A review of low-level aerial archaeology and its application in Australia

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Abstract

This paper examines methods of low-level aerial archaeology and provides a rationale for utilizing these systems more widely in Australian archaeological projects. While the value of conventional aerial archaeology is apparent, different low-level aerial photographic methods can be employed more comprehensively by archaeologists to document, interpret and monitor sites in Australia. Kite, balloon, boom and other low-altitude remotely controlled camera platforms are rarely applied in Australian archaeology despite the fact that archaeologists overseas have used these aerial imaging platforms for decades. Unmanned Aerial Vehicles (UAVs) and more conventional wireless remote sensing image technology will be used more consistently in the next decades to reconstruct and reinterpret the landscape of the past.

What is low-level aerial archaeology?

While the history of aerial archaeology is linked to the development of military reconnaissance, enterprising archaeologists during the last century have captured the elusive eye in the sky view of a landscape or excavation without the use of an aeroplane. Low-level aerial archaeology is the use of a photographic or videographic device attached to a lifting platform or elevated structure such as a kite, balloon, boom or mast. Low-level airborne platforms can be operated below the minimum altitude imposed on conventional aeroplanes and higher than legislated altitude if required. Archaeologists have ingeniously photographed excavations and landscapes from other devices such as blimps, extended ladders, cranes, bipods, powered parachute cameras (PPCs), excavators, scissor lifts, monopods and radio controlled model aircraft. In this article, the term conventional aerial archaeology refers to the use of mounted aerial cameras, hand-held SLR cameras or videographic equipment operated by persons in fixed-wing aircraft or ultra lights. The terminology archaeologists use to describe low-level aerial archaeology includes: intra-site recording (Sterud and Pratt 1975), high viewpoint photography (Wiltshire 1967), low-altitude aerial photography (Myers, Myers et al. 1992), vertical archaeological photography (Dorrell 1996; Straffin 1971; Renow 1985), vertical photographic site recording (Poulter and Kerslake 1997), overhead site photography (Graham 1981) and planimetry (Johnson 1983).

An early history of low-level aerial archaeology

Kite, balloon and boom photography in archaeology has a long history overseas with little comparable development in Australia in the past four decades. Most scholars maintain that kite aerial photography (KAP) began with Arthur Batut in France in 1888 (de Beauffort and Dusariez 1995; Pelham 1976). George R. Lawrence took remarkable aerial photographs of San Francisco before and after the 1906 earthquake with a large format camera kite system (Baker 1994, 1997). The first archaeological use of kite aerial photography was made by Sir Henry Wellcome to record excavations in the Sudan (Deuel 1973:33; Chagny 2002). KAP very nearly became a lost art during the 1940s/50s with the rise of conventional aerial photography (though see Bascom 1941). Balloon photography was pioneered by Nadar (Gaspard Félix Tournachon) over Paris in 1858 and aerial images from manned balloons were also made in Boston during the Civil War (Deuel 1973:32-33). At the end of the nineteenth century, British royal engineers introduced untethered unmanned gas balloons, which carried self-releasing cameras engineered to expose several plates in succession. Capper (1907:57) records the first pictures of an archaeological site made from a balloon over Stonehenge in 1906. P.L.O. Guy's work at Meggido (1929/30) was the first systematic attempt to record the archaeological stratigraphy of a complex site using unmanned balloon photography (Guy 1932). One of the earliest photographic platforms was a wooden bipod to overcome angle of view difficulties in recording gravesites (Kriegler 1928). Dorrell (1996:135-148) documents a number of low-level aerial photographic systems that have been applied in Europe and the Middle East in past decades.

The use of UAVs in low-level aerial archaeology

The future of low-level aerial archaeology is promising considering the US military's development of unmanned aerial vehicles (UAVs). UAVs are defined as "powered aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload" (Bone and Bolkom 2003:vii; see also Williams and Harris 2002:1). The US Defense Department has used UAVs for reconnaissance and intelligence-gathering since the 1950s and is also exploring the reconnaissance potential of much smaller Micro Air Vehicles or MAVs (Newcome 2004; Bone and Bolkom 2003; http://www.spyplanes.com). Commercialization of military technology tends to result in broader application of the technology in society. A case in point is the widespread application in archaeology of GPS, which was initially developed for military use (Jones 2003). The advent of aerial photography last century may be revisited this century with UAV devices bearing photographic equipment capable of capturing extremely sharp, high resolution images at low altitude.

