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PRECISION AND SPEED IN CLOSE RANGE PHOTOGRAMMETRY

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BALLOON AND KITE PHOTOGRAPHY : AN HISTORICAL REVIEW

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ABSTRACT

A thorough historical review of low altitude photography experiments, using balloons and kites as camera platforms, is presented. The most important efforts are described and assessed for their results and significance in terms of their photogrammetric applicability.

1. Introduction

Soon after the advent of photography in 1839, the wish to record aerial views became increasingly apparent. Many efforts were reported with different degrees of success. Later, however, the importance of aerial photography in topographic applications was realised and the efforts to obtain useful imagery became more systematic.

Balloons of various shapes, sizes and kinds were the most serious form of aviation until the appearance of the aeroplane, early in the 20th century. It was, however, from the principles of kite flying that the aeroplane design was developed. Therefore, the usefulness of both forms of aviation in aerial photography was and still is greatly acknowledged. In Table 1 the most important steps in balloon and kite flying may be followed.

2. Review of balloon photography

The knowledge that photographs taken from a balloon must be applicable for topographical purposes seems to have first occurred to Andraud in 1855 (Gruber, 1932). Felix Tournachon (also known as Nadar), however, is reputed to have photographed part of Paris from a balloon, using the daguerrotype process in 1858 (Association of Royal Air Force Photography Officers (ARAFPO), 1977). In the following years many pioneers experimented with balloon photography, including Aimé Laussedat, who had been investigating the usefulness of photography in topographic mapping since 1849 (Slama, 1980). The first really successful photograph is reputed to have been taken by two Americans, S.A.King and J.W.Black, in 1860. Also, extensive use of balloon photography as military reconnaissance tool is reported during the American Civil War, 1861-1865 (ARAFPO, 1977). In 1867, at the Paris Exposition, Laussedat exhibited a plan of Paris, based on balloon photography (Thompson, 1966a). One year later, Nadar produced some spectacular photographs of Paris taken from a balloon held captive at 500 m (ARAFPO, 1977). In 1877, W.B.Woodbury patented an automatic system for balloon photography (Gruber, 1932; Thompson, 1966a). A camera, intended to hang from an unmanned tethered balloon, was remotely operated using electric current for winding on the film and triggering the shutter. A similar device operated with a clockwork mechanism was patented by J.Fairman (Thompson, 1966a). In 1893,C.B.Adams published a method of graphical aerial triangulation, using overlapping balloon photography (Slama, 1980).

In the years that followed, balloon photography was primarily used for military reconnaissance (ARAFPO, 1977), for cloud photography and meteorological observations in general (Bacon, 1900; Bassus, 1900a) and, of course, for documentation (Spencer, 1900 and 1901). It was with S.Finsterwalder that balloon photography began to be exploited for measurement. He devised a semigraphical method to perform what today is known as photogrammetric resection (Finsterwalder, 1899). This he achieved by using the images of plumb lines on the photograph. These 50 m long plumb lines were hung from the equator of the balloon envelope in such way that at least two would be imaged on each photograph. The most important photogrammetric use of the photography obtained at the time was the completion or revision of existing plans (Baschin, 1911; Bassus, 1900a). Simple geometric relations, mainly cross ratios, were used for that purpose; considerations

about geometric qualities of the photography were described (Bassus, 1900a). Height determination using two overlapping photographs was also reported. The time required for the determination of the X, Y and Z co-ordinates of one single point was 15 minutes, with a root mean square error of 1m (Finsterwalder, 1900). A few years later in an extremely stimulating paper, Finsterwalder, (1904) established basic photogrammetric ideas using the theory of projective geometry, least squares adjustment and co-ordinate transformation. He distinguished three major steps in the whole procedure, which he called the fundamental photogrammetric operation. Firstly, the determination of the pivot points, as he named the traces of the base on the photographic planes of two, not necessarily vertical photographs of the same area, taken with a hand held camera from the basket of a balloon. This is equivalent to the interior orientation. The second step was the reconstruction of the object without determination of scale and exterior orientation, which clearly corresponds to the relative orientation. Finally, through appropriate choice of scale and careful determination of rotations, the model was compared to reality. In the fascinating example that accompanied the paper, the various steps were explicitly presented and the final product of a 10 m contour drawing at 1:10000 scale was illustrated. The claimed co-ordinate accuracy was ±1.1m.

