Ground-Based Aerial Photo

Spectacular Growth in Recent Years

Over the last few years, there has been a spectacular growth in the acquisition of low-altitude aerial photography taken from heights of 200m (600 ft.) or lower. In the past, this has been a difficult environment for the operation of manned aircraft, both in terms of air traffic restrictions and on grounds of safety, especially over urban areas. However new developments in platforms and digital imagers are now allowing low-altitude aerial photography to be obtained in a more or less routine fashion. A big advantage of these new developments is that the airborne imaging can be carried out and controlled remotely from the ground without the need for and the expense of sending someone into the air to execute the operation.

by Gordon Petrie

Figure 1 (a) - A mobile van equipped with a 80 ft. (24m) telescopic mast that is used to obtain elevated (aerial) photography using a film, digital or video camera. This particular van belongs to High Level Photography Ltd. based in Guildford, Surrey. The company owner, Keith Hallam is standing in front of the vehicle. (Source: High Level Photography)
(b) - An alternative configuration for photography using very tall masts (up to 100 ft.[30m]) is for the telescopic mast to be mounted on a trailer that is towed by a four-wheel drive vehicle. (Source: Cloud 9 Photography)

Different Techniques

Several different techniques have been developed for the acquisition of remotely-controlled ground-based aerial photography from low altitudes. Ranked in terms of their actual usage are the following:-

(1) vehicle- and tripod-mounted telescopic masts;
(2) remotely-controlled mini-helicopters;
(3) un-powered (tethered) balloons and blimps;
(4) powered (un-tethered) balloons and blimps; and
(5) tethered kites.

1. Aerial Photography Using Telescopic Masts

(a) Mast Construction

A considerable range and variety of telescopic masts have been developed for low-level aerial photographic operations by system suppliers both in North America and in Europe. These masts can be raised to maximum heights ranging from 13 ft. (4m) up to

graphy

100 ft. (30m). However these are the extreme ends of the height range; the majority of those masts being operated for the acquisition of aerial photographs in the U.K. reach maximum heights of 50 to 65 ft. (15 to 20m). These masts are usually mounted on vehicles, often equipped with four-wheel drive to be able to reach off-road sites. The shortest masts are constructed from quite narrow diameter tubes of lightweight aluminium alloy that fit (and telescope) into one another. Typically these very short masts will have a 3 inch (7.5cm) diameter for the base tube and a 1.5 inch (3.75cm) diameter for the top tube. At the other end of the height range are a few masts that can be raised to up to 100 ft. (30m). Typically these masts will have base tubes that are 5 to 6 inches (12.5 to 15cm) in diameter and comprise six to eight tubes that telescope into one another. When retracted down for transport, the height of the shorter masts may only be 5 ft. (1.5m). Thus they can be left in position if fitted to the back of a vehicle. With the longer masts, the retracted height will be 8 to 10 ft. (2.5 to 3.5m). These will usually be transported on the roof of the vehicle or occasionally on a towed trailer.

(b) Mast Weights

The weights of the masts will vary according to their length - from perhaps 30 lbs. (13kg) in the case of the very shortest masts to 80 lbs. (36kg) for a 20m mast to over 220 lbs. (100kg) for the tallest heavy-duty masts. These sizes and weights have big impact on the usage of the masts. The shortest and lightest models can be mounted on suitable tripods equipped with adjustable legs and placed on small hand-drawn trolleys or carts for local mobility. The longer, heavier models need to be mounted directly on vehicles or towed on specially-built trailers to the site of their operation. The size and the weight of a specific mast also have an impact on its actual operation. The shorter ones can be raised or lowered either manually or using a hand crank. The taller, heavier masts need to be raised using a power source. A system of wires and pulleys driven by electric motors is used in the masts constructed by the Canadian Luksa Industries company. An alternative is to use a pneumatic system employing compressed air to raise the telescopic tubes. This is the system used by the Clark Masts company which has factories both in the U.K. and Belgium. Power for all of these taller systems is normally supplied by a suitable 12 volt DC battery.

