to wear arctic gear and oxygen masks.

At this time, allied military reconnaissance was conducted in part by camera-equipped, modified four-engine B-17 and B-24 aircraft and modified two-engine P-38 and F-5 fighter planes, along with the British Mosquito. The P-51 Mustang, equipped with an oblique camera, was also used for reconnaissance.

Airships played an important part in surveillance in World War I and, in spite of the newer, faster airplanes that were being developed for use in commercial and military aviation, airships continued to be used for a variety of activities during and following World War II, including submarine spotting.

Airships travelled more slowly than fixed-wing aircraft, were generally more fuel-efficient, could stay airborne for longer periods of time, and were faster than most marine vessels. These characteristics made them useful for many types of visual and telescopic surveillance. (In recent years they are coming into use as radar-carrying platforms, especially for large-aperture radars.) For their size, airships had relatively low radar signatures due, in part, to the streamlined shape.

L. Fletcher Prouty offers this personal perspective on his War experiences:

> "We also learned while we were there that Frankfurt was the European base for the border flying and other aerial surveillance activities. This was before the U-2 started operating; it later became the European base for U-2's. We had aircraft flying the borders, doing surveillance with either radar or photography in that period. They were quite effective. We also had an enormous balloon program. We would launch large balloons, loaded with leaflets or loaded with instrumentation, that would provide various propaganda information throughout Eastern Europe....
>
> It was an interesting program. You'd think that just random balloons wouldn't accomplish much, but they apparently did.... There was a base at Wiesbaden which was entirely operated under what we called "Air Force cover," but was for the operation of CIA aircraft. And they were very active all over Europe."
>
> [David T. Ratcliffe electronic edition of "Understanding Special Operations And Their Impact on the Vietnam War Era: 1989 Interview with L. Fletcher Prouty, Colonel USAF (Retired): Military Experiences 1941-1963," rat haus reality press.]

The 1950s - The Postwar Boom and the Cold War Years

> "On Soviet Aviation Day in 1955, foreign observers saw, during an exhibition in Moscow, a surprisingly large number of new heavy bombers fly by, leaving the impression that the Soviets were building a powerful bomber force. However, it was learned later that the same bomber squadron had been flying around in circles. Since 1956, U.S. U-2 operations supplied evidence that the Soviets, in fact, are concentrating on rockets and not on the production of bombers."
>
> [Dr. George Walter, "Intelligence Services," Military Review, August 1964.]

The fear and distrust that had flared up between the U.S. and the Soviet Union in World War II wasn't alleviated by later events. Each nation spied on the other and western concerns were fueled by some of the expansionist and repressive policies of the Soviet government. In turn, the Soviet government perceived the Americans as militarily aggressive and unsympathetic to communist doctrine. All in all, satisfactory political negotiations were not prevalent at the time.

President Eisenhower wanted more military intelligence on the capabilities of the Soviets than they were voluntarily revealing and, in December 1955, authorized project GENETRIX, to consist of high-altitude balloons carrying photographic equipment. The balloons drifted over Soviet territory in early 1956, collecting images along the way, and were subsequently recovered in the air over the Pacific Ocean. Not surprisingly, the Soviets objected strongly to this, as no doubt the U.S. would have done if unauthorized Soviet balloons had flown over the Midwest, and the program was discontinued, only to resurface a few months later in the form of the first significant U.S. spy plane.

The Beginnings of Space Travel

In 1957, the Russian Federation announced in print that they were going to send up a satellite and published the frequencies so that radio operators worldwide could monitor its progress. They made good on their announcement and launched Sputnik I in October 1957. Considering the advance notice, it is somewhat surprising that the U.S. reacted with so much surprise. A month later, the Federation sent up Sputnik II, which housed a dog named Laika. Spurred into action, the U.S. stepped up its own rocket program and, in December, before a television audience, attempted to launch the Vanguard satellite, which blew up on the launch pad.

People were, in some ways, more trusting of the government in the 1950s. Television was still rare and only scattered news came through the radio. Since it was harder to know just what the government was doing at any given time, compared to today, there was less of an expectation of being able to have a voice in political affairs. As a result, there was less pressure on public officials to reveal the internal workings of their defense and spying activities. Occasionally accidents on foreign soil would reveal clues as to what kinds of surveillance activities were being undertaken.

The First Spy Planes

Planes had always been used to spy, but it was not until the 1950s that very specialized stealth planes began to be designed and manufactured.

Construction of the single-engine *CL-282 spy plane* began at the Lockheed Experimental Department in the mid-1950s, with the aircraft becoming operational in June 1956. Its first use was during the Suez Canal Crisis. The CL-282 was specifically designed to fly higher and longer than previous planes, in order to carry out foreign reconnaissance, particularly over the Soviet Union. In other words, it was effectively a replacement for the GENETRIX balloon program. In spite of its covert intentions, there were internal reports that the craft, now better known as the U-2, was not particularly difficult to detect or track. In spite of this vulnerability, it managed to fly many missions before it was shot down. During the course of its service, scientists and engineers discovered that it was more difficult to use radar to track planes that were flying at supersonic speeds. By 1959, approval for improved stealth aircraft was given by the President.

In early 1960, the general public knew nothing about the U-2 aircraft. The Soviets had been protesting American violation of Soviet airspace, while the Americans denied any such activities. Then news reached President Eisenhower that a U-2 spy plane, dispatched on a surveillance mission over Soviet territory, had disappeared on 1 May 1960. Assuming that the pilot either couldn't have survived the crash or would have sacrificed himself and the plane rather than being captured, the Eisenhower administration announced that it was nothing more than a U.S. weather plane, studying the upper atmosphere; it must have gotten lost over Turkey, perhaps even crashed. To support the story, a U-2 was given NASA decals and presented to the press. A few days later, the Soviets revealed the complete falsity of the American assertion by announcing that they had recovered the live pilot, the wreckage, and the exposed surveillance film. This caused significant embarrassment to the President. More importantly, however, it resulted in the cancellation of planned Presidential trips to Paris to attend an important multinational summit meeting and to Moscow to attend a June diplomatic meeting with the Soviets.

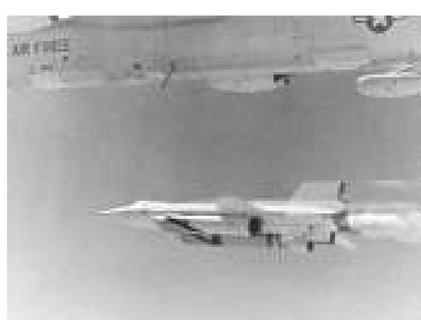
The U-2 continued to fly surveillance missions along the Soviet borders, sometimes straying across those borders, with further protests from the Soviets and various apologies from the U.S. Later, the U-2 was also used to provide aerial intelligence in the region between Florida and Cuba during the Cuban Missile Crisis in 1962, a serious diplomatic situation that almost led to a major war. Plans for adapting the U-2 craft so it could be launched from aircraft carriers were soon underway, with testing of modified U-2s beginning in August 1963. It was found that the planes could take off from carriers, but needed more modifications to be able to land effectively.

In science and technology, one of the most important areas of research and engineering in the early 1960s was the development of titanium alloys. These strong industrial materials would permit construction of new generations of aircraft and deep-ocean-going craft. Research into materials, designs, and strategies that could reduce radar signatures was also continued and applied to the U-2 planes.

Thus, general and applied research into stealth technology and airplane design continued and the successor to the U-2, the A-12 (part of a project codenamed OXCART), flew in 1962. The A-12 could travel at three times the speed of sound and had a range of more than 3,000 miles. It would cruise at altitudes three times as high as large commercial airline services. The A-12 was less vulnerable than the U-2 and incorporated better photo-reconnaissance equipment. It also incorporated special quartz windows which could admit infrared light. Perkin-Elmer cameras were selected with Eastman Kodak as backup supplier. The A-12 project didn't continue past 1968, but it provided research information that resulted in a fleet of two-seater A-11s, now known as SR-71s.

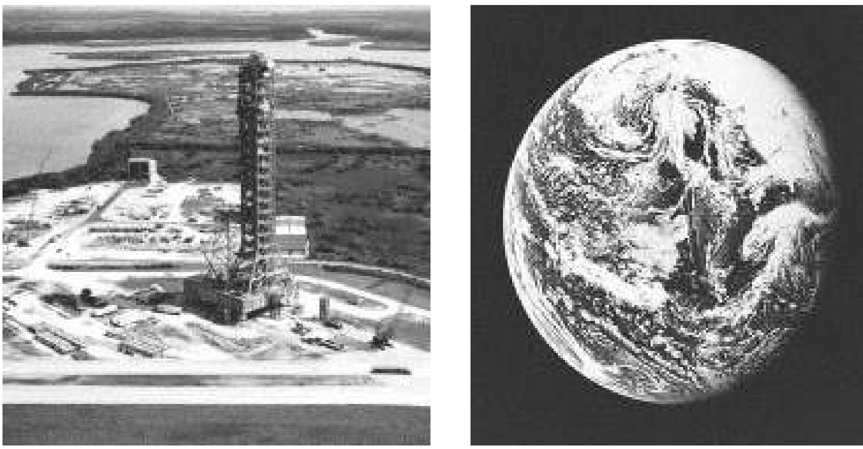
The Beginnings of Space Surveillance

While atmospheric surveillance aircraft were being improved, the U.S. space program was also getting underway and many aspects of it were top secret.



The X-15 was a rocket-powered, missile-shaped aircraft designed for high-altitude testing and the deployment of scientific sensing and data-collection instruments. Like the later Space Shuttle, the X-15 was launched from another craft at high altitude, in this case a B-52 aircraft (right). It would then glide in powerless flight and execute a glide landing. There is an X-15 rocket plane exhibited in the National Air and Space Museum in Washington, D. C. [NASA/ Dryden Flight Research Center 1960 and 1968 news photos, released.]

There was a great deal of overlap in the research and design of high-altitude, high-endurance aircraft and the design of rockets and space capsules as the U.S. space program got underway. In 1959, the X-15 research aircraft was developed to provide in-flight information on aerodynamics, flight control, and the effect on pilots of high-speed, high-altitude flight. The aircraft was also used to carry sensors and scientific payloads beyond the Earth's atmosphere, remaining in regular service for the next decade.



Left: Mobile launcher I was constructed during the period from 1966 to 1968 by NASA at the Kennedy Space Center. It was an integral part of the Apollo program. The structure was altered in the mid-1970s and finally disassembled in 1983 soon after this picture was taken. Right: Earth from 250,000 miles away as photographed by the astronauts of the Apollo 10 space mission in May 1969. [Library of Congress HABS/HAER collection; NASA/Ames Research Center news photo, released.]

CORONA

In the early days of space missions, public sources of information on the U.S. surveillance satellite programs were scarce. Occasional news reports appeared in the media, as when John Finney reported a satellite capsule-recovery in an August 1960 issue of the U.S. Times, but that was only the tip of the iceberg. Three decades later, oral histories and declassified information began to show the extent of the programs and fill in some of the gaps.