UAV technology is being tested for a wider variety of civilian applications which will eventually extend to archaeological imaging. In the future, commercial operators will launch UAV devices for terrestrial or maritime search and rescue, firefighting, fisheries patrol or to document real estate (Flinders Journal 2003; Williams and Harris 2002). Codarra Advanced Systems in Australia has recently

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Figure 1 AVATAR unmanned aerial vehicle test flight image over suburb (courtesy of Warren Williams, Codarra Pty Ltd).

Figure 2 Vertical kite aerial photograph of Harbour Master's Cottage, Port Willunga, South Australia. Photo: Matt Schlitz.

developed a UAV that is being tested for applications in the mining industry (Williams and Harris 2002). The AVATAR is autonomous and capable of transmitting real-time images to a laptop computer over a range of ten kilometres. The modular design fits in a backpack and can be assembled in about ten minutes making it suitable for archaeological survey along inaccessible coastlines or terrain. The body of the AVATAR is just over a meter long, is five kilograms in weight and can be launched by hand. The electric propulsion system provides for one hour of airtime and the flight path can be predetermined by GPS coordinates. The images from AVATAR are of high quality but not yet critically sharp so future stabilization of the digital image is required (Fig.1). While less expensive aerial platforms such as kites and balloons are currently more practical, once vibration control, technological cost and civilian licensing of UAVs are resolved archaeologists will adopt the UAV for low-level aerial imaging.

The benefits of low-level aerial archaeology platforms

There are advantages in using kite, balloon or other elevated photographic platforms side-by-side or in place of conventional aerial archaeology. Given that elevated photography without the use of an aeroplane is not consistently applied in Australian archaeology, is there an on-going perception that the methods are too difficult or that this country has no 'monumental' sites worthy of recording from above? Perhaps the answer lies in the perception that it is not vital given the occasional use of conventional aerial archaeology and that remote camera platforms are expensive and difficult to source, develop or modify. Practical and cost-effective low-level aerial platforms need to be available to archaeologists. As Zurawsky (1993) notes:

> Everyday excavatory practice needs a handy, reliable and inexpensive vehicle capable of shooting aerial pictures at a particular moment of the fieldwork, e.g., when the outline of a grave shaft has been exposed, the tops of walls have been cleared or the outlines patiently cleaned by broad surface cleaning has to be destroyed. *Neither satellite nor a plane equipped with an aerial camera will come to shoot that particular moment. The field archaeologist desperately needs a reliable, stand-by tool, which enables the momentary picturing of the excavation from an altitude higher than the last thread of the stepladder (my emphasis)*.

There are various types of photographs that archaeologists require from low-level aerial archaeology: localized site feature photographs taken with an vertical camera (directly overhead), images for site plans or mosaics, and oblique photographs to provide a site overview (Sterud and Pratt 1975). Use of low-level aerial images now extends to panoramas, photographic modelling and even digital elevation models (DEMs).

Low-level aerial archaeology has a number of advantages over conventional aerial photography at low altitude as described by Connah and Jones (1983). Connah and Jones (1983:75-76) argue that conventional low-level aerial photographs from fixed-wing aircraft are an efficient means of site recording, interpretation and discovery and may be useful for site prediction. This is