(c) Mast Cameras

For mast photography, high-quality SLR film cameras equipped with motorized film advance mechanisms are still being used quite extensively in conjunction with a tiny video camera placed behind the viewfinder. This allows the correct pointing of the film camera towards the desired object or area to be carried out under the control of the operator based at ground level. However, nowadays, many operators use digital frame cameras. A few are now using panoramic cameras that provide 360° coverage of the whole area around the mast. Whichever type of camera (film, digital or video) is being used, it is mounted on a motorized pan-and-tilt head that is fitted to the top of the mast. This allows the pointing and coverage of the frame camera image to be controlled very precisely by the operator - using the joystick forming part of a control unit located in the vehicle or placed on the ground - before the image is actually exposed. During this set-up operation, the camera image is being transmitted down via a video cable either to the purpose-built control unit (which is equipped with a display monitor) or to a laptop computer having suitable control software. This arrangement allows the operator - and even sometimes the client - to spend time over the composition and timing of the aerial image. The actual exposure of the image is implemented using a remote shutter release. On a very sunny day, a sun-shade or hood will be placed over the control unit or laptop computer to eliminate glare on the screen of the display monitor.

(d) Applications

The low oblique aerial photography acquired using these telescopic masts finds numerous applications. Acquiring imagery for use in urban modelling is an obvious photogrammetric and GIS application, as its widespread use by architects, planners and site developers. The mast method is relatively simple and unobtrusive to implement. It is also much cheaper and quicker to produce results and is much less likely to cause an obstruction to traffic than having to hire and position a large crane or cherry-picker - which was the method used previously in such situations. The routine photography of building and construction sites to monitor and record progress and to authorize payments for the actual work that has been done is another widespread application. Needless to say, estate agents often commission low-level mast aerial photography of sites and buildings that they wish to sell. The elevated images ensure that the resulting views of the buildings and sites are no longer obstructed or hidden behind hedges, trees, walls, fences or other buildings. Yet another common application is to take low oblique aerial photography of traffic accidents or crime scenes for use by police traffic and criminal investigation departments. In these situations, the resulting images can be handed over to police officers on compact disks at the actual scene of the accident or crime or they can be sent via phone lines or over the Internet to the appropriate police authority, emergency service or media organization. Panoramic images of individual large rooms or halls indoors within buildings can even be taken using a very short mast mounted on a tripod. In the U.K., there is an extensive network of more than 50 mast aerial photographers who compete strongly for business, especially in the densely populated and very prosperous parts of Southern England and the West Midlands.

2. Remotely-Controlled Mini-Helicopters

The field of powered radio-controlled model helicopters is one that has been active for some time with many thousands of enthusiasts pursuing it as a hobby and the more serious ones competing in national and international aerobatic competitions.
However recent developments have led to the introduction of somewhat larger remotely-controlled mini-helicopters that are designed specifically as platforms for aerial photography. Before anyone thinks that this is some kind of fringe activity, there are already over 70 small companies in the U.S.A. engaged in this activity that are listed in my Web Links Database. Indeed the rapid development in this field has led to the establishment of the

Remote Control Aerial Photography Association (RCAPA) in the United States to which most of these companies belong. More details about the activities of the Association and its members can be obtained from its Web site - www.rcapa.net/ . In the U.K., there are at least 10 similar companies and there are a number of others scattered throughout the rest of Western Europe.

(a) Mini-Helicopter Platforms

The mini-helicopters that are used in aerial photographic work are typically 5 to 6 ft. (1.5 to 1.8m) in length with the main rotor blade having a diameter of 5 ft. (1.5m). Most feature a skeletal frame of lightweight aluminium tubes. However some newer models are being constructed using a very lightweight but very rigid frame made of carbon fibre. The power for the smaller models of mini-helicopters is provided by an electric motor that gets its power from a set of small rechargeable batteries. These motors have the advantage of being almost silent in their operation, which is a big advantage in noise-sensitive areas. On the other hand, electrically-powered mini-helicopters are also limited in their flight duration and in their lifting power. Therefore the more powerful types of mini-helicopter are powered by very small petrol (gas) engines. For example, the ***Bergen Observer -*** which is purpose-built for aerial photography - uses a Zenoah 26cc petrol engine that allows a payload of 8 lbs. (3.6kg) of camera and radio control equipment to be carried. The still more powerful ***Bergen Observer Twin*** uses a twin-cylinder Zenoah engine with double the engine capacity (52cc) and generating 8 horsepower. This allows a payload of 20 lbs. (9kg) to be carried, including a built-in pan-and-tilt system for the camera. This motorized pan-and-tilt system sits on a special anti-vibration mount that isolates it from the mechanical vibration of the mini-helicopter. Enough fuel can be carried by the Observer helicopters to provide half-an-hour's flying time. Other purpose-built mini-helicopters for use in professional aerial photography include the Maxi-Joker 2 machine that is manufactured by the ***Minicopter*** company in Germany. However this is powered by a electric motor driven by batteries. Thus the weight of its payload is limited to 4.5 lbs. (2kg) and the flight time is reduced to 20 minutes. Another new development from Germany is the ***DigiFLY*** that has been developed by the IGI company that is well known for its CCNS and AEROcontrol flight management systems for aerial photography. This platform uses four propellers driven by brushless electric motors