The CORONA space reconnaissance satellite was conceived and contracted out in the 1950s as part of the Air Force Weapon System 117L (WS-117L). The CIA was given responsibility for the surveillance aspects of the project. In 1957, the project came to be known by the codename SENTRY and thereafter as Samos. By 1960, Samos consisted of a number of basic aerial imaging technologies that characterize much of aerial surveillance today, including

Project 101A - high-magnification visual surveillance images readout

Project 101B - high-magnification visual reconnaissance film recovery

Program 201 - high magnification visual reconnaissance film recovery

MIDAS - Missile Defense Alarm System, an infrared surveillance sensor intended to detect the hot gases from launched weapons

Discoverer (CORONA) - visual reconnaissance film recovery

Beginning in August 1960, Lockheed's CORONA satellite, the first photo reconnaissance system, collected images of the Earth of about 12 meters resolution, the width of a small city lot, using an Eastman Kodak Company camera. By the early 1970s, the resolution had been improved to about three meters, the length of a small bedroom, and the volume of film had been increased as well. While President Johnson alluded to the use of satellites for surveillance activities in the mid-1960s, classified documents regarding the CORONA system were not released to the public until 1995. Some of the details will never be known, as much of the information was conveyed by mouth and never recorded in print. During its tenure, the CORONA project imaged Soviet submarines, bomber and fighter jets, atomic weapons storage installations, ICBM complexes, the Missile Test Range north of Moscow, and ocean-going Soviet vessels. The MIDAS sensing system eventually evolved into early warning satellite systems.

Continued Aircraft Surveillance

As was mentioned earlier, the A-12, A-11, and eventually, the SR-71 aircraft evolved out of the original U-2 surveillance planes and project OXCART included the readying of planes for the possibility, if not the fact, of flying over Communist China. This resulted in Operation Black Shield, which was called up in 1965 to address the needs of Far East operations, based out of Kadena Air Force Base in Okinawa.

In May 1967, the first Black Shield missions were flown over North Vietnam and the Demilitarized Zone. Reconnaissance photos of 190 SAM sites were taken from the aircraft and there were no indications that they had been detected by foreign radar on the initial flights. Later flights that detected radar tracking signals were not greeted with hostile actions and the sortees determined that North Vietnam did not have surface-to-surface missiles. The planes were fast. A single pass over North Vietnam in the A-12 took less than 13 minutes. On landing, the photographic film was removed and sent for processing.

On one reconnaissance flight over North Vietnam, the surveillance aircraft was detected and a missile fired, all of which was documented photographically by the reconnaissance camera. It was the first time the electronic countermeasures equipment associated with the A-12 had been used in real action and it apparently functioned effectively.

By the late 1960s, the public was becoming better informed about satellite surveillance as less-speculative articles about military satellites were being published in popular journals by this time.

The '70s - Space Stations and Civilian Satellites

Commercialization of the satellite imagery market was not a smooth process, but it has been an important one. Access to detailed information about the Earth not only influences the balance of power between governments and civilians, but also greatly affects how surveillance professionals, environmental groups, businesses, and individuals can access information. The quality and price of images also strongly affects how the information is used and by whom.

Landsat, the first civilian remote-sensing satellite was developed by the U.S. National Aeronautics and Space Administration (NASA). Launched in 1972, it was designed to capture multispectral images at a resolution of 80 meters (about the size of a playing field). Due to the limitations of cost and resolution, these images were mostly of interest to scientists, educators, and government agencies, and didn't yet meet the requirements of most commercial entities. With Landsat 4 and 5, which had an improved 30-meter resolution (about the length of a city lot), commercial marketing of the technology became feasible. Thus, commercialization was initiated with the Carter administration 1979 *Presidential Decision Directive* that transferred operation of Landsat to the National Oceanic and Atmospheric Administration (NOAA) and directed NOAA to increase private sector access to the technology. The commercialization was to be initiated gradually as the market developed.

At the same time that new satellites were being launched, ground-based space surveillance complexes were being developed. With so many more vessels being launched into space, there was a strong motivation for developing telescope-based centers that could detect and monitor all the new space objects. The interest in deep space and the celestial environment outside our solar system was increasing as well. The *Maui Space Surveillance Complex* was one of the centers established at this time to surveil a larger part of our universe.

The 1980s - Politics, Peace, and the Pressure to Commercialize

In 1982 and 1983, the U.S. government commissioned some studies to determine the feasibility of commercializing the satellite imaging field and found that the commercial market for Landsat imagery, at the time, was underdeveloped and that commercialization "should be done gradually." Three subsequent studies supported this conclusion and some analysts warned that subsidies would be necessary if commercialization proceeded too fast. In spite of this, the Reagan administration chose to accelerate commercialization.

The U.S. Congress responded to the President's commercialization directive by signing into law the *Land Remote Sensing Commercialization Act* (P. L. 98-365) in July 1984, the year Landsat 5 was launched. The intent of the LRSCA was to increase commercial access on a nondiscriminatory basis and to establish a licensing process. The commercial sector still didn't respond enough to support commercial ventures, so the U.S. government agreed to approximately $300 million in subsidies through the late 1980s, with EOSAT to assume all operational costs upon launch of Landsat 6. In a reversal of support in the 1987 Reagan budget proposal, nearly half the promised subsidy ($125 million) was deleted and EOSAT instituted layoffs and a dramatic downsize in marketing.

While U.S. politicians were busy trying to work out the timetable and terms of commercialization, foreign nations were stepping up their own satellite programs, with France launching Spot-1 in February 1986.

After more studies and proposals, by spring 1988, the U.S. government agreed to subsidize EOSAT in the development of Landsat 6. Any project cost overruns were to be covered by EOSAT.

The U.S. IRS-1A satellite, with visible spectrum and several ranges of infrared imaging, was launched in 1988. It had a spatial resolution of about 72 meters with a 148 km swath.

Over the next several years of the Bush administration, subsidies to continue operations of Landsat 4 and 5 beyond the original contracts were approved.

Unfortunately, the premature commercialization of the satellite imaging market increased the price of image scenes to over $4,000. As costs rose, demand fell. Between the mid-1980s and 1990, purchases dropped to a quarter of their previous volume. Even research institutions were finding it difficult to justify the increased costs.

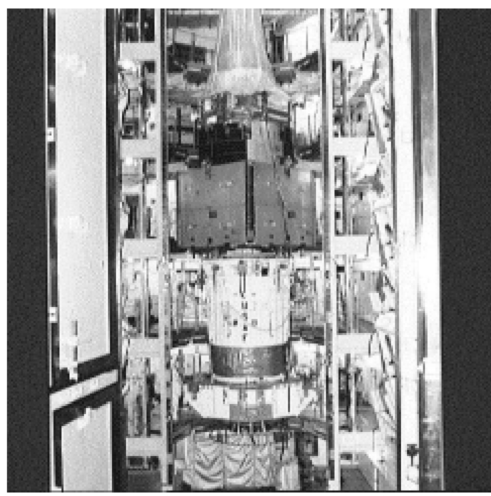
In spite of various setbacks and disappointments in commercialization of satellite imagery, a number of private and public companies began to plan ways to market imagery. One of these was Aerial Images, Inc., which was founded in 1988, partnering with Microsoft and Kodak to create the Terra-Server online image server in the 1990s. A similar venture was founded in 1995 as Space Imaging, also in association with the Eastman Kodak Company. Back in the late 1980s, however, it was difficult to predict how successful these ventures would be, and how long it would take to launch commercially viable private satellites.

The 1990s - Global Conflicts and the Commercial Sector

In the 1990s, both surveillance and commercial satellites were beginning to share the orbital space around the Earth and like good land, good orbits began to be much in demand.

In 1990, France launched Spot-2, and while it did not meet the spectral and swath specifications of the U.S. Landsat systems, it could compete with higher resolution images, thus potentially challenging U.S. dominance of the satellite imaging market.

The 1990-1991 Persian Gulf War was a technological war on many fronts. Not only were new land- and air-based missile-sensing and targeting systems put into use, but the Defense Intelligence Agency (DIA) reported that space satellite images from the Landsat systems were used for military surveillance, including terrain analysis, and planning and execution of some of the tactical maneuvers in Operation Desert Storm.



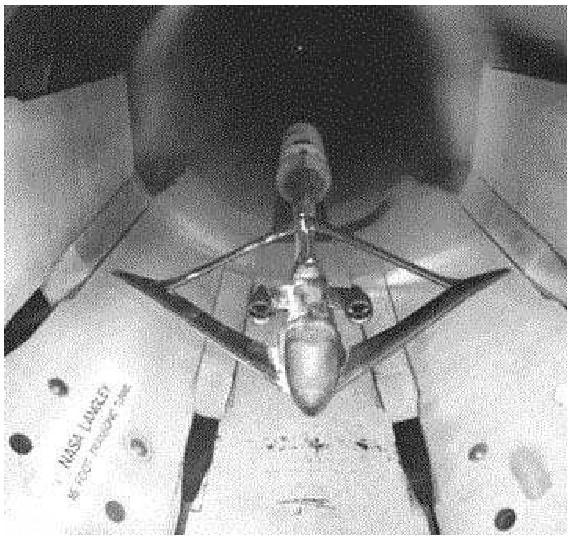
The STS-44 is a Defense Support Program (DSP) surveillance satellite that was designed to detect missile and space launches and nuclear detonations. An infrared sensor was installed in the top of the craft and it was scheduled for launch into a geostationary orbit in 1991. [NASA/JSC 1991 news photos, released.]

The IRS-1B satellite, with visible spectrum and near-infrared imaging, was launched in 1991. The craft's spatial resolution for imaging was about 36 meters with a 146 km swath.

In May 1992, a Presidential Directive from the Bush administration enabled more people, including environmental scientists, to make use of aerial surveillance data for monitoring the globe and its environment.

In the private sector, entrepreneurs were now interested in satellite imaging profits. In July 1992, WorldView Inc. applied to NOAA for a license to operate a commercial satellite with three-meter (about the size of a bedroom) panchromatic resolution.

In response to the increased use of satellite images in national defense and other activities, the U.S. Congress passed the *Land Remote Sensing Policy Act* (P.L. 102-555), signed into law by President Clinton in 1992. The Act recognized the importance of satellite imagery in studying the environment and in carrying out activities related to national security. The Act further acknowledged some of the problems associated with previous attempts at full commercialization and the loss of global leadership in the U.S. satellite imaging market. It consequently transferred control of the program to the National Aeronautic and Space Administration (NASA) and the Department of Defense (DoD). The authority for licensing private satellites remained with the U.S. Secretary of Commerce.



The Boeing EX, shown here in model form in a Transonic test tunnel, is an advanced surveillance aircraft concept proposed by Boeing to replace the Grumman E-2C "Hawkeye." Each wing is designed to hold active-aperture radar arrays to allow the craft to be more aerodynamic than previous aircraft. [NASA/Langley Research Center 1993 news photo, released.]

In January 1993, The WorldView Inc. commercial license was granted, opening the doors to private-sector commercial satellite imaging ventures in competition with the Landsat systems. A few months later Commercial Remote Sensing System (CRSS) applied for a license through Lockheed Martin for its IKONOS 1 system.