A comprehensive review of the various methods devised and employed in the extraction of metric information from balloon photography at that time was given by Dr.W.Kutta (Aachen) in Suering (1911). The chapter included elements of the determination of the principal distance and the principal point (camera calibration), it described methods for the computation of the camera station co-ordinates (resection) and gave hints on the transfer of points onto a map (paper strip method; restitution).

At the same time, however, balloonists encountered numerous practical photographic problems, mainly due to the lack of suitable cameras. In the effort to enlarge the photographic field of view a number of "panoramic cameras" were constructed. The first apparatus of this kind is attributed to Woodbury in 1881 (Gruber, 1932). This incorporated a revolving lens, through which several plates mounted on a prismatic drum were exposed. In succeeding years, numerous such panoramic apparatus were developed and patented, including Thiele's Panoramagraph which appeared in 1898 (Bassus, 1900a) and Scheimpflug's eight lens camera in 1904 (Gruber, 1932; Thompson, 1966a). Their development, however, was not pursued, firstly, because of the development of new photogrammetric techniques and, secondly, because of the appearance of the aeroplane. Efforts to predetermine the tilts of the camera were also made. A fine example is the so called photogrammetric gun, which was designed by Professor S. Finsterwalder (Anon., 1912; Bassus, 1900b; Georgopoulos, 1980).

Then came the aeroplane. It was only natural that balloons would lose in importance as camera platforms. New techniques and better instrumentation were developed in the years that followed (Gruber, 1932). The merits of balloon photography, however, were not completely forgotten and this technique was used, though rarely, for small projects and, primarily, for documentation purposes (Guy, 1932). It was only two decades ago that the interest in balloon photography was revived. Its economic value and its applicability in projects dealing with relatively small areas were recognised (Brains trust, 1960). Investigations of the capabilities of balloons were initiated (Brown and Newton, 1962; Ross, 1969) and certain applications were actually carried out. These included monitoring of hydrographic phenomena and marine observations (ASP, 1969; Newton, 1964), meteorological observations (Air Force Cambridge Research Laboratory (AFCRL), 1967), study of the effects of nuclear and high explosive detonation in the atmosphere (AFCRL, 1967), agricultural and forestry applications (ASP, 1969; Private communication with J.R.Tallowin), testing of remote sensors (ASP, 1969; Reeves, 1975), monitoring water pollution (ASP, 1969), study of coastal dynamics (Sonu, 1969), X-ray polarimetry (AFCRL, 1970), radio altimetry and gamma ray astronomy (AFCRL, 1970) and, finally, remote sensing applications using multiband cameras (Reeves, 1975a and 1975b; Whittlesey, 1972 and 1975). The majority of these applications made use of large balloons capable of ascending to high

altitudes(Riedler, 1977). This, clearly, defeats the argument of cost effectiveness of balloon photography in small projects. Moreover, the photography obtained in these cases was, with a few exceptions, not exploited so much for the quantitative as for the qualitative information it contained.

Archaeological applications were the main stimulus for developing low altitude flying systems using balloons (Whittlesey et al., 1977) and non-metric cameras (Chliveros,1976 and 1979;Whittlesey,1970). No metric evaluation of the photography was attempted; photomaps and mosaics were constructed instead (Chliveros, 1976; Johnson, 1977). Recently, the interest in the use of relatively small balloons, carrying non-metric cameras, has increased and various systems have been developed (Badekas et al., 1980; Robinson, 1980). Lubowski and Waldhaeusl (1980) used a tethered kite shaped balloon, filled with hydrogen, for archaeological photography. However, they employed an extremely complicated procedure for determining the exterior orientation of the camera which considerably increased the time necessary for each photograph. This could be considered unnecessary, if the photography were to be evaluated analytically, but this was not the case. It is also worth mentioning the tethered hot air balloon system, developed by the Bergbaumuseum, Bochum, which was exhibited during the 14th Congress of the International Society for Photogrammetry in Hamburg. No photographic results with this system have been reported.

Summarising, balloons provide an easily operated, reliable, relatively safe and cost effective camera platform suitable for use in small projects where large scale photography is needed (Table 2).