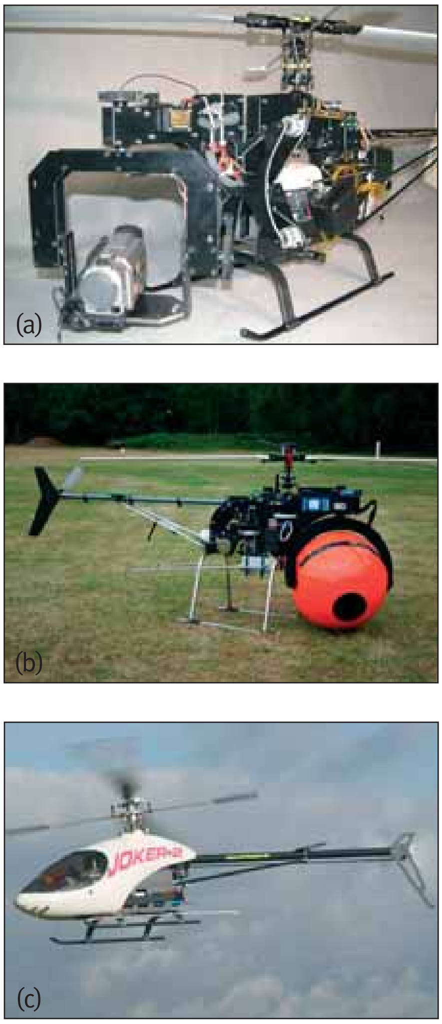

Figure 2 (a) - The Bergen Observer EB remotely-controlled helicopter equipped with a Zenoah G-26 petrol driven engine. A pan-and-tilt system on which the camera is mounted is located at the front end of the helicopter and provides a 270° field of view. The pan-and-tilt system is isolated from the helicopter mechanical elements through the use of four heavy-duty isolators. (Source: Bergen R/C Helicopters)
(b) - One of the radio-controlled helicopters that is operated by the High Spy Company in the U.K. This particular example utilizes a frame built by the German manufacturer, Vario Helicopters and a Zenoah 23cc petrol engine. The on-board electronics include a 3-axis gyro-controlled camera mount, a GPS set, a magnetic compass and a barometric height sensor. (Source: High Spy)
(c) - This electrically powered Maxi-Joker radio-controlled helicopter was designed specifically as an aerial camera platform and was built by the Minicopter company based in Vollmer, Germany. (Source: Minicopter)

and features an integrated GPS/IMU/barometer combination to provide an electronic flight-stabilization system. Various types of imager - digital, thermal-IR or video - can be used to provide the imaging of the ground. The latest development in this field is to fit small gas turbine engines to mini-helicopters. This increases the available power very substantially and therefore the payload that can be carried - but at a very substantial financial cost.

(b) Mini-Helicopter Cameras

In the main, the companies operating mini-helicopters equip them either with medium-format (6 x 4.5; 6 x 6; or 6 x 7cm) film cameras fitted with motorized film transport mechanisms and zoom lenses or, more usually nowadays, with lightweight small-format digital frame cameras that produce relatively high-resolution images with an image size of 6 to 14 Megapixels. Alternatively, if the client requires video imagery, then small high-quality video cameras will be used. A few operators have also utilized lightweight high-definition video (HDTV) cameras to capture ground images. In the larger mini-helicopters, a motorized gimbal or pan-and-tilt mount is used to carry the camera.
A miniature radio transmitter/receiver unit mounted in the helicopter receives the appropriate signals from the operator's control unit on the ground. These signals are passed to the motors both on the camera and on the camera mount to carry out the appropriate movements - pan left/right; tilt up/down; zoom in/out - to ensure the correct pointing and coverage of the camera. As noted above, these movements of both the mount and the camera are isolated from the vibration of the helicopter as much as possible. On exposure, each image is transmitted at high speed via a wireless video downlink to the control unit on the ground where it is displayed on the monitor screen of the unit and recorded. Later the captured images can be imported into a CAD or GIS system on which the relevant map of the area is stored, so that the images can be geo-referenced.