Satellite and aircraft imaging in the early days was primarily used for scientific research, early warning systems, and foreign spying. Now these systems were being used in commercial applications, newscasting, and federal and local law enforcement on a regular basis. As an example, in April 1993, the FBI used aircraft-mounted forward-looking infrared radar (FLIR) to surveil the Branch Davidian compound in WACO, Texas. The videotaped transcript also included some audio of radio messages. Two tapes containing about 3.5 hours of video footage were later released to the public, in September 1999.

Improving Aerial Photography and Resolution

It was clear, after control of the Landsat program was transferred to NASA and the DoD, that scientists and administrators recognized the need for higher resolution images. For future systems, NASA favored 15-meter resolution (about the size of a house), whereas the DoD favored 5-meter resolution (about the size of a living room). As with most technologies, there was a trade-off between price and resolution; higher-resolution images would be more costly. While NASA and the DoD were airing their differences, the unexpected happened. In October 1993, the realities of launching expensive equipment into space became apparent when Landsat 6, which had cost almost $300 million, plunged into the ocean only a few minutes after launch. The DoD subsequently left the Landsat program.

The following year, a *Presidential Decision Directive* (PDD-2) announced that NASA would be responsible for the development and launch of Landsat 7, with NOAA operating the satellite and ground systems. Data would be archived and distributed by the Department of the Interior. The Directive also eased up on restrictions regarding the sale of satellite imagery to foreign agencies.

With declassification of U.S. documents on CORONA, ARGON, and LANYARD early in 1995, and release of CORONA photographs over the next several months, information about the CORONA surveillance satellite project started reaching the popular media. Nearly a million images of the Earth's surface, collected between 1960 and 1972, were declassified. Multinational cooperation in space and satellite programs increased at this time.

In 1995, it was reported that the KH-11 reconnaissance satellite was being updated to increase the downlink rate in order to bring it closer to realtime coverage. Some SR-71 reconnaissance aircraft, descendents of the U-2, were reactivated for tactical purposes.

It became apparent that there was a trend to change the structure of the U.S. surveillance satellite program from a few large-scale satellites to more small-scale satellites and to attempt to add stealth components to the vessels similar to those used in stealth aircraft.

Commercial Competition and Image Servers

By March 1994, the U.S. Department of Commerce began issuing licenses to commercial satellite companies. One of the first to be granted a Federal Communications Commission (FCC) license was Space Imaging, chartered by Lockheed Martin and Raytheon, with its IKONOS system eventually becoming a major contractor. In February 1995, Eastman Kodak Company and Space Imaging, Inc. announced a strategic business alliance to market satellite imaging products and services. This alliance would lead to consumer access to imaging products from a variety of satellites.

In April 1995, the commercial OrbView-1 satellite was successfully launched by Orbital Sciences Corporation, equipped with atmospheric instruments to provide weather-related data to U.S. government agencies.

In 1996, Lockheed's Space Imaging purchased EOSAT and its Mapping Alliance Program in a bid to become the commercial leader in this market. Meanwhile other companies and nations were seeking to enter the potentially lucrative market.

In May 1997, Aerial Images, Inc., Microsoft Corporation, and Digital Equipment Corporation announced the Terra-Server project, a joint project to provide a global online atlas of two million square miles of two-meter resolution satellite images derived from the Russian Space Agency's SPIN-2™ satellite. On 18 February 1998 the satellite was successfully launched into orbit from Kazakhstan. Images from SPIN-2 are typically 500 MB, but the Terra-Server is designed to 'slice' these images to suit the user. The images can be downloaded as tiles, previewed, and purchased for about $30 per square mile if they meet the consumer's needs. Thus, the Terra-Server commercial system is essentially a map-on-demand system served 24 hours a day over the Web providing posters, custom images, and digital data on CD-ROM. This project is significant not only in its scope, but in that it represents a cooperative commercial effort between the U.S. and Russia.

The Terra-Server and other Web-based commercial satellite image servers such as Space Imaging, promise to fundamentally change the relationships between government agencies, intelligence organizations, and individuals. Information that was previously impossible to get, even by intelligence agencies, can now be downloaded in a few minutes through the Web.

Following the launch of OrbView-1 in 1995, OrbView-2, a color imaging satellite providing daily updates, was launched in August 1997. A Web image server was developed over the next several years, offering Web-based browsing and purchasing, with images delivered via Internet, computer tape, or CD-ROM. The OrbView-2 system was equipped with the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) which included six visible and two infrared imaging channels. OrbView-3 and Orbview-4 were added to the launch schedule for the first half of 2001 to provide high resolution options. OrbView imagery were made available through OrbImage and other commercial imaging partners of Orbital Sciences Corporation.

The Old and the New

The 1990s was a time when old technologies were brought back to be combined with new innovations and in which entirely new types of craft were built to serve surveillance objectives. Some of the most interesting of these were remote-controlled and autonomous aircraft.

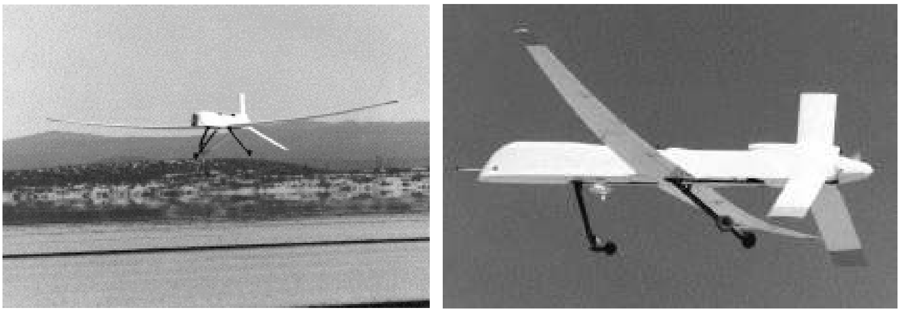
Very few people in the 1970s or the 1980s would have predicted the return of airships in the late 1990s. After laying dormant for almost half a century, the historic Zeppelin airships were put back in service, showing their continued viability as a technology. By the mid-1990s, the U.S. Navy was building an airship sufficiently large to carry a phased-array radar system and entrepreneurs were attaching still and video cameras to a variety of types of balloons and airships for taking aerial photographs.

This is the 71M Aerostat Test Balloon equipped with a radar system located in a streamlined protector against the belly of the balloon. This system can be used to track aircraft and cruise missiles up to a range of about 150 nautical miles. It is shown ready for liftoff from the Aerostat Test Bed in a multinational defense exercise during Operation Roving Sands. [U.S. DoD 1996 news photo by Benjamin Andera, released.]

In the mid-1990s, the U.S. Navy began flying Predator aircraft off their carriers in simulated aerial reconnaissance operations. The Predator was a new unpiloted air vehicle (UAV) equipped with near-realtime infrared sensing and color video capabilities. The sensor data can be transmitted to controllers on ships and in ground stations.

UAVs were used in NATO scouting missions over Kosovo for imaging troops and installations, relaying the signals to overhead aircraft.

The Altus 1 was built for NASA's Environmental Research Aircraft and Sensor Technology program and was followed by the Altus 2. Both are variants on the Predator surveillance drone built by General Atomics/Aeronautical Systems Inc. The Altus remotely piloted drones are designed for high-altitude, long-duration, scientific sampling missions.



The Altus 2, a variant of the Predator unpiloted air vehicle (UAV), is designed for scientific sensing/sampling. On the right it is shown retracting its landing gear. [NASA/Dryden Flight Research Center 1997 news photo, released.]

Aerial and Satellite Technologies - Successes

In April 1999, Landsat 7 was launched, with a resolution of 15 meters for panchromatic images and 30 meters for multispectral images of the Earth. The images were to be made available to consumers at cost. Thus, prices dropped tenfold in a few years, averaging about $550, depending on the degree of processing and correction applied to the data. With these services, the U.S. was endeavoring to recapture the global satellite imaging market. Meanwhile commercial companies were improving their technology, as were other countries.

Before the final testing and calibration of IKONOS, Space Imaging, which offers images from IKONOS 1, the Indian Remote-sensing systems, U.S. Landsat, Canadian RADARSAT, Japanese JERS, and the European Space Agency's ERS systems announced, in Nov. 1999, the imminent availability of high resolution images. Through its CARTERRA™ product line, Space Imaging specifically states that the imagery can be used for "monitoring specific natural and human events" leaving little doubt about its surveillance potential. Space Imaging lists utility and transportation companies, resource managers, real estate developers/brokers, and intelligence agents as potential buyers.

Much of the satellite contracting business had been handled by Lockheed Martin over the last three decades, but in fall 1999, the Seattle-based Boeing Corporation received approval to build a new generation of imaging satellites through a NRO Future Imagery Architecture (FIA) funding award.

Aerial and Satellite Technologies - Problems

There is always a tug-of-war between what the public wants to know and what the government wants to reveal. As of about April 1999, the Department of Defense no longer provided tracking data on military satellites for posting on NASA's Orbital Information Group Web site. Until that time, the site had been providing object orbit location and apogee/perigee information.

Commercial aerial imaging had evolved to the point that the U.S. Government began making purchases from commercial systems to supplement the information received from government systems. They were especially interested in Ikonos 1, Orb View 3, and QuickBird-1 high-resolution images. These sources have the benefits of easy access and lower classification levels and thus less red tape. One of the disadvantages of using these sources for government purposes is the general vulnerability of commercial systems, which are built for profitability rather than security. They lack stealth technology and extra shielding and thus may be vulnerable to attack.

The positioning of satellites is an art in itself and is not always successful. In April 1999, Lockheed Martin and its associates attempted to place the IKONOS 1 satellite at 423 miles above Earth, but the launch vessel was unable to accomplish the task. On 24 September 1999, Lockheed Martin, in association with Raytheon, Mitsubishi Corp., Eastman Kodak Company, et al., successfully launched its IKONOS imaging satellite aboard the Athena II launch rocket and successfully placed it in a sun-synchronous, circular, low-Earth orbit. IKONOS was designed to deliver satellite images with one-meter-resolution monochrome (the size of a desk) and four-meter-resolution color (the size of a room).

While new commercial satellites were being launched, regular military atmospheric reconnaissance was continuing closer to home. Aerial reconnaissance in unfamiliar territory has many hazards. In July 1999, crewmembers of a U.S. Army Dehavilland RC7 reconnaissance plane were reported missing in southern Columbia, South America while flying a counter-narcotics surveillance operation. Unfortunately, the occupants of the plane didn't survive the crash in a remote, mountainous region of forest.

New Multinational and Humanitarian Projects

Fast planes, satellite images, the Internet, and human mobility have created a stronger sense that we are a global community and the effects can be seen in greater cooperation in scientific and commercial ventures. The late 1990s and early 2000 were a time when reconnaissance and surveillance technologies and personnel were used to aid victims of many disasters, including floods, hurricanes, earthquakes, and volcanic eruptions. Aerial surveillance information can be extremely valuable in administrating relief efforts.

Left: A U.S. Air Force Combat Shadow (MC-130P) flies over South Africa on a reconnaissance mission to surveil damaged roads in Central Mozambique. Relief efforts aided the Africans following torrential rains and flooding. Right: P.O. 3rd Class Anita Lillibridge rotates the propeller on a P-3C Orion aircraft at Entebbe, Uganda. The Orion was being used for reconnaissance missions over Zaire to support United Nations refugee relief efforts. [DoD March 2000 and Nov. 1996 news photos by Cary Humphries and Barbara Burfeind, released.]