3. Kites and kite photography

"...The tradition is that kites were invented by the Greek scientist Archytas of Tarentum in the 5th century B.C., but they have been in use among Asiatic peoples and savage tribes like the Maoris of New Zealand from time immemorial..." (Anon., 1975). Kites were flown in China more than 2000 years ago. The popular pastime quickly spread to Japan and the other countries of the Far East, each contributing, with its own tradition and legends, to the evolution of the form of the kites. Through India and the Arabic world kites reached Europe in the 15th century (Lloyd and Thomas, 1978). However, it was not until 1804, when Sir George Cayley first established the principles of aviation and introduced (1852) his man lifting "governable parachute", that kites were considered as a serious form of flying mechanism (Lloyd and Thomas, 1978).

Koeppen and Rotch in Suering (1911) define the kite as "a solid body which, being specifically heavier than air, may be kept hovering through the conversion of the horizontal air pressure on one or more inclined planes, while tethered to the ground by one or more lines". The first serious scientific experiments with kites are attributed to A.Wilson (1749) and B.Franklin (1752), who conducted meteorological observations. Later (1855-1910), L.Hargrave developed his box shaped kite, which was a breakthrough in kite flying (Hargrave, 1897). In 1889, the first kite supported human flight by O.Lilienthal was reported (Lloyd and Thomas, 1979). In 1894, the first registering instrument with clockwork mechanism was lifted by kite at the Blue Hill Observatory, Massachusetts. Since then the use of kites has been pursued more systematically and rapid developments were to follow (Suering, 1911). Marvin (1895) intensified his investigations and by 1891 there were 17 weather stations in the United States using kites for their observations (Suering, 1911). In the meantime, C.J.Lamson and W.A.Eddy were each developing their own kite designs (Lloyd and Thomas, 1978; Rotch, 1899 and 1901), while Captain B.F.S.Baden-Powell (1897) introduced his man lifting war kites (Baden-Powell, 1897).

The first photographs obtained from a kite were taken by E.D.Archibald in 1883 while he was experimenting with measuring wind velocity at various altitudes (Rotch, 1901). Kite photography was further developed by Batut and Wenz in France until 1898, when Lieutenant H.D.Wise first described his complete system (Wise, 1898). This consisted of several kites lifting a 4x5 inches (100x125 mm)

camera, which was operated either by a clockwork mechanism or by an electric device. The usefulness of the photography in topographic mapping and its value for military work was also mentioned. A comprehensive account of the various existing kite systems was given by Captain Baden-Powell, who later also reported of his own experiences with his war kites during the South African war (Baden-Powell, 1898 and 1899; Lloyd and Thomas, 1978).

Among the chief scientific uses of kites the following were included : meteorology, wireless telegraphy, traction, military reconnaissance and life saving missions (Rotch, 1901). Eddy and Woglom used kites for photography from a few hundred feet, with the intention of assisting ground surveys (Eddy, 1899; Lloyd and Thomas, 1978; Rotch, 1901). So far, however, no demonstration of the real capabilities and accuracy of the photography had been given. The development of kite design continued with the introduction of the tetrahedral kite (1903) by A.G.Bell and the experiments of Rev. J.M.Bacon and Saconney (Lloyd and Thomas, 1978). In 1904 an international kite competition was held on the Sussex Downs. Several new kite designs took part including C.Brogden's six winged kite, S.F.Cody's winged box kite and S.H.R.Salmon's multiple-celled rhomboidal kite (Boys and Bruce, 1904; Cody, 1905). At the same time the Wright brothers were conducting experiments with large kites and gliders, which would soon lead to the invention of the first aeroplane (Lloyd and Thomas, 1979).