(c) Applications

Obviously quite a number of the possible applications of the images acquired by the mini-helicopter will overlap with those that can be implemented using a telescopic mast. These will include the monitoring of construction sites. In this respect, the telescopic mast can often operate more closely to the specific building or structure being inspected, especially in urban areas. Whereas the mini-helicopter, operating at a greater altitude, can provide the wider coverage needed for a large site. The mini-helicopter is, of course, also well suited to the acquisition of imagery of wetlands and swampy areas for environmental assessment and analysis where wheeled vehicles equipped with masts cannot operate or penetrate. The higher operating altitude of the mini-helicopter is also advantageous when woodland has to be assessed from an overhead position rather than at the low oblique angle given by the mast. When equipped with a video camera,

Figure 3 (a) - This 18 ft. (5m) long helium blimp belongs to the PhotoComAsia company and is based in Bangkok, Thailand. The position and height of the platform is controlled by the tether rope attached to the front of the blimp. The camera and its mount are suspended by additional ropes attached to the middle of the blimp's envelope. (Source: PhotoComAsia)
(b) - A tethered blimp operated by the Skycell company of York, England is being launched to acquire aerial photography of the Roman amphitheatre in Chester. (Source: Skycell Ltd.)


(a)


(b)


(c)

(c) - An oblique aerial photograph of part of the Castle Howard estate located near York, England taken from a tethered blimp. It includes the magnificent 18th Century mansion with its distinctive dome (in the background); an ornamental bridge (in the middle ground) and the Mausoleum (in the foreground). (Source: Skycell Ltd.)

the helicopter also provides a highly mobile platform from which continuous video 'fly-over' imagery of the ground can be generated. However it must also be said that the mini-helicopter is much more likely to be at risk from damage through engine failure, loss of control or flight into an obstruction such as telephone or power lines. Special care needs to be taken in urban areas where the risk to both people and property could be high. It is interesting to note that some aerial photographic companies operate both telescopic masts and mini-helicopters, thus allowing them to select the most suitable platform for a particular task.

3. Un-powered (Tethered) Balloons & Blimps

(a) Balloons and Blimps

As is well known, the very first aerial photograph was taken from a tethered balloon over the Bievre Valley in France by Gaspard Felix Tournachon (better known by his nom-de-plume as 'Nadar') in 1858 - nearly 150 years ago! Even at that time, it was apparent that un-tethered balloons were not suitable platforms for the acquisition of aerial photography - since they simply travel where the wind takes them and not necessarily over the targeted area. Still it is worth noting that spherically-shaped un-tethered balloons are being used extensively for certain types of scientific research - for example, by NASA undertaking atmospheric and astronomical research at ultra-high altitudes (120,000 ft. = 36km or more) in the stratosphere. However these high-altitude research balloons do not need to reach or stay over a specific area or target on the ground - as is required for aerial photography. Instead streamlined aerodynamically-shaped blimps equipped with fins arranged in an X- or Y-shaped configuration that provide much more stability are used for low-altitude aerial photography. The blimp envelope is made of a lightweight polyurethane-coated nylon material that is highly resistant to being torn. The fins are sometimes made from a stiff

Figure 4 (a) - A powered balloon operated by Skycell Ltd. acquiring photography in Wells Cathedral in Somerset, England. The ducted propellers can be seen on each side of the balloon with the digital camera on its mount hanging down from the centre of the main envelope of the balloon. (Source: Dr. Szymanski, University of York)
(b) - A powered blimp operated by the av8pix company based in Guernsey in the Channel Islands acquiring photography in the nave of Hereford Cathedral in the west of England. (Source: av8pix)
(c) – A lightweight gondola slung below the powered blimp showing the camera housing and ducted propellers. (Source: av8pix)
(d) - A blimp with its trailer-cum-hanger that is being towed by a four-wheel drive vehicle. (Source: av8pix).

but lightweight composite material. Even when tethered, these blimps can only be used as stable camera platforms in fairly calm conditions or at very low wind speeds - below 10 mph (15 kph). Nevertheless, in spite of these limitations, there are now quite a substantial number of commercial operators using unmanned, tethered blimps routinely for aerial photographic purposes in the more highly developed countries of North America, Western Europe and Australia. Most of these blimps are quite small in size - typically 10 to 20 ft. (3 to 6m) in length. Costs are kept low since there are quite a number of competing manufacturers who build blimps in quantity for commercial advertising purposes.