In early 1999, the U.S. Department of Defense hosted Japanese specialists from the Japanese Defense Agency to train as space imagery interpreters and analysts in preparation for a

Japanese satellite reconnaissance program scheduled to be put in place over the next several years. The satellites were being developed by Japan's National Space Development Agency, in part using U.S. technology. These actions were in part initiated because of political unrest existing between Japan and North Korea.

In June 2000 a more surprising alliance occurred when President Clinton and the new Russian leader negotiated the beginning of a U.S./Russia early warning system, a milestone in collaborative international surveillance.

Clearly, aerial surveillance is, and will continue to be, an important tool for surveilling our world and monitoring a wide variety of resources, people, and activities.

5. Description and Functions

This is a supplemental rather than a primary chapter. As such, the description of the basic technologies used in aerial imaging are introduced in the Infrared, Visual, Ultraviolet, Radio, and Radar Surveillance chapters and should be cross-referenced. To some extent, sonar is also dropped or towed by helicopters, planes, and remote-controlled craft and submarine-spotting is an integral aspect of military aerial reconnaissance, so the Sonar Surveillance chapter can be cross-referenced as well.

5.a. Cameras

There are hundreds of different cameras and camera-like imaging systems used for aerial surveillance and so just two examples associated with spaceborne systems are given here. You are encouraged to cross-reference information in the Radar, Infrared, Ultraviolet, and Visual Surveillance chapters, as there are considerable diversity and overlap in various camera-related imaging systems. The Infrared and Ultraviolet Surveillance chapters have more details on the specifics of taking pictures with special IR and UV films and filters.

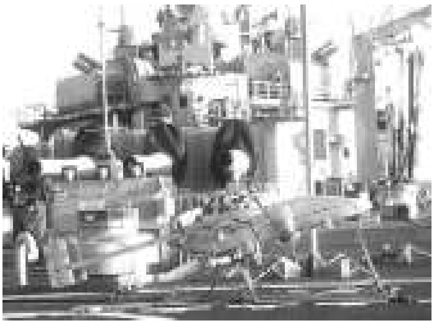
TK-350 - A Russian high-resolution topographic satellite imaging camera. Accurate, detailed, with wide swatch capabilities. This camera is suitable for photogrammetry and relief definition mapping applications. Topographic maps of 1:50,000 scale can be created. It has a rectangular frame format with the long edge coincident to the flight direction. The focal length is 350 mm, with a relative aperture of 1:5.6 and stereoscopic overlap of 60% or 80%. Press rollers are used to maintain film flatness. It has an accuracy of 10-meter ground resolution which can be enhanced with concurrent two-meter data from the KVR-1000.

KVR-1000 - A Russian high-resolution panoramic satellite imaging camera. This camera is accurate, detailed, with wide swatch capabilities. It is suitable for ground identification applications with an accuracy of two-meter ground resolution at an altitude of 220 km. The focal length is 1000 mm, with a relative aperture of 1:5 and a longitudinal overlap of 6% to 12%. It is used in conjunction with the TK-350 in the creation of satellite cartographic systems.

5.b. Remote-Controlled and Autonomous Vehicles

Many of the newer aerial surveillance technologies are based on radio remote-control or computer-programmed autonomous flight.

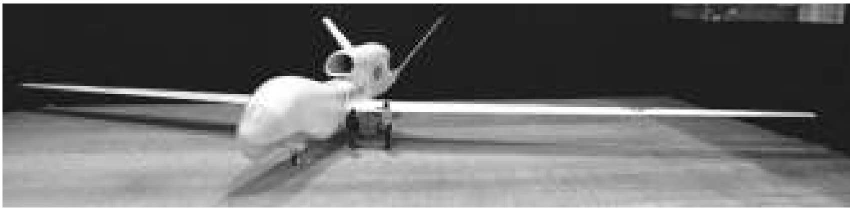
Remote-controlled vehicles are those which are linked to a control console by wired or wireless links. Wireless links are usually preferred because they offer greater flexibility of movement. Wire links are usually used in cases where not much movement is required (sometimes just pan and tilt) and where very long ranges or tighter security might be needed. Some use a combination of wired and wireless links, typically set up in relays. It is likely that wired and wireless links will continue to coexist, rather than one superseding the other, due to the different strengths and benefits of each method and because they can be used in combination.



The Pioneer I is a remotely piloted vehicle shown here in a 1986 test on a U.S. Navy battleship. The Pioneer is equipped with a stabilized television camera and a laser designator designed for over-the-horizon targeting and reconnaissance. The system can be controlled from the host console to a range of about 110 miles with an operating endurance up to about eight hours. [U.S. DoD news photos by Jeff Hilton, released.]

Autonomous air vehicles are those which fly by themselves once they are set to go. Computer programming has made autonomous vehicles possible and the more sophisticated ones can take off, fly a programmed mission, return, and land without further instruction. Hybrid vehicles can also be designed which are capable of autonomous flight, but which may also accept instructions or programming changes en route. Autonomous vehicles are useful in commercial and military applications where larger craft are not cost effective or where there is risk of injury to a pilot and crew.

This is a U.S. Air Force Tier III Minus, or "DarkStar," which doesn't require a pilot or remote-control mechanism to fly missions. The DarkStar can autonomously execute preprogrammed flight maneuvers in conjunction with differential Global Position System (dGPS) data. It is a high-altitude, high-endurance air vehicle optimized for reconnaissance up to a distance of about 500 nautical miles in highly defended areas. Sensors can optionally be electro-optical or synthetic-aperture radar (SAR). Darkstar's initial flight was in March 1996. [U.S. DoD 1996 news photo, released.]



This unpiloted air vehicle is a U.S. Department of Defense Global Hawk, a high-altitude, long-endurance aerial reconnaissance system designed to provide high-resolution, near-realtime imagery of large areas. It includes a variety of surveillance technologies, including synthetic-aperture radar (SAR), electro-optical, and infrared sensors. It can survey an area of about 40,000 square nautical miles in a day to a resolution of about one meter. [U.S. DoD 1997 news photo by David Gossett, courtesy of Teledyne Ryan Aeronautical, released.]

5.c. Commercialization

Now that it has become less expensive to create aircraft and satellite images and since federal regulations have been relaxed somewhat to promote commercialization, there are a number of sources of aerial imagery available to members of the general public. These can be purchased to aid in land management, law enforcement, construction, resource reclamation, wildlife habitat assessment, and even to provide pictures of a person's home from the air.

Satellite photos can be purchased for as little as $20 for about a half block square from sources on the Web that are listed in the resources section at the end of this chapter. It is important to have a good idea of the specific part of the world you wish to image and to remember that if you live in an area with constant cloud cover, it may not be easy to obtain a clear picture. Keep in mind also that the images on hand in the databanks aren't necessarily recent. You may have to use remote-controlled airplanes or balloons to get timely photos.

Licensed Commercial Satellite Systems (1984 to 1999)

Company	Applied	Approved	System	Web Site
WorldView Inc./Earth Watch	15-Jul-92	04-Jan-93	EarlyBird	www.digitalglobe.com/ewhome.html
EOSAT	06-Oct-92	17-Jun-93	Landsat 6	www.spaceimaging.com/
Lockheed/Space Imaging	10-Jun-93	22-Apr-94	IKONOS-1	www.spaceimaging.com/
OrbImage	14-Dec-93	05-May-94	OrbView-1	www.orbimage.com/
OrbImage	14-Dec-93	01-Jul-94	OrbView-2	www.orbimage.com/
Astrovision	26-Mar-94	25-Jan-95	N/A	
EarthWatch/Ball	18-May-94	02-Sep-94	QuickBird	www.digitalglobe.com/ewhome.html
GDE Sys. Imag./Marconi N.A.	02-Mar-95	14-Jul-95	N/A	www.marconi-is.com/
Motorola	31-Mar-95	14-Jul-95	N/A	
Boeing Commercial Space	19-Jan-96	16-May-96	N/A	www.boeing.com/defense-space/space/
CTA Corporation	06-Sep-96	09-Jan-97	N/A	
RDL Space Corporation	01-Mar-97	16-Jun-98	RADAR-1	www.rdl.com/
Space Technology Dev. Corp.	11-May-98	26-Mar-99	NEMO	www.spacetechnology.com/

[Source: NOAA; National Environmental Satellite, Data, and Information Services, 13 May 1999.]

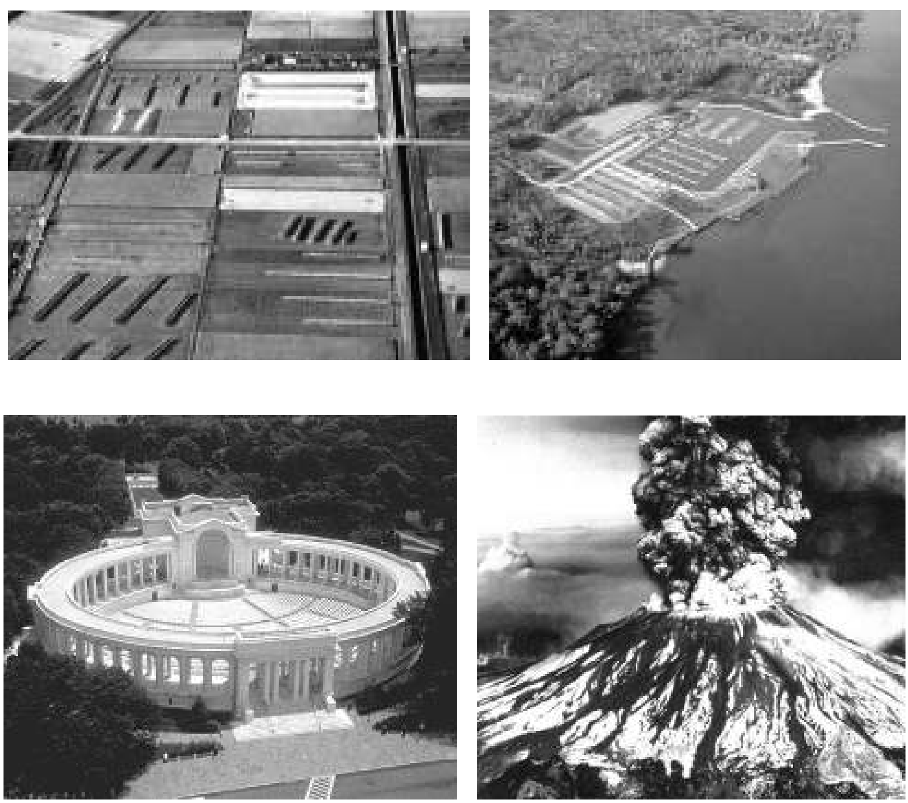
6. Applications

Aerial photography can be applied to almost every field of scientific study and to thousands of commercial and industrial projects. It should also be remembered that aerial photographs are not just taken from planes, helicopters, and remote-controlled balloons, sometimes they are taken while the photographers are skydiving, leaning over tall buildings, climbing towers or bridges, or perching on the top of trains, as some of the following examples show.