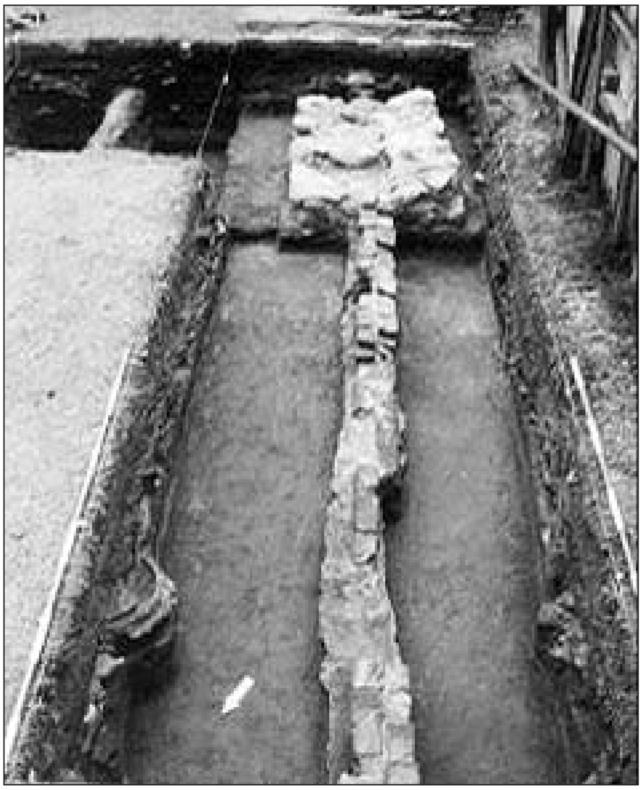

Figure 3 Wide angle photograph from a ladder at the Quebec Street excavation, Port Adelaide, South Australia, 2002. Photo: Peter Birt.

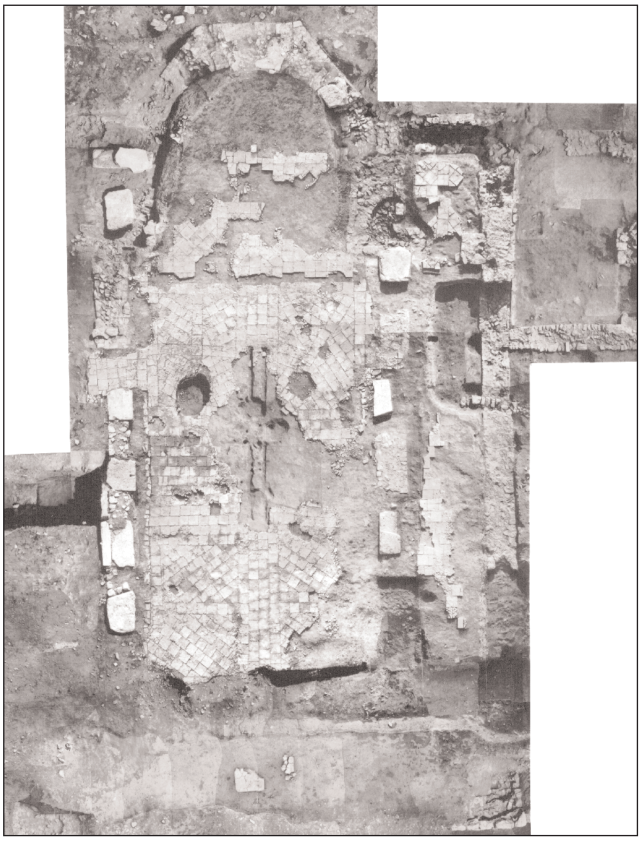

Figure 4 Holmes boom photograph of the Basilica at Nicopolis ad Istrum, Bulgaria. Photo: Andrew Poulter and Ivor Kerslake. Photo Mosaic: Ivor Kerslake.

certainly true, but a major advantage of a low-level aerial kite, balloon or boom platform is the ability to *maintain* the position of the camera at a *much lower altitude* above the subject (Fig.2). Being closer to the subject allows for larger scale photographs and higher image resolution. Archaeologists need to photograph detailed site elements at particular times of day which makes low-level aerial photography necessary on most sites. It is difficult to source large scale and extremely low-altitude aerial photographs with the necessary resolution and the required viewpoint from a government agency (Connah and Jones 1983:73-74; Zurawsky 1993). A low-level aerial archaeology platform that can be used time and time again for projects is generally cheaper, more cost effective and flexible than employing a pilot and aerial photographer to undertake specific flights over a site. Low-level conventional flying is prohibited unless the pilot has the correct qualifications, experience and CASA permit. Without this CASA permit, a fixed-wing aircraft or helicopter must stay at an altitude above 1000 feet over built-up areas and 500 feet elsewhere. Hiring an aircraft or helicopter (approximately $1000 per hour) is expensive for archaeologists and the danger of crashing increases the closer the helicopter is to the ground. Operating a kite, balloon or boom platform from the ground is inherently less hazardous.