(b) Helium Blimps v. Hot-Air Balloons

Regarding the blimps and balloons used for low-altitude aerial photography, there is a choice to be made between the different lighter-than-air gases that can be used as the lifting medium within the envelope. Since hydrogen and methane are both highly flammable gases, for safety reasons, they are not suitable for use in blimps and balloons. So the choice really lies between helium and hot-air. For a given volume, helium has a much greater (5x) lifting capacity than hot air, which is produced using a propane burner attached to a suitable storage tank. So a hot-air balloon must be much larger in terms of its size and volume for a given lifting capacity and is correspondingly more expensive to manufacture and to buy than a helium blimp. Thus almost all aerial photographic blimps use helium which is available stored in transportable steel cylinders at a fairly low cost in most highly developed countries. However hot-air balloons do have one small advantage in that propane is much more readily available in small easily-transported tanks - since it is used extensively for heating and cooking purposes world-wide. With the helium blimps, the gas is sometimes released into the atmosphere once the aerial photographic session has been completed - since it is very difficult, indeed impractical to return it to the storage cylinder. However, nowadays, most commercial aerial photographic operators transport the small blimp fully inflated in a suitable towed trailer. In which case, the gas will not be vented deliberately into the atmosphere - though it will do so slowly through leakage over a period of time.

(c) Blimp Cameras

The types of camera and the mounts that are commonly used for the aerial photography being taken from blimps are similar to those discussed above in the context of masts and R/C mini-helicopters. Either motorized medium-format film cameras such as the Pentax and Mamiya models with a 6 x 7cm format or small- to medium-format digital cameras are commonly used. A few operators, e.g. Dartmap in Canada, use a calibrated photogrammetric camera (such as the RolleiMetric) designed specifically for mapping purposes. Each film or digital camera will also have a tiny auxiliary video camera fitted to it for viewing purposes. The camera will sit in a motorized mount that is controlled from the ground. This allows it to be pointed in the required direction and give the desired coverage. The pan-and-tilt mount is often attached to a keel or rail fitted along the bottom of the blimp. Since the blimp will be tethered using a strong but very light-weight rope or cord, the control signals and the digital images being downloaded after their exposure will usually be transmitted to and from the control unit on the ground using a video cable attached to and wound round the tether rope. However some operators use a wireless (radio) link to transmit signals and video image data to and from the blimp. In calm conditions, the tether rope attached to a small blimp can be attached at the other end to a harness worn by the camera operator on the ground. He can then walk and manoeuvre the blimp into the correct position with the aid of the portable video monitor of the control unit. However other operators attach the tether to a small winch equipped with a crank handle to control the length of the line that has to be paid out. To change the film or the camera lens, the blimp is simply brought back down to the ground by hand or using the winch and crank handle, an action that only takes a few minutes to complete. The blimp can then be re-launched as soon as the required changes have been made.

(d) Applications

As for the applications of blimp aerial photography, many of these will be the same as those described above for mast and R/C helicopter photography - especially the monitoring of construction sites and the elevated oblique photography of properties that are being developed or put up for sale. The tethered blimps can be operated at flying heights of up to 400 ft. (120m) without the need to obtain permission or file flight plans with the air traffic control authorities - though operation over or near to defence installations and around airports and airfields is strictly controlled. This ability to fly blimps at greater altitudes than can be used with telescopic masts allows them to achieve greater area coverage of the ground and the use of steeper angles if this is required. In this respect, blimps compete with R/C helicopters. Indeed quite a number of service providers of ground-based aerial photography use masts for altitudes up to 75 ft. (23m) and blimps if still higher altitudes are required.