Agriculture, Wildlife and Park Management

Aerial surveys make it possible to evaluate property before it is purchased and to manage it for specific uses, including crops, livestock, wildlife, and parks. They also make it easier to assess damage from storms, pests, or disease and can aid in limiting the spread of the damage.

Many of the resource management concepts that apply to agricultural lands are also used in the development and management of parks, campgrounds, and wilderness areas, including construction and disaster response, and may also include search and rescue.



Top Left: The Sagami River rice harvest in Japan 1997. Top Right: The Genava State Park small harbor and breakwaters project which combined federal and local funding. Bottom left: The Arlington National Cemetery amphitheater, 1997. A dramatic photo of the Mt. St. Helen's volcanic eruption. The eruption necessitated search and rescue, disaster relief, and restoration efforts from a number of agencies. The U.S. Army Corps of Engineers is involved in a number of these federal projects. [First three photos U.S. Army Corps of Engineers news photos 1997 by Doyal Dunn, 1992 by Ken Winters, and 1997 by Susanne Bledsoe, released. Mt. St. Helens photo May 1980 U.S. Geological Services (USGS), released.]

Archaeology

Aerial photography has many benefits in archaeology, from locating suitable dig sites to finding patterns in the topography that have been left by ancient civilizations that are not visible from the ground. By adding infrared photographs, impressions of old villages that are otherwise invisible can sometimes be seen, as well.


Sometimes dam, bridge, and flood construction or damage restoration projects will result in the discovery of new archaeological sites or, conversely, will be planned for areas that are already established as archaeological sites. Aerial photos can help determine the importance and range of the sites and aid in recording the progress of digging up artifacts and fossils. Left: An archaeological dig in the State Road Coulee flood control area, Wisconsin, showing the 'grid' method. Right: A Gray's Landing Lock and Dam dig. [U.S. Army Corps of Engineers news photos, 1991 by Ken Gardner and 1988 by Bill Lukitsch, released.]

Engineering and Construction

There are almost unlimited opportunities for using aerial photographs for monitoring engineering and construction projects. From building bridges and dams to constructing flood control channels and hurricane barriers, aerial photos make it possible to evaluate the landscape and settlements before doing any work, to monitor projects in progress, and to record finished projects and any problems or adjustments that occur over time.

Aerial photos can also provide a means to record and evaluate demolition projects and to assess damage from hurricanes, floods, and earthquakes in the process of handling insurance claims and making plans for reconstruction.


Left: The Alcan Highway White Pass Line in the Yukon, in 1942. This very scenic and sometimes hair-raising route is now the main artery to the new Alcan International Highway. Right: The Blue River Dam project in Oregon, a flood control and recreational project. [USACE Office of History photo; Army Corps of Engineers news photo by Bob Heims, released.]

Top left: An aerial view of the damage caused by the Kansas City District flood in 1993. Top Right: A new levee installed for Westwego/Harvy hurricane protection in 1998. Bottom Left: A Pentagon renovation project. Bottom Right: San Francisco and the Golden Gate Bridge. [U.S. Army Corps of Engineers news photos 1997 by Susanne Bledsoe and Robert Campbell.]

Environmental

There are many environmental applications for aerial photographs.

Left: Operation Fish Run, in which juvenile salmon were shipped downstream on a barge for release below the dam, 1984. Right: A General Motors chemical waste site in which silt curtains are being installed prior to a planned dredging cleanup in this section of the St. Lawrence River. [U.S. Army Corps of Engineers news photos, released.]

Aircraft and satellite environmental imaging applications include geological and marine ecology assessment, pollution and toxic wastes monitoring, habitat restoration, dike and levee construction, and wildlife tracking and conservation. Aerial photographs have been used to survey reefs and active volcanoes, to track whales and bears, and to aid in decision-making on the setting aside of habitat for parks and preserves. They have also been used to locate industrial wastes and to provide valuable data that aid in waste reduction and removal.

Top Left: Colonel Crear arriving for the Mississippi Delta Wildlife and Wetland Tour in the Vicksburg District in 1987. Top Right: Alligator mom in the Mississippi wetlands, just one of the many species observed during the Wetland Tour. Bottom: Erosion protection measures are illustrated where the mouth of the Mississippi River flows into the Gulf of Mexico, including banks and rock dikes, 1994. [U.S. Army Corps of Engineers news photos, released.]

Military Reconnaissance

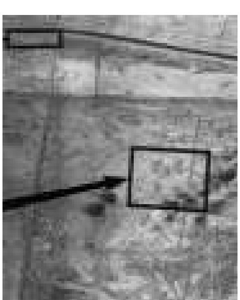
Aerial images are used in almost every aspect of military reconnaissance and many of the technologies developed for use on fast planes are highly sophisticated, with high resolution, fast frame rates, and computer processing of the resulting images.

Since even before World War I, images from high vantage points were being used for tactical and strategic missions. As the sophistication of the technologies improved, the number of applications for which they were used have steadily increased. At the present time, aerial imaging is primarily used to patrol borders and to assess foreign military activities, weapons storage installations and armament purchases and manufacture, including nuclear and chemical production facilities. The military makes regular use of both air and space images from a variety of craft and communications systems. The images come not only from classified photo systems and surveillance craft, but also from commercial sources.

Left: U.S. surveillance photo of the Shifa Pharmaceutical Plant in the Sudan. Right: U.S. aerial photo of the Zhawar Kili Support Complex, Afghanistan. These images were used by the U.S. Secretary of Defense and General H. Shelton of the U.S. Army to brief reporters in the Pentagon on the U.S. military strike on a chemical weapons plant in the Sudan and training camps in Afghanistan. [U.S. DoD 1998 news photo, released.]

A P-3C Orion patrol aircraft flies over a U.S. and a Korean submarine during RIMPAC '98 exercises. Historically, many types of aircraft have been used for submarine spotting including fixed-wing planes, helicopters, rigid and nonrigid airships, and balloons. Now remotely operated and autonomous air vehicles are being added to the arsenal. [U.S. DoD 1998 news photo by August Sigur, released.]

Top: These U.S. Navy F-14B Tomcats were used to patrol over a Persian Gulf no-fly zone, operating from a nearby aircraft carrier. Bottom: U.S. Air Force F-15C Eagles flying on a patrol mission over Southern Iraq. Imaging 'pods' are often attached under the belly of aircraft. [U.S. DoD 1998 news photos by Bryan Fetter and Greg L. Davis, released.]



The left photo is a U.S. Department of Defense image of the Khamisiyah Ammunition Storage Complex in Southern Iraq, taken 10 Feb. 1991 and released to the public as a news photo in 1996. The smaller rectangle in the upper left is a region called 'The Pit.' The photo on the right is reported by the DoD as being a U.S. Navy photo of a submarine purchased from Russia by Iran that was being towed through the Mediterranean Sea toward Egypt. [U.S. DoD 1996 news photos, released.]

Military Communications

Wireless links through satellites are now an essential aspect of military communications.

This mobile 20-foot satellite antenna designed for military communications was set up by U.S. Air Force personnel from several Combat Communications Squadrons. Called the *Quick Reaction Satellite Antenna*, it was used in southwest Asia in Feb. 1998 in support of Operation Southern Watch. [U.S. DoD 1998 news photo by Efrain Gonzalez, U.S. Air Force.]

Space Surveillance

Amateur, commercial, and military surveillance of the far reaches of space has yielded an astonishing amount of information about our origins and the billions of galaxies and solar systems that were once beyond the reach of our technology and almost beyond the reach of our imaginations. The continued evolution of telescopes and the launching of the early space vehicles prompted the development of both ground and space-based space surveillance strategies and complexes. Information on space surveillance is provided in the Infrared, Visual, and Ultraviolet Surveillance chapters.

Marine Patrol

There are many activities that are patroled in marine environments.

Left: The HC-130 Hercules is used by the U.S. Coast Guard as a long-range surveillance and transport aircraft for search and rescue, law enforcement, marine environment protection, military readiness, and refugee monitoring. Right: The HH-65A helicopter serves similar functions as the Hercules and can take off from land or from medium-endurance Coast Guard cutters. [U.S. Coast Guard news photos by PAC Tod Lyons and USCG, released.]

Aerial surveillance vessels and equipment are used regularly in the enforcement of coastal territories and fishing rights, wildlife conservation, smuggling detection and prevention, and search, rescue, and salvage operations.

The most common surveillance technologies used in marine patrol are sonar, radar, and aircraft-mounted optical devices (mostly visual and infrared spectra).

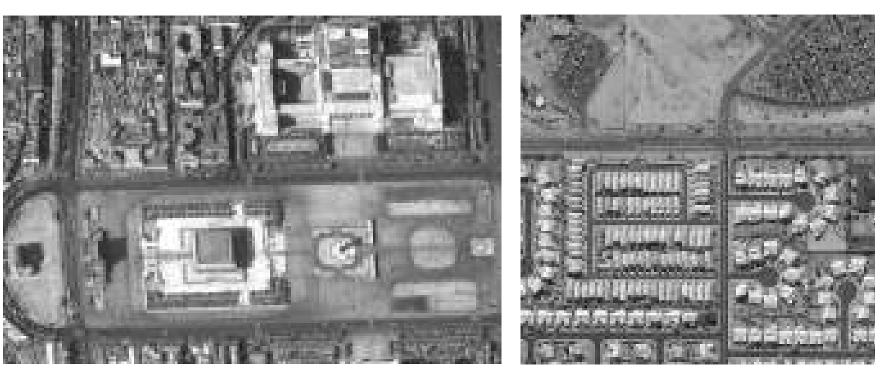
Refugee Monitoring

Most nations are concerned about refugee movements, not only because they can represent an influx of illegal immigrants, but also because refugees may be suffering from significant economic hardships and health problems that may pose risks to themselves and others.

Refugees traveling on foot on a road near Goma in Zaire (left) and in a refugee tent camp in Kilambo (right) as photographed by the U.S. Navy. [U.S. DoD 1996 news photos, released.]

Commercial Imaging Products

These are just two examples of the many thousands of types of imagery that are now available from satellite databanks, but they are sufficient to give an idea of the resolution that is now possible for commercial and personal applications. When reproduced full size, they are sufficiently detailed to distinguish bushes, architectural structures, and individual cars.



Left: Monochrome image of Tiananmen Square and the Temple of Heaven in Beijing, China, imaged by the IKONOS satellite 22 October 1999. Right: Monochrome image of residential area from the CARTERRA™ Precision database. Such photos can be used for census confirmation, property assessment, community development, insurance adjustments (e.g., after natural disasters), licensing, permits, and other applications. [© 1999 Space Imaging news photos, used as per copyright requirements. http://www.spaceimaging.com/]

7. Problems and Limitations

Technical Limitations

Aerial surveillance encompasses such a diverse spectrum of technologies that it is difficult to make generalizations about the limitations of aerial surveillance devices. Limitations of specific categories of devices are discussed in other chapters. In general, resolution, storage capacity, image stabilization, and frame speed have been the main limitations, but even these have been overcome to a remarkable extent in the last five years. The price of aerial images is no longer even a significant limitation as digital storage has dropped dramatically in price, as has the cost of commercial satellite imagery.