Another limitation with conventional aerial photography is that archaeological features require the use of a telephoto lens to fill the negative frame and maximize further enlargement resolution. Telephoto lens require higher shutter speeds and therefore consequently faster film, resulting in a potential loss of resolution; whereas the use of very low-altitude cameras with shorter focal lengths (28-50 mm) enables slower shutter speeds, prevents flattened perspective in oblique views and increases resolution from the negative. Other factors which affect photographic resolution are film speed (ISO) and the forward speed of the camera platform. In the case of kite, balloon and boom platforms there is minimal forward movement compared to the forward motion of a mounted or hand-held camera in fixed-wing aircraft. When an excavation image is taken from the ground, ladder, building or scaffold and a wide-angle (28-35 mm) camera focal length is used, the lines of the trench converge in the photograph (Fig.3). However, the use of a very low-level boom system with a standard (50 mm) lens directly overhead eliminates this distortion in trench photographs (Fig.4).

There are major advantages in designing and using a photographic boom system over renting mechanized trailer lifts or knuckle booms on Australian sites. An archaeologist can take the excavation photograph with a boom at the moment they require and have no need to employ a specialist operator or hire elevating equipment (eg: http://www.skyreach.com.au). While an archaeologist might have developer or council support to arrange photographs from a scissor lift or ‘cherry picker’, full-time use over the duration of the dig would be a costly exercise. Photographic booms and masts constructed from lightweight materials are more portable at remote sites such as horizontal rock art surfaces (Fig. 5), are cost-effective, impact less on fragile sites and, depending on construction, are not restrictive in terms of occupational health and safety.

Figure 5 Planimetric system used to record rock-art surfaces, Photo: John Clegg.

Site plans, excavation sequences and mosaics

Archaeological illustration and photography are complimentary recording methods. Low-level aerial archaeology is a cost effective means to graphically record the site during planning and to document phases of excavation (Myers, Myers and Cadogan 1992:5-6; Figs 6 and 7; Jones 1989). The images can aid the process of interpretation and plan drawing which may take weeks to achieve manually. Excavations of cultural sites in Australia under threat can benefit from the application of low-level aerial photography, especially if plans are required in limited time. Guy's foresight in photographing an area of some 29,000 square meters at Megiddo resulted in an incredibly valuable excavation phase archive (Guy 1932; Cooper and Myers 1981). A photographic boom was used to record large excavated sections of a basilica at *Nicopolis ad Istrum* in Bulgaria (Poulter and Kerslake 1997; Fig. 4). These images in turn were extremely useful in the construction of site plans. Nylén (1951,1964) developed a heavy but extremely effective tripod boom platform to take vertical photographs of Iron Age grave sites to record excavation sequences. Similar work is possible at Australian excavations of non-indigenous or indigenous gravesites, where both individual graves and the entire site are photographed from above at different phases. With output directly to field laptops via wireless, video or firewire data transmission, real-time digital photography from an elevated platform may give the archaeologist a 'polaroid' overview to interpret the excavation or determine how it should progress (Dorrell 1996). Low-level aerial archaeology can document construction phases of historical buildings in Australia. A regular or stereoscopic camera rig in conjunction with a small, tethered helium balloon can record structural elements which are quite difficult to access from the ground (http://perso.wanadoo.fr/kap-chagny/page4.html).