Only T.Scheimpflug seriously contemplated using kite photography in topographic mapping (Scheimpflug, 1904). He started his experiments in 1896 and, although he gained considerable experience with kite flying and taking photographs, he did not seem to be fully aware of its possibilities at the time. Interesting features of his experiments were, firstly, a specially modified camera to photograph a level bubble simultaneously with the object and, secondly, the fact that he was always positioning the camera inside the kite structure for obvious reasons. Kites and kite photography had the same destiny as balloons and balloon photography when the aeroplane took over. The experiments of C.R.Lawrence with kites carrying extremely heavy cameras are, however, reported (Thompson, 1966b). F.V.Thompson used a box shaped kite to obtain oblique photography over an area near Rainham, Kent in 1906 (Atkinson, 1980). Also in 1913, a very simple kite supported photography system was reported (Gault, 1913). The box camera was hanging from the tether line and was operated by burning a punk which, sent up the line by a "traveller", in turn, released a band that was holding the shutter. O.G.S.Crawford, who was subsequently appointed the first Archaeology Officer of Ordnance Survey (UK) and who made such a significant contribution to aerial archaeology, was impressed by the use of a box kite to get vertical photographs of sites while working on an excavation in the Sudan in 1914 for Sir Henry Wellcome (Seymour, 1980).

Just as in the case of balloons and because of the lack of suitable instrumentation and means for processing the data, kite photography remained photogrammetrically unexploited. It was some years after the second World War that it was again seriously considered (Laws, 1959). In the late sixties Whittlesey reported some experiments with cameras attached to a parafoil (Reeves, 1975b). In the 1967-68 field season the Swiss archaeological expedition to Kellia, Lower Egypt, used kite photography for documentation purposes with very poor results (Private communication with D.Weidman). In 1971, R.C.Anderson employed with some success a box shaped kite supported system to record excavations in Cyprus. He resorted to kites because the winds in the area made the use of a balloon almost impossible and dangerous (Anderson, 1980). Later he developed a more sophisticated system employing a Jalbert airfoil and a pulley on the tether line to lower or raise the camera. This he used in archaeological sites in Syria with a high degree of success (Anderson, 1980).

D.Dunford and J.A.Cochrane have developed two large kite photography systems (Cochrane, 1980). A single line one with a delta shaped plane kite and a twin line one involving the rhomboidal Dunford Flying Machine 2000 (Georgopoulos, 1981).

Summarising,the advantages of the kite as a camera platform become apparent. Kites are cheap and easily available mechanisms. They are easy to fly and some of them are quite stable. They may not be as reliable as balloons, but they can be used in weather conditions under which balloons become almost useless.

Zusammenfassung

Eine ausführliche Rückschau wird auf Aufnahmeversuche mit Ballons und Drachen gehalten. Die wichtigsten Versuche werden beschrieben. Die Ergebnisse und die Bedeutung werden im Sinne ihrer photogrammetrischen Anwendbarkeit ausgewertet.

Résumé

Un aperçu historique et approfondi est présenté sur des expérimentations de prises de vue de hauteurs basses en employant des ballons et cerfs-volants comme plateformes des chambres photographiques. Les efforts les plus importants sont décrits et évalués pour leurs résultats et signification en vertu de leur applicabilite photogrammétrique.

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SUBJECTIVE APPRAISAL OF LOW ALTITUDE PHOTOGRAPHY SYSTEMS					
	GROUND BASED	SELF-PROPELLING	GROUND CONTROLLED	BALLOONS	KITES
Payload					
Cost effectiveness					
Stability					
Safety					
Availability					
Applicability					
Weather resistance					
Reliability					
Ease of operation					
Simplicity of construction					
Rate of performance: poor average high	scaffolding, cranes, masts, bipods	helicopters, small aircraft	model aeroplanes, model helicopters	kite shaped, spherical	

Table 1

COMPARATIVE HISTORICAL REVIEW OF BALLOON AND KITE DEVELOPMENT

BALLOONS		KITES
	5th c. BC	ARCHYTAS kite invention
	2nd c. BC	Chinese kites
	15th c AD	Early European kites
	1749/52	WILSON/FRANKLIN meteorology
MONTGOLFIERE first balloon ascent	1783	
	1804	CAYLEY principles of aviation
ANDRAUD concept of air survey	1855	HARGRAVE box shaped kite
TOURNACHON (NADAR) first aerial photography	1858	
KING, BLACK first successful picture	1860	
military reconnaissance	1861-65	
LAUSSEDAT plan of Paris	1867	
WOODBURY automatic camera	1877	
	1883	ARCHIBALD first photographs
	1889	LILIENTHAL human flight
ADAMS graphical aerial triangulation	1893	
	1894	first registering instrument on a kite
SPENCER balloon photography	1895	MARVIN kite design
BACON balloon meteorology	1896	LAMSON kite design
	1897	BADEN - POWELL man lifting war kites
FINSTERWALDER/BASSUS balloon photogrammetry	1898	WISE photographic kite
FINSTERWALDER photogrammetric gun	1900	EDDY photographic kite
development of cameras	1904	BELL tetrahedral kite
FINSTERWALDER photogrammetric restitution		kite competition
		SCHEIMPFLUG kite photography