Satellites are not suitable for all types of observation. Aircraft, dirigibles, and the newer autonomous and remote-controlled air vehicles will continue to be used for many applications, especially those that require realtime information associated with specific locations. They are especially favored for scientific observation, wildlife and border patrol, news broadcasting, and tactical reconnaissance activities.

Political Considerations

One of the problems inherent in global economics is that those who have more continue to have the resources to widen the gap. Thus, discrepancies between the economic resources of developed and undeveloped nations continue to widen as technology advances. This is also true in the commercial use of aerial imaging. Countries that can get the information from aerial images have some clear political and economical advantages over those that can't. There are entrepreneurial opportunities provided by the new imaging technologies that favor those with existing resources.

Because it is a relatively new field, many trade secret protections do not apply to satellite imagery. If you want to get a picture of the production yard of a competing contractor in your own country, or in another, there are currently few restrictions on doing so. However, the long-term trade imbalances that could result from open access to images may come under scrutiny in the near future.

8. Restrictions and Regulations

International law is still being developed with regard to aerial surveillance and aerial images. At the present time, it generally favors the open use of imaging from outer space, since the benefits of international open access are many.

In Presidential Decision Directive (PDD) 54, President Carter transferred operation of Landsat systems to the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. NOAA was directed to further private sector access to civil remote-sensing to move the technology into the hands of the private sector to encourage growth of the industry. In recent years, commercialization has steadily grown.

Two United Nations documents of relevance to aerial surveillance include

The Outer Space Treaty of 1967 - States that outer space cannot be claimed as national territory, consequently, satellites can travel over any territory.

U.N. General Assembly 1986 - The Assembly adopted a set of legal principles on civilian remote sensing that do not require prior consent. It declares that the sensed State shall have access to them on a nondiscriminatory basis and on reasonable cost terms.

In 1992, the U.S. Congress passed the *Land Remote Sensing Policy Act* (P.L. 102-555), which was signed into law by President Clinton. The Act recognized the importance of satellite imagery in studying the environment and in carrying out activities related to national security. The Act further acknowledged some of the problems associated with previous attempts at full commercialization and the loss of global leadership of the U.S. satellite imaging market. It consequently transferred control of the program to the National Aeronautic and Space Administration (NASA) and the Department of Defense (DoD). The authority for licensing private satellites remained with the Secretary of Commerce.

Since a great deal of aerial surveillance involves radio-transmitting the data to Earth, the Federal Communications Commission (FCC) regulations apply to many aerial surveillance transmission and should be consulted. The regulation of the bandwidth has not been an easy challenge. Radio wavelengths are a limited resource and are tightly controlled. Amateurs, in particular, tend to lose operating frequencies to larger commercial interests through political pressure on the FCC. This applies to other surveillance technologies besides just aerial surveillance. For example, in 1998, the FCC temporarily restricted amateur access to 76 to 77 GHz to provide increased bandwidth for commercial development and use of frequencies for applications such as vehicle radar collision-avoidance systems in spite of reports that incompatibility would not be a problem. Sometimes trade-offs are negotiated, as when the FCC upgraded amateur and amateur-satellite allocation of 77.5 to 78 GHz from secondary to coprimary.

9. Implications of Use

The Emerging Surveillance Society

The availability of surveillance imagery to the general public opens the door to broader 'policing' of commercial, military, and civilian activities and the more stringent monitoring of abuses of our global populace and global resources. Nonprofit organizations and watchdog groups are taking advantage of the wider dissemination of information to enlist volunteer help in reducing weapons proliferation, human rights abuses, and environmental exploitation and destruction.

Amnesty International, concerned about allegations of serious human rights violations in Kosovo, made an urgent plea to those with good reconnaissance and intelligence capabilities to monitor humanitarian concerns in the area and to divulge the results to the public, where appropriate.

There are few restrictions on how a generic technology like an aerial photo can be used. Thus, they are at great risk of being abused. For example, an imaged country planning a strike on another nation could request and purchase pictures of that nation from a commercial entity, without having to state the reason for the purchase.

Future Technologies

Unpiloted air vehicles (UAVs) and DARPA micro air vehicles (MAVs) as small as six inches have risen in importance. Even smaller ones that fly like hummingbirds or bees have been considered. If these technologies are successful, there may come a time when tiny spies can be deployed anywhere.

Into the new century, the emphasis on aerial surveillance is definitely shifting from aircraft to spacecraft. An orbiting satellite cannot be shot down the same way a plane can be shot down over foreign territory. If an orbiting satellite can unobtrusively record and transmit images of one meter or better, there is less reason to hire planes and helicopters to chart the globe. If an orbiting vessel can function for years off of a few solar panels, it's economical to operate compared to a piloted jet plane. There are many international restrictions on aircraft that do not apply to satellites; once launched, the cost of keeping a satellite in orbit is negligible compared to the cost of keeping a plane or helicopter in the air for 24 hours a day.

10. Resources

Inclusion of the following companies does not constitute nor imply an endorsement of their products and services and, conversely, does not imply their endorsement of the contents of this text.

10.a. Organizations

American Society for Photogrammetry and Remote Sensing (ASPRS) - A scientific association found in 1934 with over 7,000 international members. ASPRS seeks to seeks to understand and promote the responsible use of photogrammetry, remote-sensing, and geographic information systems (GIS). ASPRS holds an annual conference and publishes a peer-reviewed journal.
http://www.asprs.org/

Commercial Satellite Imagery Library (CSIL) - Hosted by the Defense Intelligence Agency, this library is available on the Intel Link Network.

National Aeronautics and Space Administration (NASA) - NASA handles a vast research, development, and applications structure devoted to space science and related spinoff technologies. NASA cooperates with many agencies and contractors and disseminates a great quantity of news and educational information related to its work. Of interest are the many satellite and other aerial sensing systems that have been used and are continually being developed. http://www.nasa.gov/

National Imagery and Mapping Agency (NIMA) - A resource and repository for geospatial and imagery information to support U.S. national security objectives. Many of the NIMA aeronautic, nautical, hydrographic charts, and publications are available for purchase to the public through NOAA Distribution. NIMA topographic maps and gazettes are available through the USGS.
http://www.nima.mil/

National Photographic Interpretation Center (NPIC) - The Center is managed by the Directorate of Science and Technology and functions with the National Reconnaissance Office (NRO), which designs and operates the nation's reconnaissance satellites and supplies them to patrons such as the CIA and the Department of Defense. The NRO is part of the U.S. Intelligence Community.
http://www.nro.odci.gov/

Nigel J. Clarke Publications - This is a commercial U.K. organization selling Luftwaffe Aerial Reconnaissance photography taken from 1939 to 1942. Photos include grain silos, barrage balloon depots, barracks, wireless stations, etc. around Bristol, Cardiff, Dover, and Dublin, etc. They are also available in book form in two volumes as "Adolf Hitler's Holiday Snaps."

ORBIMAGE - An affiliate of Orbital Sciences Corporation which provides imagery and services from a global system of advanced imaging satellites, ground stations and Internet-based distribution channels. Their first OrbView system was launched in 1995, the second in 1997, with more planned. OrbView-2 provides daily color images of Earth's topography. http://www.orbimage.com/

Skyscan Aerial Photography - A commercial U.K. company offering resources for balloon-based aerial photography, an extensive aerial photo library and information on infrared photography.
http://www.skyscan.co.uk/

Smithsonian National Air and Space Museum - The largest collection of historic air and spacecraft in the world. It is a center for research into space flight, located in the National Mall in Washington, D.C. http://www.nasm.si.edu/

Space Imaging - Commercial satellite images, including the CARTERRA™ series of images.
http://www.spaceimaging.com/

TopoZone - Resources for outdoor enthusiasts and other users of topographic maps available through cooperation with the USGS. TopoZone provides detailed interactive maps of the entire United States. http://www.topozone.com/

United States Air Force Museum - Among the exhibits is a replica of the 1897 glider designed by Octave Chanute.

University of Texas History of Aviation Collection - This extensive collection includes *over two million items related to aviation history* comprising more than 200 donations of private collections. It includes documents and photos related to lighter-than-air vessels, general aviation, World Wars I and II, the Air America Association, and much more. Researchers and potential donors are invited to contact the Eugene McDermott Library Special Collections section.
http://www.utdallas.edu/library/special/aviation/

U.S. Geological Survey (USGS) - The USGS has extensive data repositories of satellite and other images gathered, processed, and archived since the 1960s beginning with the CORONA era of satellite-imagery. They are used by many levels of government and by scientists and commercial industry. They include data such as demographics, environmental wildlife and ecosystem trends, hazards, resources, and much more. Many of these various types of images and topographic maps are available for download or print/negative/positive purchase, usually at cost. http://www.usgs.gov/

10.b Print Resources

These annotated listings include both current and out-of-print books. Those which are not currently in print are sometimes available in local libraries and second-hand book stores, or through interlibrary loan systems.

Arnold, Robert H., "Interpretation of Airphotos and Remotely Sensed Imagery," Prentice-Hall, 1996, 262 pages.

Arthus-Bertrand, Yann; Bessis, Sophie; Baker, David, "Earth From Above," London: Thames & Hudson, 1999, 424 pages. Not a technical reference, but one of the best of the aesthetic, political essays of the Earth as told with over 200 aerial photographs captioned by scientists and sociologists; it appeals to all age groups.

Avery, Thomas Eugene; Berlin, Graydon Lennis, "Fundamentals of Remote Sensing and Airphoto Interpretation," New York: MacMillan Pub. Co., 1992, ca. 496 pages.

Ball, Desmond, "Soviet Signals Intelligence (SIGINT)–Intercepting Satellite Communications," out of print.

Ball, Desmond, "A Base for Debate: The U.S. Satellite Station at Nurrungar," Sydney: Allen & Unwin, 1987, 122 pages.

Beschloss, Michael R., "Mayday: Eisenhower, Khruschev and the U-2 Affair," New York: Harper & Row, 1986. The events, politics, and people involved in the shooting down of the U-2 spy plane.

Bewley, Robert; Donoghue, Danny; Gaffney, Vince; van Leusen, Martijn; Wide, Alicia, Editors, "Archiving Aerial Photography and Remote Sensing Data: A Guide to Good Practice," Oxbow Books Ltd., 1999, 46 pages. A peer-reviewed reference on the issues of standardization and archiving, preservation, and retrieval of archaeological survey data.

Bowden, Mark, "Black Hawk Down: A Story of Modern War," New York: Atlantic Monthly Press, 1999, 386 pages. An account of a 1993 firefight in Somalia which in part utilized satellite imagery, SIGINT, camera-equipped helicopters, and other surveillance technologies. The interesting account is very relevant to aerial surveillance and application of current technologies.

Burrows, William E., "Deep Black: Space Espionage and National Security," New York: Random House, 1986.

Burrows, William E., "Deep Black: The Startling Truth Behind America's Top-Secret Spy Satellites," Berkeley Publishing Group, 1988. Aerial surveillance from the World War to the present and how politics have been influenced by information from spy satellites.

Cameron, Robert, “Above London,” “Above Paris,” “Above Los Angeles,” et al. As a photographer, Cameron has coauthored, over the last two decades, an extensive series of photographs of major cities from the air, available from a variety of publishers. There is a similar series by David King Gleason which includes “Over Boston,” “Over Miami,” and others.