Mosaics composed from low-level aerial archaeology provide a valuable addition to conventional illustration. Mosaics convey three dimensionality of features below and above the original primary excavation level (Poulter and Kerslake 1997; Nylén 1964). Telescopic masts or even modified survey staff provide high viewpoint oblique photographs and even near vertical images (Dorrell 1994; Johnson 1983; Wiltshire 1967; Straffin 1971) but booms with adjustable head assemblies or bipods are required for vertical photographs in order to construct plans and mosaics (Poulter and Kerslake 1997; Whittlesey 1970, 1975; Stenow 1985). Aerial images can be taken with a photographic scale for a general vertical excavation record and without a scale to eventually create a plan mosaic (Fig.4). While a platform able to maintain a level camera datum is generally desirable, with the recent advent of desktop photogrammetric software, exact camera to subject distance is not so critical when repositioning the device for overlapping photographs and subsequently processing the images to form a mosaic. Cosmos Coroneos (Cosmos Archaeology Pty Ltd) has undertaken work with Tony Aitken, a surveyor in Queensland who uses a four-wheel drive mounted boom with real time video to monitor the camera position to create photo mosaics and the final site plan. Paul Rheinberger (Umwelt Australia Pty Ltd) used a five metre offset boom to record one metre square quadrats at the Lake Innes House excavations.

3D photogrammetry

A benefit of recording calibrated low-level aerial images systematically on Australian sites is the creation of 3D site models. There is a need to promote the application of virtual reality (VR) in Australian archaeology not for its own sake but when the image can augment the research question being asked or provides a complimentary record of heritage under threat. The general public in Australia increasingly see overseas archaeological programming with 3D modelling content such as reconstructions of historical structures, artefacts and landscape fly-throughs which 'visualize' the site for the public. Vertical or oblique low-level images of sites in combination with photographic modeling software can provide 3D photorealistic illustrations of interiors or exterior ruins, large cave shelters, extensive rock art surfaces or excavations in Australia. (http://www.photomodeler.com). A combination of commercial or improvised mast photography and QuickTime VR software can be used to create 360 degree oblique site panoramas (http://web.ukonline.co.uk/megalithics/index.htm; http://www.stoa.org/metis/; http://www.floatograph.com). 3D photogrammetric models of such sites can be a valuable complimentary record to drawing and conventional photography and particularly when redevelopment will affect a site not protected by heritage legislation.

Low-level aerial archaeology can be also applied with ground-based spatial technologies such as topographic surveying, geophysics and GIS. Dr Bernard Noel Chagny of France (Chagny 1994, 1996, 1997, 1998, 2000) and Professor Jan Driessen from Belgium have used kite aerial photography for the last decade on numerous sites around

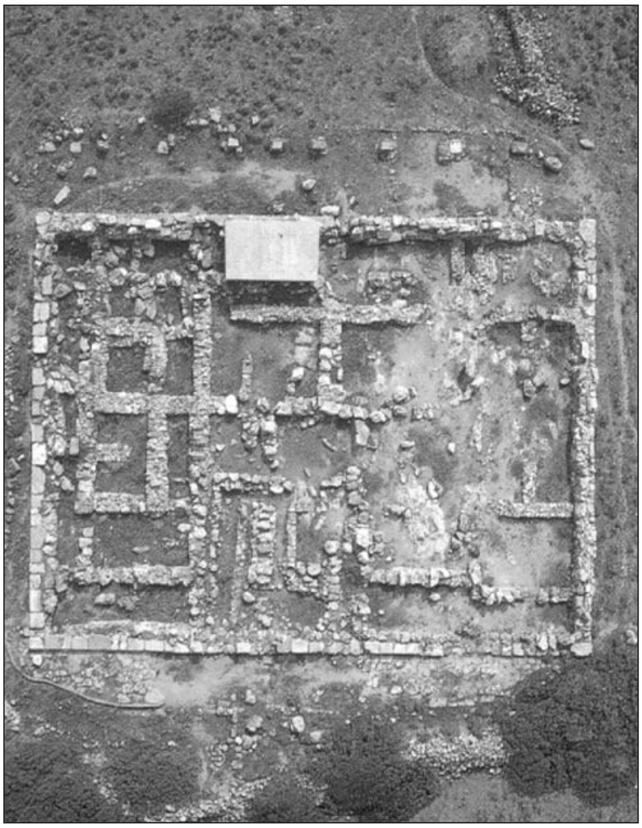

Figure 6 Vertical balloon photograph of Chrysolakkos, Crete. Photo: Professor W and E Myers.

Figure 7 Ground-based photograph of Chrysolakkos, Crete. Photo: Professor W and E Myers.