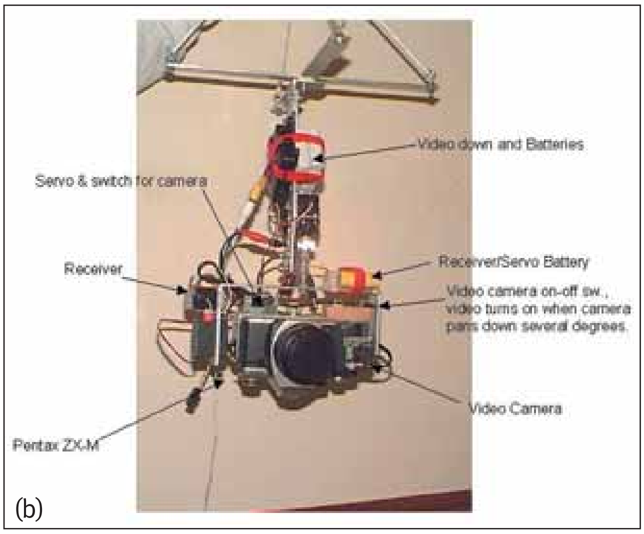

Figure 5 (a) - Aerial photography is being acquired in this photo using a Flowform kite being flown by Scott Haefner of Palo Alto, California. The Nikon digital camera is attached to the main tether line using a set of Picavet suspension cables that carries the cross-shaped base plate and the camera mount. (Source: Scott Haefner)
(b) - A detailed annotated photograph of the camera set-up devised by Dennis Williams of Clinto, Massachusetts, which he uses to acquire kite aerial photography (KAP). (Source: Dennis Williams)

4. Powered (Untethered) Balloons & Blimps

The fitting of engines to provide power to blimps and balloons means that they can be operated without tethers to much higher altitudes and enables them to carry a much greater payload. These characteristics lead to them being described sometimes as unmanned mini-airships. While some of these platforms are being used purely for advertising purposes, quite a number are now being used for the acquisition of aerial photography using still (frame) film, digital and video cameras. With the availability of motors, blimps can carry out a larger and more systematic photographic coverage in a much shorter time.

(a) Platforms

The powered blimps can be equipped either with electric motors or petrol-fuelled engines, giving forward speeds of up to 30 knots (55kph). As with the R/C mini-helicopters, the use of brushless electric motors gives a near-silent operation, whereas the use of petrol engines provides a substantial increase in range, endurance and payload. However occasionally problems may be experienced with noise and exhaust smoke emitted by petrol engines. Whichever type of engine is used, typically they drive three-bladed ducted propellers. These can be vectored (tilted) over a considerable range to provide the control of the powered blimp or balloon in-flight using the radio-control signals being transmitted from the ground control station. A GPS-based autopilot is sometimes used for the main (photographic) flight, although the take-off and landing of the blimp will still be controlled manually. Since the size of the blimp is quite small - typically up to 30 ft. (9m) in length and 9 ft. (2.5m) in diameter - it is usually transported fully inflated in a specially-built trailer. The trailer also acts as a protective hangar when away from the base and carries the helium storage cylinders.

(b) Cameras

The powered blimp is usually fitted with a very lightweight gondola made of carbon fibre, as are the ducts that shroud the propellers. This gondola carries the motors; the re-chargeable batteries and the transmitter/receiver used for control purposes. Typically it will also carry a lightweight rotatable camera mount, again made of glass- or carbon-fibre that allows a 360° (pan) rotation and a full range of tilt movements. In some cases, the mount is gyro-stabilized. The actual cameras that are used inside this sophisticated mount are the digital, film and video cameras described above in the section on tethered blimps.

(c) Applications

Obviously the use of a powered blimp allows low-altitude aerial photographic surveys to be undertaken over more extensive areas of the terrain in a timely manner than is practical using an unpowered blimp employing tethers. In the U.K., an extensive series of surveys of churches and other historic buildings has been carried out by two commercial operators of powered blimps - av8pix and Skycell. These have largely eliminated the need for and the associated costs involved in erecting scaffolding. Needless to say, these surveys have generated extensive publicity, including being featured on national television. The surveys have included the systematic photography of both the exterior and interior of large churches such as York Minster and Hereford, Wells, Winchester and Gloucester Cathedrals. These images now form part of the National Monument Record of the English Heritage organisation. Skycell has also carried out imaging surveys of the Roman Amphitheatre in the city of Chester that is currently the subject of an investigative and renovation project being carried out by English Heritage and Chester City Council. The resulting images have been used to construct a computer-based model of the site.

5. Tethered Kites

The golden age of kite aerial photography (KAP) was the 15 year period prior to World War I. However, with the development of aircraft, kite aerial photography almost died out. Over the last 20 years, it has regained some ground and is now pursued as a hobby by hundreds of enthusiasts worldwide. It is also being used as an aid to certain research activities in geomorphology and hydrology by a small number of university field scientists. Still it is difficult to envisage kite aerial photography being adopted commercially as a standard technique. Most of the very small number of commercial operators that offer kite aerial photography do so as a supplement to one of the other ground-based techniques described above.

6. Conclusion

Ground-based aerial photography has developed rapidly over the last few years and has now become firmly established in certain more highly developed countries. Further developments in platforms in combination with the new forms of digital imaging will almost certainly lead to its spread and adoption on a world-wide basis.

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