Campbell, Melville, “City Planning and Aerial Information,” out of print.

Cindrich, Ivan; Del Grande, Nancy K., “Aerial Surveillance Sensing Including Obscured and Underground Object Detection: 4,6 April 1994 Orlando, Florida,” Bellingham, Wa.: SPIE, Volume 2217. This is only one of many dozens of technical publications and conference proceedings by the Society of Photo-Optical Engineers that relate to remote sensing and aerial imaging.

Collins, Mary Rose, “The Aerial Photo Sourcebook,” Scarecrow Press, 1998, 224 pages. A beginner’s illustrated reference bibliography of over 800 books and articles related to aerial photography. Includes government and commercial sources and collections.

Conway, Eric D.; Maryland Space Grant Consortium, “An Introduction to Satellite Image Interpretation,” Baltimore, Md.: Johns Hopkins University Press, 1997, ca. 256 pages.

Darvil, Timothy, “Prehistoric Britain from the Air: A Study of Space, Time and Society (Cambridge Air Surveys),” Cambridge: Cambridge University Press, 1996.

Day, Dwayne,; Logsdon, John M.; Latell, Brian, Editors, “Eye in the Sky: The Story of the Corona Spy Satellites,” Washington, D. C.: Smithsonian Institution Press, 1998. Essays dealing with the technical and political aspects of the surveillance satellites.

Donald, David, “Spyplane: The Secret World of Aerial Intelligence-Gathering,” Middlesex, U.K.: Temple Press, 1987, 127 pages. Out of print.

Erickson, Jon, “Exploring Earth from Space,” Blue Ridge Summit: Tab Books Inc., 1989, 192 pages. Covers early space travel, planetary probes, spy and communications satellites, image interpretation, different spectra used for aerial observation, and sample applications. The book is well illustrated with line drawings and photographs and written at a clear, succinct college/high school reading level.

Gerken, L., “Airships: History and Technology,” American Scientific Corporation, 1990.

Goddard, Brigadier General George W. (USAF Retired); Copp, DeWitt S., “Overview: A Life-long Adventure in Aerial Photography,” New York: Doubleday & Co., 1969. Out of print.

Holz, Robert K., “Surveillant Science: Remote Sensing of the Environment,” John Wiley and Sons, 1985, 413 pages. Updated version of Houghton Mifflin 1973 publication. Out of print. While an older text, it is worthwhile in that it brings together basic technical discussions from many different sources and experts in the various fields, including aerial surveillance, in a graded manner from basic physics concepts to more technical aspects of implementation.

Hough, Harold, “Satellite Surveillance,” Port Townsend, Wa.: Loompanics, 1991, 196 pages. Loompanics tends to publish information on gray area subjects that traditional publishers may choose not to print. Their books are often intended to point out issues of concern to the general public; their authors vary somewhat in expertise, but most appear credible. The book describes how government tools are now within the purview of the public and how private citizens can gain access to aerial ‘spy’ services and images (this is now somewhat dated).

Kagan, Boris M., “Soviet ABM Early Warning System: Satellite-based Project,” out of print.

Lashmar, Paul, “Spy Flights of the Cold War,” Great Britain: Sutton Publishing Ltd., 1998 (new edition). Aerial surveillance between the Soviets and the western nations.

Layman, R.D., “Naval Aviation in the First World War: Its Impact and Influence,” London: Chatham Publishing and Annapolis, Md.: The Naval Institute Press, 1996, 224 pages. An illustrated, well-researched overview of many aspects of naval aviation, strategy, and operations.

Lillesand, Thomas M.; Kiefer, Ralph W., “Remote Sensing and Image Interpretation,” New York: John Wiley & Sons: 1999 (4th edition), 736 pages. Illustrated, plus color plates. An introduction to remote sensing for students studying upper level resource management who are already familiar with the remote-sensing nomenclature. Includes photointerpretation, hyperspectral scanning, satellite systems, and classification topics. More theoretical than how-to.

Lind, Marilyn, "Using Maps and Aerial Photography in Your Genealogical Research," Linden Tree, 1985. Note, there is also a 1987 supplement to this book.

Lloyd, Harvey, "Aerial Photography: Professional Techniques and Commercial Applications," New York: Amphoto Books, 1990, 144 pages. This book is a beautiful showcase of aerial photographs and discussion of some of the basic equipment, but note that it is not an in-depth technical book on how to recreate images, as the title might suggest. The "Kodak Guide to Aerial Photography," by Rokeach, 1998, is similar in that there are many excellent examples, but less technical detail on improving professional technique.

Parkinson, Claire L., "Earth from Above: Using Color-coded Satellite Images to Examine the Global Environment," University Science Books, 1997, 175 pages.

Pedlow, Gregory W.; Welzenbach, Donald E., "The Central Intelligence Agency and Overhead Reconnaissance: The U-2 and OXCART Programs, 1954-1974," CIA, 1992. Available now in Adobe Acrobat format as "The CIA and the U2 Program," 1998.

Peebles, Curtis, "The CORONA Project: America's First Spy Satellites," Annapolis, Md.: Naval Institute Press, 1997, 352 pages.

Pocock, Chris, "Dragon Lady: The History of the U-2 Spy Plane," England: Airlife, 1989, 128 pages. The development and mission of the U-2.

Rich, Ben R. with Janos, Leo, "Skunk Works: A Personal Memoir of My Years at Lockheed," New York: Little, Brown and Co., 1994, 372 pages. A history of spy and stealth planes and the secret division at Lockheed.

Richelson, Jeffrey T., "America's Secret Eyes in Space: The U.S. Keyhole Satellite Program," out of print.

Richelson, Jeffrey T., "America's Secret Eyes in Space: The U.S. Spy Satellite Program," New York: Harper and Row, 1990.

Richelson, Jeffrey T., "America's Space Sentinels: DSP Satellites and National Security," University Press of Kansas, 1999, 330 pages. Richelson is associated with the National Security Archive and has written numerous books on the topics of intelligence and national security. This text offers a comprehensive look at satellite technologies, infrared surveillance, and early warning systems, beginning in the 1960s up to the SBIRS of the current century.

Ruffner, Kevin C., Editor, "CORONA: America's First Satellite Program," Washington, D. C.: CIA History Staff, 1995. Declassified images and documents related to the CORONA project.

Skrove, Johnny, "The Kola Satellite Image Atlas: Perspectives on Arms Control and Environmental Protection," out of print.

Skyscan Photography; Burton, Neil, "English Heritage from the Air," Sidgwick & Jackson, 1994. Picture book of about 400 aerial photos of British heritage sites.

Steinberg, Gerald M., "Satellite Reconnaissance: The Role of Informal Bargaining," Praeger Pub. Text, 1983, 208 pages.

Thompson, Don W., "Skyview Canada: A Story of Aerial Photography in Canada," Ottawa: Information Canada, 1975, 270 pages. The author describes the history, equipment, and persons involved in aerial surveying in Canada. Illustrated.

van Zuidam, R.A., "Aerial Photo-Interpretation in Terrain Analysis and Geomorphologic Mapping," out of print.

Yost, Graham, "Spies in the Sky (World Espionage Series)," New York: Facts on File, Inc., 1990, 140 pages. A light but interesting overview of aerial intelligence written at a young adult level that can serve as an quick intro for anyone new to the field of aerial surveillance. Describes the U-2 missions, spy satellites, and related topics.

Articles

Air Intelligence Agency, "History of the Air Intelligence Agency: RCS: HAF-HO(A&SA)7101," declassified U.S. Government document, 15 December 1995.

Brown, Stuart F., "America's First Eyes in Space," *Popular Science*, Feb. 1996, pp. 42-47. Surveys and illustrates the development of U.S. satellite surveillance.

Bulloch, Chris, "View from the Top–Intelligence Gathering from Aircraft and Spacecraft," *Interavia*, V.39, Jan. 1984, pp. 543-548.

Cairns, Donald W., "UAVs–Where We Have Been," *Military Intelligence*, Mar. 1987, pp. 18-20. A brief history of UAVs in the U.S. military.

Day, Dwayne A., "CORONA: A View Through the KEYHOLE," *Intelligence Watch Report Quarterly*, V.2 (1) 1995, pp. 17-21.

Evans, Charles M., "Air War Over Virginia," *Civil War Times*. The author is the founding curator of the Hiller Air Museum in Redwood City, California. This article is a fascinating account of the early air balloons that were used in the civil war and the rivalry that existed not just between warring sides, but between individual balloon promoters on the Union side.

Falk, Richard A., "Space Espionage and the World Order: A Consideration of the Samos-Midas Program," *Essays on Espionage and International Law,* 1962, pp. 45-82.

Greer, Jerry D., "Airborne Reconnaissance and Mount Everest," in Fishell, Wallace G.; Henkel, Paul A.; Crane, Jr., Alfred C., Editors, "Airborne Reconnaissance XVIII," *Proceedings SPIE,* 1994.

Klass, Philip J., "Military Satellites Gain Valuable Data," *Aviation Week & Space Technology*, 15 Sep. 1969, pp. 55-61.

Krepon, Michael, "Spying from Space," *Foreign Policy*, V.75, Summer 1989, pp. 92-108. The author proposes that a three-tiered system is developing with regard to space surveillance.

McDonald, Robert A., Editor, "Between the Sun and the Earth: The First NRO Reconnaissance Eye in Space," *American Society for Photogrammetry and Remote Sensing Monograph,* 1997. The story of the first U.S. reconnaissance satellite.

Ono, Philbert, "PhotoHistory," *PhotoGuide Japan*, 1996. http://photojpn.org/

Orlov, Alexander, "The U-2 Program: A Russian Officer Remembers," Center for the Study of Intelligence. An interesting historical perspective on the U-2 spy missions over Soviet territory.

Ruffner, Kevin C., Editor, "CORONA and the Intelligence Community: Declassification's Great Leap Forward," *Studies in Intelligence 39*, No. 5, 1996, pp. 61-69. Preparation of CORONA materials released to the public in May 1995.

Sweetman, Bill, "Spies in the Sky," *Popular Science*, Apr. 1997, pp. 42-48. A good summary overview of a variety of U.S. surveillance satellites.

Wheelon, Albert D., "CORONA: The First Reconnaissance Satellites," *Physics Today*, Feb. 1997, pp. 24-30. The author was Deputy Director for the CIA Science and Technology department in the early 1960s. He provides an overview of the development and operation of the CORONA surveillance satellite.

Journals

"Aerospace Technology Innovation," is a NASA Commercial Technology Division publication. The publication can be downloaded in Adobe PDF format. Previous issues dating back to 1993 are available online. http://ctd.hq.nasa.gov/innovation/index.html

"Air & Space Magazine," published by the Smithsonian Institution.

"Aviation Week and Space Technology," published by McGraw-Hill.

"Imaging NOTES," Earthwide Communications, Colorado. Consumer/professional magazine with articles on the applications of satellite imagery in a broad range of fields, including the environment,

mapping, data integration, utilities, telecommunications, etc. Six issues per year. http://www.imagingnotes.com/

"The International Journal of Aerial and Space Imaging, Remote Sensing, and Integrated Geographical Systems."