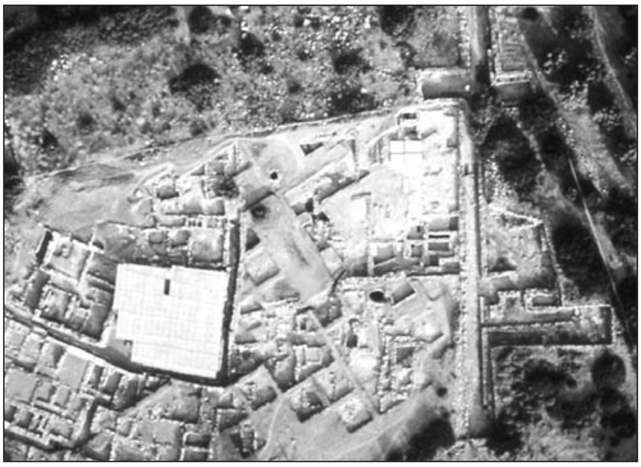

Figure 8 Vertical kite aerial photograph of Palaikastro, Crete, Photo: Professor Jan Driessen.

Figure 9 Professor Jan Driessen using kite aerial photography (KAP) over the palatial ruins of Zakros, Crete, 1998. Photo: Matt Schlitz.

the Mediterranean and Middle East (Figs 8-11). Chagny (1996) has used a novel combination of topographic surveying and geo-rectified KAP to create composite records of gravesites in Sudan. Kite or balloon aerial photographs combined with photogrammetry software can also be used to validate or augment ground penetrating radar (GPR) survey results (Chagny 1996). Archaeological balloon photography has been employed in combination with GIS at Kerkenes in Turkey (Summers 1993). KAP has also been successfully used to create a large scale digital elevation model (DEM) in the earth sciences (http://activetectonics.la.asu.edu/atf/cameltrench/). Low-level aerial archaeology can likewise provide the necessary image scale and resolution to create three-dimensional topographical models of Australian sites.

Aesthetic images and interpretatation

Before commencing an excavation project or recording a site, archaeologists are required to photograph a site

Figure 10 Tomb of New Empire necropolis, Saï island, Sudan. Oblique kite aerial photograph by Bernard Noel Chagny, Section Françaises des Antiquités du Soudan (SFDAS), 1999.

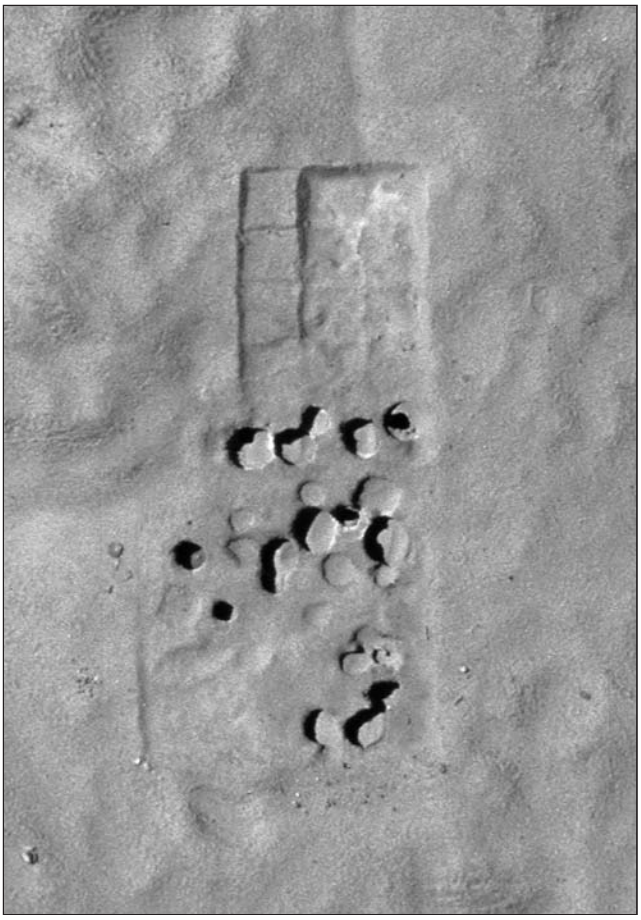

Figure 11 Grenier à grains (granaries), Méroïtic period, Saï island, Sudan. Vertical kite aerial photograph by Bernard Noel Chagny, Section Françaises des Antiquités du Soudan (SFDAS), 1999.