	1906	LAWRENCE kite photography
		THOMPSON box shaped kite photography
BASCHIN map revision	1911	
	1913	GAULT kite photography
GUY archaeological photography	1932	
interest revived	1959	LAWS reported earlier military significance
BROWN, NEWTON investigation of potentials	1962	
SONU/ROSS applications of balloon photography	1969	
WHITTLESEY archaeological photography	1970	
	1971	ANDERSON archaeological photography
	1975	WHITTLESEY parafoil system
CHLIVEROS/JOHNSON archaeological photography	1976	
BADEKAS/LUBOWSKI archaeological photography	1980	COCHRANE Dunford kite system

Table 2

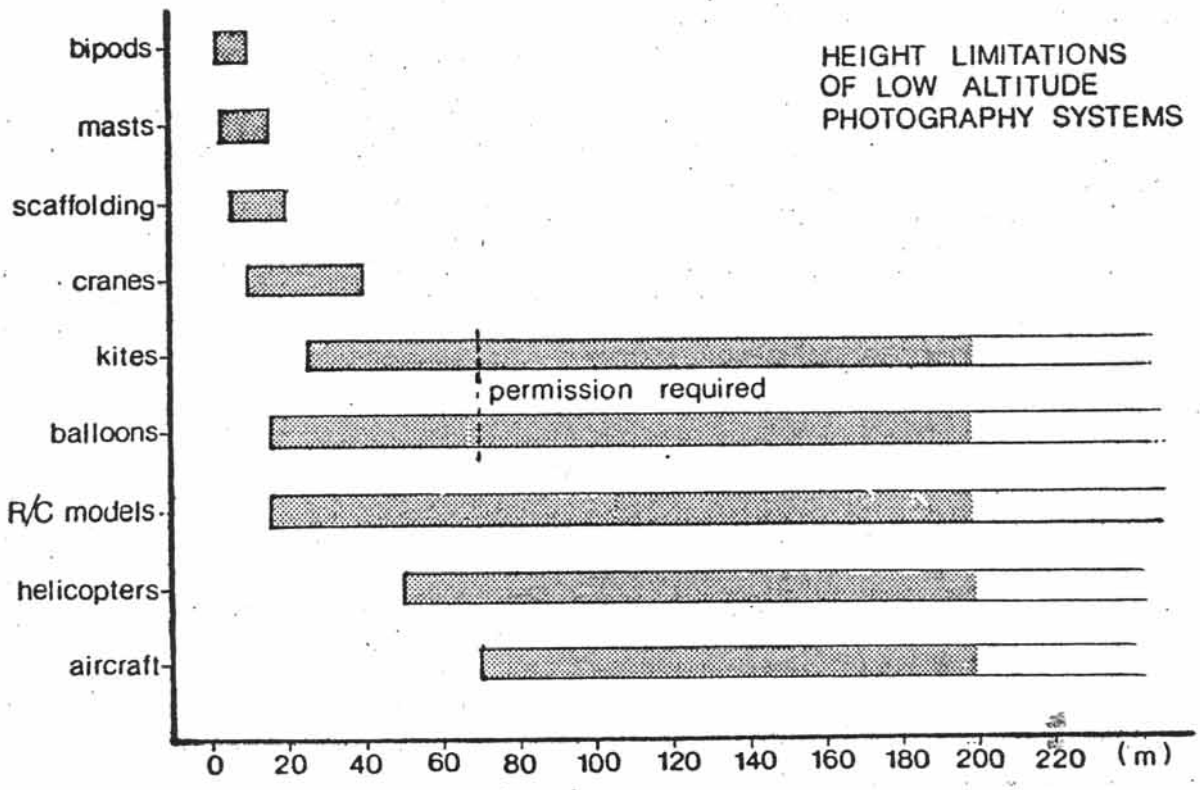

Table 3