10.c. Conferences and Workshops

Many of these conferences are annual events that are held at approximately the same time each year, so even if the conference listings are outdated, they can still help you determine the frequency and sometimes the time of year of upcoming events. It is very common for international conferences to be held in a different city each year, so contact the organizers for current locations.

Many of these organizations describe the upcoming conferences on the Web and may also archive conference proceedings for purchase or free download.

The following conferences are organized according to the calendar month in which they are usually held.

"Satellite 2000 Conference" Washington, D.C., 1 Feb. 2000.

"14th Annual GIS 2000" Toronto, Ontario, 13-16 March 2000. Topics in 2000 include forestry, natural resources, business geographics, Internet GIS, Telco and more. Applications and solutions-oriented program. http://www.gis2000.com/

"GITA Annual Conference XXIII/GITA 2000" Denver, Colorado, 26-29 March 2000. Sponsored by the Geospatial Information & Technology Association to provide education and information exchange on the use and benefits of geospatial information and technology in telecommunications, infrastructure, and government utility applications. http://www.gita.org/

"National Space Symposium" Colorado Springs, Colorado. 3-6 April, 2000. http://www.spacefoundation.org/

"ASPRS 2000. Start the 21st Century: Launching the Geospatial Information Age" American Society for Photogrammetry & Remote Sensing, Washington, D.C., May 2000. ASPRS holds an annual conference and publishes a peer-reviewed journal devoted to Earth and space remote-sensing technologies and applications. http://www.asprs.org/

"WorldSat 2000" New York, NY, 15-17 May 2000.

"No More Secrets? Policy Implications of Commercial Remote Sensing Satellites," Carnegie Endowment, May 1999. International conference sponsored by the Carnegie Endowment Project on Transparency focusing on the technical and policy issues associated with commercial high-resolution satellites. http://www.ceip.org/

"AFCEA" Association for Communications, Electronics, Intelligence & Information Professionals, June 2000, Washington, D.C.

"20th Annual ESRI International User Conference" 26-30 June 2000, San Diego, California. Geographic Information Systems (GIS) practical applications. Session topics with over 800 papers include the fields of agriculture, business, cartography, databasing, archaeology, forestry, law enforcement, telecommunications, transportation, public works, and more. http://www.esri.com/eventus/uc

"Interagency Workshop on Requirements for Measuring/Monitoring Fires from Space" Sponsored by the NASA Langley Research Center and the U.S. Forest Service. The monitoring of fires from space for detection, monitoring, and surveillance. NASA Langley, 4-5 Sept. 1997.

"NSGIC 2000" National States Geographic Information Council, 29 Sept.-4 Oct. 2000, Lake Tahoe, Nv. http://www.nsigic.org/

10.d. Online Sites

Airship Heritage Trust. A charitable organization in Britain which provides an illustrated history of the development of British airships and ways in which they were used in military and commercial applications. http://www.aht.ndirect.co.uk/

Aviation Museums. Sponsored by the Aeroclub of Chania, this site lists aviation museums worldwide (U.S., Canada, Australia, etc.) and some relevant journals.
http://www.otenet.gr/aeroclub/link_museums.htm

Space Imaging Launch Information. Interesting illustrated educational and press information about commercial imaging satellite technology in text, video, and audio formats is available on this site. Topics include the launch of the IKONOS 1 (including a video of the launch), the satellite, the camera, and the ground station. Press releases detailing the history of the venture and video of the post-launch news conference are also archived. http://www.connectlive.com/events/spaceimaging/

SPIN-2 Space Survey Photocameras for Cartographic Purposes. A white paper by Viktor N. Lavrov, Sovinformsputnik, which provides details and charts of the specifications of two Russian high-resolution space cameras which, used together, form a high-resolution (two-meter) wide-swath cartographic satellite imaging system. This site also describes Web server provisions of remotely sensed images, including those from the SPIN-2. http://www.spin-2.com/

U.S. Air Force Military History. An illustrated history with many historic events, people, and technologies related to the military from the early part of the 20th century.
http://www.wpafb.af.mil/museum/history/

Note: If you don't enjoy typing in those long Web addresses (URLs), you can go to the following support site where the author has set up the links for you. http://www.abiogenesis.com/surveil

10.e. Media Resources

"Code Name: Project Orion," part of the *History Channel* History Undercover series. Project Orion is about declassified documents that give a glimpse into the secret dreams at the dawn of the space age. Physicist and author Freeman Dyson, who worked on deep-space projects in the 1950s, discusses their goals and projects. VHS, 50 minutes. May not be shipped outside the U.S. and Canada.

"Francis Gary Powers: The True Story of the U-2 Spy Incident," a feature film starring Lee Majors and James Gregory, directed by Delbert Mann. A 1976 dramatization of the capture of Gary Powers and his subsequent imprisonment. This received only lukewarm reviews, but may be of interest. VHS, 1 hr. 40 minutes.

"Pioneers in Space," from the *History Channel* Pioneers in Space series. This is a chronicle of the birth of the American space program in the early 1960s. It includes a closer look at the Mercury Project. VHS, 50 minutes. May not be shipped outside the U.S. and Canada.

"Project Manhigh," from the *History Channel* History Undercover series. This project began even before the space program, in the 1950s, when the Air Force had grand, seemingly impossible, goals of putting a man 20 miles above the Earth in a capsule attached to a helium balloon. VHS, 50 minutes. May not be shipped outside the U.S. and Canada.

11. Glossary

Airborne and spaceborne vehicles and craft employ a wide variety of surveillance systems, including infrared, visible spectrum, and radar technologies. Here are some common acronyms associated with air and space imaging to extend and supplement those included in the Infrared, Optical, and Radar Surveillance chapters.

Titles, product names, organizations, and specific military designations are capitalized; common generic and colloquial terms and phrases are not.

AASR	advanced airborne surveillance radar
AM/FM	automated mapping and facilities management
ARS	airborne radar system, aerial reconnaissance and surveillance
ASARS	advanced synthetic aperture radar system
ASR	airport surveillance radar
ATAR	advanced tactical radar, automatic target recognition
BWER	bounded weak echo region. A region of weak radar reflectivity which is bounded by a differently reflecting environment, as might occur in a storm with variations in updraft and precipitation.
CANOPUS	Canadian satellite observing systems incorporating advance imaging radar, optical, and sensing instruments.
CANTASS	Canadian Surveillance Towed Array Sonar System. A long array of small hydrophones which is towed. Used in submarine sensing and warfare.
CARS	Contingency Airborne Reconnaissance System
DAIS-1	Digital Airborne Imagery Systems. A commercial, multispectral, digital image-capture system designed and built to Space Imaging's specifications for producing radiometrically calibrated aerial imagery.
DAR	defense acquisition radar
DEM	digital elevation model. A geographic information systems (GIS) aerial map showing vertical dimensions of a region. In GIS modeling, this often comprises the topographic base map.
ESM	electronic surveillance measures
ETRAC	enhanced tactical radar correlator
FAAR	forward area alerting radar
FFR	fire finder/finding radar
FIRESTORM	Federation of Intelligence, Reconnaissance, Surveillance, and Targeting, Operations and Research Models
FLIR	forward-looking infrared radar
FLTTD	Field Ladar Technical Transition Demonstration. A laser radar program of the U.S. Army.
FOPEN	foliage penetration
FOSIC	Fleet Ocean Surveillance Information Center
FSS	frequency surveillance system
GBR, GSR	ground-based radar, ground surveillance radar
GCA	ground control approach. Aircraft landing systems which typically include radar systems monitored by air traffic controllers.
GIS	geographic information systems
GPR	ground-penetrating radar

GSTS	ground-based surveillance and tracking system
HIPAR	high power acquisition radar
IFSAR	interferometric synthetic aperture radar
ISTA	intelligence, surveillance, and target acquisition
Joint STARS, J-STARS	Joint Surveillance and Target Attack Radar System. An air-to-ground E-8C aircraft surveillance system for locating, classifying, and tracking ground targets. See AWACS.
JTIDS	Joint Tactical Information Display System. Tactical information provided through a digital link. This is a passive display system that can provide information about the surrounding environment without generating a transmissions signature. Suitable for use in stealth and fighter aircraft to indicate the positions of other aircraft or proximate objects.
ladar/lidar	laser radar/light radar. Can be used for weather information and for the detection of airborne chemical and biological agents. Suitable for long-range applications such as detection, tracking, and imaging hard and soft objects. In addition to the range and velocity information provided by traditional radar, ladar can be used to calculate length through a 'soft' object, for example, and can provide information about complex motion. The length-measuring capabilities are highly valuable in studying and imaging specific objects in order to determine their type and dimensions (tanks, helicopters, decoys, etc.).
LOPAR	low power acquisition radar
LRS	long-range surveillance
MIR	micropower impulse radar
MSTAR	man-portable surveillance and target acquisition radar
NAVSPASUR	Naval Space Surveillance System. NAVSPASUR makes use of continuous wave (CW) multistatic radar systems to reflect energy beams to receiving stations where position and trajectory information is calculated. In 1965 the frequency was changed from the SPASUR system's 108 MHz to 216.9-217.1 MHz. Called NAVSPACECOM fence since the early 1990s.
NORAD1	North American Aerospace Defense Command
PAR	precision approach radar
PHALCON	phased-array L-band conformal radar. A commercial aircraft long-range radar system manufactured in Israel. Diplomatic feathers were ruffled when Israel offered this system to the Chinese for use in their Air Force. U.S. officials were concerned about the use of U.S. technology in products being sold to other foreign powers.
Radio Electronic Combat	An information warfare strategy which aims at disabling an enemy command and control infrastructure.
racon	radar beacon. A safety, homing, or location signal which transmits a particular signal which identifies the beacon. Beacons are intended to provide information to navigators of various types of moving vessels, such as ships, aircraft, and ground troop vehicles.
RISTA	reconnaissance, intelligence, surveillance, and target acquisition
RSIP	radar system improvement kits. Technology to upgrade aging radar systems, especially on aircraft. Improvements usually include greater range and higher resolution radar imaging.
RSR	en route surveillance radar

RSTA	reconnaissance, surveillance, and target acquisition
SBIR	space-based infrared system
SCADA	supervisory control and data acquisition
SPADATS	Space Detection and Tracking System. A joint effort of the U.S. and Canada which tracks Earth-orbiting satellites.
SPASUR	U.S. Navy Space Surveillance system. Evolved in the early 1960s from the Vanguard Satellite Program which used a combination of intercepted and bounced signals from orbiting bodies to provide tracking and positioning information. This later was integrated into Naval Space and Command and NORAD. See NAVSPASUR.
SRIG	surveillance, reconnaissance, and intelligence group
SSR	Secondary Surveillance Radar.
TAR	terminal area surveillance radar
TMD	Theater Missile Defense. Ship-borne radars are one of the technologies used to carry out TMD missions.
TRACON	Terminal Radar Approach Control
TTR	target-tracking radar
UAV	unpiloted/unmanned/unstaffed aerial vehicle, autonomous or remote-controlled vehicle used in surveillance, reconnaissance, and target acquisition. Flights are often short-term, though endurance is increasing. Information may be transmitted through satellite links.
UGV	unpiloted/unstaffed ground vehicle, autonomous or remote control
VISTA	very intelligent surveillance and target acquisition