Figure 12 Oblique kite aerial photograph of Ismanstop Borg (ca. 1200AD), Sweden. Photo: Wolfgang Bieck.

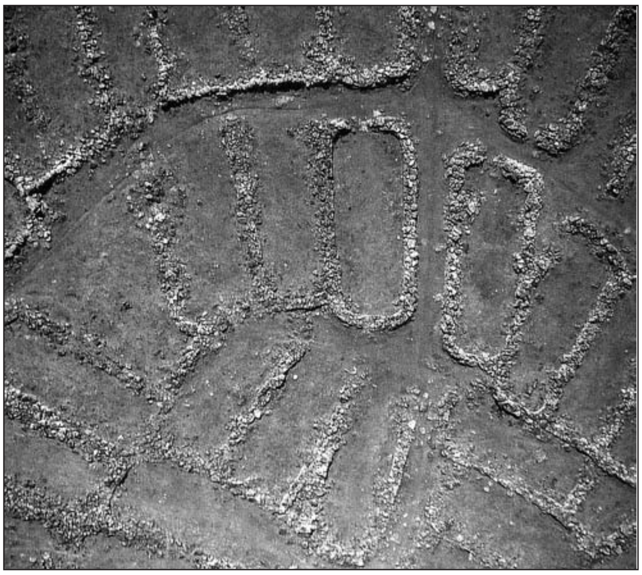

Figure 13 Vertical kite aerial photograph of Ismanstop Borg (ca. 1200AD), Sweden. Photo: Wolfgang Bieck.

overview and by elevating their camera can often obtain a more aesthetic view (Deuel 1973; Dorrell 1994). Professor W. J. Myers and Eleanor Myers used archaeological balloon photography to systematically record hundreds of sites in the Mediterranean and Middle East (Myers 1978; Myers and Myers 1990; Myers et al. 1992; Myers 1993, 1995). Not only are their 35 mm and medium-format balloon photographs of a very high standard with great resolution and aesthetic value but the images proved very useful in accurate plan illustration and the interpretation of intra-site room function. (Myers et al. 1992, Figs. 6 and 7). German KAP experts have applied their skills to photograph stone foundations from oblique and vertical angles (Figs 12 and 13). Australian open area rock art images can be recorded in suitable lighting conditions using low-level aerial booms or kites if the surface is distinct enough. Using low-level aerial archaeology for example, archaeologists can record a large scale, high resolution image of small knapping areas, contact sites or ceremonial stone arrangements or indigenous fish traps to examine spatial relationships or interpret the morphology of the structure (see Connah and Jones 1983; Figs 6, 7, 9, 12, 13). The use of infrared film or multispectral cameras with low-level aerial platforms might reveal pockets of historical vegetation or sub-structures as indicators of past human activity in Australia (Brooke and Donoghue 2004; Aber 2001; Whittlesey 1970, 1975; Whittlesey et al. 1977).

Site discovery, condition monitoring and submerged landscapes

While past human activity might be 'invisible' to the field survey team, low-level aerial archaeology may assist the archaeologist to discover sites or features such as animal and transport tracks, historic plough or fence lines, market garden activity or the impact of industrial processes. Kite photography has been consistently applied in large field survey projects such as the UNESCO Libyan Valleys project (Jones 1989) and in the North Kharga Oasis Survey (NKOS 2003) not just to map known sites but to reveal new structures or ancient routes. Hi-Cam in Australia produces a miniature transceiver/receiver system with a hi-resolution digital video camera for model aircraft that would be practical for intensive, close videographic survey of rock shelters, rock art or structures in inaccessible locations such as cliff faces, awkward terrain or over tidal and estuarine zones (http://www.hicam.com.au; see Connah and Jones 1983:76) Low-level aerial archaeology can also provide cultural heritage managers with large scale photographs to monitor the site condition and the impact of erosion on suitable Australian sites (Myers et al. 1992:5; Zurawsky 1993). Aerial archaeology platforms such as kites or balloons can also provide 'through-water' aerial images over submerged cultural heritage in Australia. The potential to photograph cultural remains in a shallow water environment such as the *Star of Greece* (1888) shipwreck in South Australia is excellent given the right conditions and technical considerations (Kniest 1990; Connah and Jones 1983). The best aerial photography conditions over water are minimal wind turbulence, minimal swell and the absence of refracted light rays at the air-water interface. A boat-launched balloon camera at Halieis in Greece was used to document and interpret submerged foundations. The resulting images were so clear that interpretation of the site and plan drawings depended upon them (Jameson 1976; Whittlesey 1975).

Considerations and limitations

There are considerations and limitations to be taken into account when constructing low-level aerial platforms. Different low-level systems must be applied to different archaeological sites and platforms are dependent on weather conditions and the environment. A kite system is more stable on a site with consistently high winds, whereas a balloon is suitable in minimal wind. Whereas a photographic boom or small balloon system would be more practical in an urban environment, KAP is generally suitable at smaller scale less populated or remote sites. One consideration when using a powered parachute camera (PPC) is noise pollution in the urban environment. Significant vegetation cover and awkward terrain may inhibit the operator of a kite or balloon platform. Photographic booms are useful for extremely low-level aerial photography up to fifteen metres.

There are key factors in the construction and use of a low-level photographic system: it must be transportable to the site without considerable inconvenience; it requires minimal operational staff; it is constructed without the possibility of danger to any member of the project team or public; there is minimum delay in its operation for the excavating or survey team; it has a reliable power supply; it requires vibration control; and it is inexpensive to construct (Poulter and Kerslake 1997; Dorrell 1994; Graham 1981). Low-level aerial platforms are not commercially produced in Australia, although there are suppliers of radio-controlled camera or video systems in the United States (http://www.floatograph.com). These expensive systems are generally used by aerial photography firms and real estate agents. In comparison, it is relatively inexpensive for archaeologists with technical support and some funding to develop a low-level aerial platform. Australian civil aviation regulations restrict operators using tethered balloons and kites near aerodromes and at heights in excess of 300 feet without permission (CASA 2002). Arriving in a country with low-level aerial platforms can be problematic as some officials prohibit the use of 'remote sensing' equipment. Operators of low-level aerial systems also have to be aware of issues such as public liability and their own safety.

Conclusion

Dedicated practitioners of low-level aerial archaeology in Australia are rare. Experts overseas have developed kite and other remote photographic systems to provide a bird's eye view of archaeology that is often too expensive to obtain via commercial means. These non-conventional aerial platforms are under-utilized in the photography of sites in Australia. Conventional aerial photography does not offer the benefits and flexibility of low-level aerial platforms which can be used at the convenience of the project director to provide cost-effective large scale, higher resolution images. Greater application of proven systems like kite, balloon and boom platforms and emerging technologies such as UAV photography can further enrich our appreciation and understanding of the Australian cultural landscape.

Acknowledgements

I thank the following people who provided expert assistance: Professor Jan Driessen (Départment d'Archéologie et d'Histoire de l'Art, Belgium), Dr Bernard Chagny (France) and Wolfgang Bieck (Germany) for their images and technical information on KAP in archaeology. Thanks to Dr Andrew Poulter who provided the mosaic image of the excavated basilica of *Nicopolis ad Istrum*. Associate Professor Jorg Hacker and Dr Paul Dare of Airborne Research Australia (Parafield Airport, South Australia) provided information on scientific imaging with fixed-wing aircraft. Warren Williams (managing director of Codarra Systems, Australia) and David Harris (University of South Australia) provided further background to the Australian UAV project and kindly provided photographs from the AVATAR unmanned aerial vehicle. Many thanks to Kerrin Pine at Flinders University/DSTO for his information on radio direction finding in UAV maritime search and rescue and to Michele Brus who assisted with the KAP photography. I wish to thank the reviewers who provided valuable comments on the draft.

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