SMALL FORMAT MICROLIGHT SURVEYS.

R.W.Graham.
R.E.Read.
J.Kure.
AIS Ltd, Amersham, U.K.
ITC, Enschede, The Netherlands.

Commission. 1.

Abstract.

Conventional survey aircraft, with their sophisticated camera and navigation systems, are mainly designed to cover the photog rammetric requirements of line mapping. But for less exacting cover, where metric accuracy is not of such prime importance, there are urgent reasons for seeking a more economic and approp riate method of gaining the primary data. In this paper the au thors explain the important advantages, as well as limitations, of small format microlight surveys (SFMS) for developing countr ies and give details of suitable combinations of aircraft, came ras, films and processes. Considerable interest in SFMS has al ready been shown by earth scientists, urban planners, photogram metrists, and survey contractors. Current research employs two different types of microlight aircraft which are piloted by the authors and others, and two different types of camera, 70mm, an d 35mm. Results obtained so far show great promise for the fut ure growth of this work, particularly with the entry of the nex t generation of microlights which are now in production. Micro light platforms offer an economic, and highly practical solutio n for MSP research and at least two units are known to be worki ng in this field using both 70mm and 35mm cameras and films.

Introduction.

The task of the aerial photographer is to make available to pr ospective users a product that goes as far as possible to meet his particular needs. In the past aerial photography develope d along the lines of providing the best possible image quality combined with coverage of the largest possible area per photog raph. Thus the 23cm x 23cm format and the wide-angle lens beca me the industry standard and, in a precisely calibrated form, useable for mapmaking by photogrammetric means.

As the types of camera needed for this format became more sop histicated, the demands for higher levels of precision followe d. Penalties came in the form of increased weights in the cam eras and their growing number of accessories, with climbing co sts per photograph as more demanding specifications became the norm. Aerial photographers were no longer able to deliver eco nomic coverage of small, specific need areas, such as local ur ban study projects, limited size agricultural, archaeological, geological or forest area studies.

Aircraft costs also climbed as a result of higher oil prices and many specialist users of aerial photography were forced to explore other methods of obtaining such airborne information. Smaller format cameras were pressed into service and light aircraft from private owners and flying clubs used as the platform.

If we compare the ground coverage of a standard wide-angle lens on 23cm x 23cm format and that of say a Hasselblad 5.6cm x 5.6 cm, with a similar photo-scale at the negative, then several difficulties facing the aerial photographer can be seen. If we take a minimum overlap of only 25% in both forward and lateral directions (standard for photogrammetric work being 25% lateral and 60% forward overlap) then we would require at least 36 frames to cover a similar area. Using 35mm film at the same photo-scale the number of photographs required increases to 117, due to the smaller size of the 36mm x 24mm negative.

Whilst this would seem to rule out small format operations, not only on the grounds of cost but also in complexity of flying and assembly of material, other factors enter the equation which swing the argument back to favour small format photography. 'Normal' aerial photography (large format metric standard) comes into its own at scales smaller than 1:3,000 and of economic sized areas. When mobilizing an aerial survey aircraft a minimum cost will be incurred, usually somewhere in the region of the cost of one hours flying. If this cost is born by the photo-cover of one small, two or three, photo task then it will be prohibitive for the small user who is usually concerned with only a single project at a time. Large numbers of such projects which, twenty years ago, would have been served by such aerial photography are now resorting to other means rather than incur such crippling costs.

The means to restore accessable aerial survey products to these sectors of land users and, more importantly, to put the means for their production in the hands of those users are now to hand. No single factor is responsible for such progress however, more a combination of widely separated, but adaptable, new features in existing techniques which include important developments in camera design, improved films in both monochrome and colour, and extremely lightweight aircraft - the microlight in fact.

The most unusual item of equipment used in this branch of aerial photography is the microlight. Manufactured from a combination of thin gauge aluminium tube and dacron material these 'minimum aircraft' have now become an accepted part of the general aviation scene with very respectable flight envelopes which can include typical performance figures such as: speeds from 20 to 80 knots, range up to 200 km, flight durations from one to four hours and operational altitudes of 12,000 feet. Most microlights will take-off in a roll of less than 30 meters and, depending on the wind vector, land in half that distance.

It is this slow speed and STOL (short take-off and landing) capability that makes this type of craft suitable for low level, localised aerial survey. The simplicity of construction makes portability possible either by car-top transportation or within a small trailer.

Yet another advantage of the microlight is the flight training with the average student taking less than seven hours to solo with a full 3-axis machine and even less than this with a weigh t-shift or hybrid type.

It is now feasible to expect that the small portable aircraft will also find its place with survey field crews, each group su pporting itself with its own photography, as and when required.

Using the microlight as a camera platform has been made easier by the recent developments in, and availability of, new motor-drive-fitted small format 70mm and 35mm cameras. These easily available 'amateur' cameras are designed with the highest quali ty optics at the cheapest price simply because of their large market. Coupled with a range of high quality, large aperture, lenses and with automatic exposure control these cameras can be used from dawn-to-dusk with a large range of photographic films and operated by the pilot with relative ease.

Perhaps the most important feature of SFMS research has been th e unexpected bonus of having new films available from two promi nant manufacturers. During our research programme we were able to exploit a number of new 35mm films, both monochromatic and colour and the results have indicated avenues of research that we would not have pursued were it not for their unique qualitie s. In this respect we can mention 20x enlargements from Kodak Technical Pan film type 2415 with not the slightest suggestion of 'graininess'. Indeed, this film alone introduces a complete answer to the old question of 35mm quality and enlargements of 50x are not out of question providing that the associated LC developer is employed. The new 'T grain' technology of Kodak's VR colour film range span a film-speed range from 100 to 1000 ISO with minimum 'graininess' providing splendid results from low contrast areas, and the Ilford XP1 monochrome film with its chromogenic developer allow for a system with very flexible ima ge qualities. The nature of these new films soon proved that 35mm systems had a distinct advantage over the 70mm format sinc e the latter film size, which is not as popular as 35mm, is exc luded from the new range. Whereas traditional thinking always looked to the 70mm format as being a distinct advantage, in ter ms of it being larger than 35mm and therefore provided for grea ter coverage, cameras such as the expensive Hasselblad no longe r can be justified in these terms since the use of a good wide-angle lens (f=35mm for example) with type 2415 film allows for the same coverage with a less expensive 35mm system.

The shift of emphasis from 70mm to 35mm was only made possible by the introduction of the new films, although tests with the well established fine-grain Panatomic-X, and Pan-F films gave sufficient evidence to support this move. As a result it is possible to take full advantage of the modern 35mm camera and the very wide range of materials available for its use. Films that range from the very high resolution 2415 (ISO speed 32)to Tri-X or HP5(ISO speed 500), with the admirable Panatomic-X, Pan-F, Plus-X, and FP4 films in the middle range of speeds.

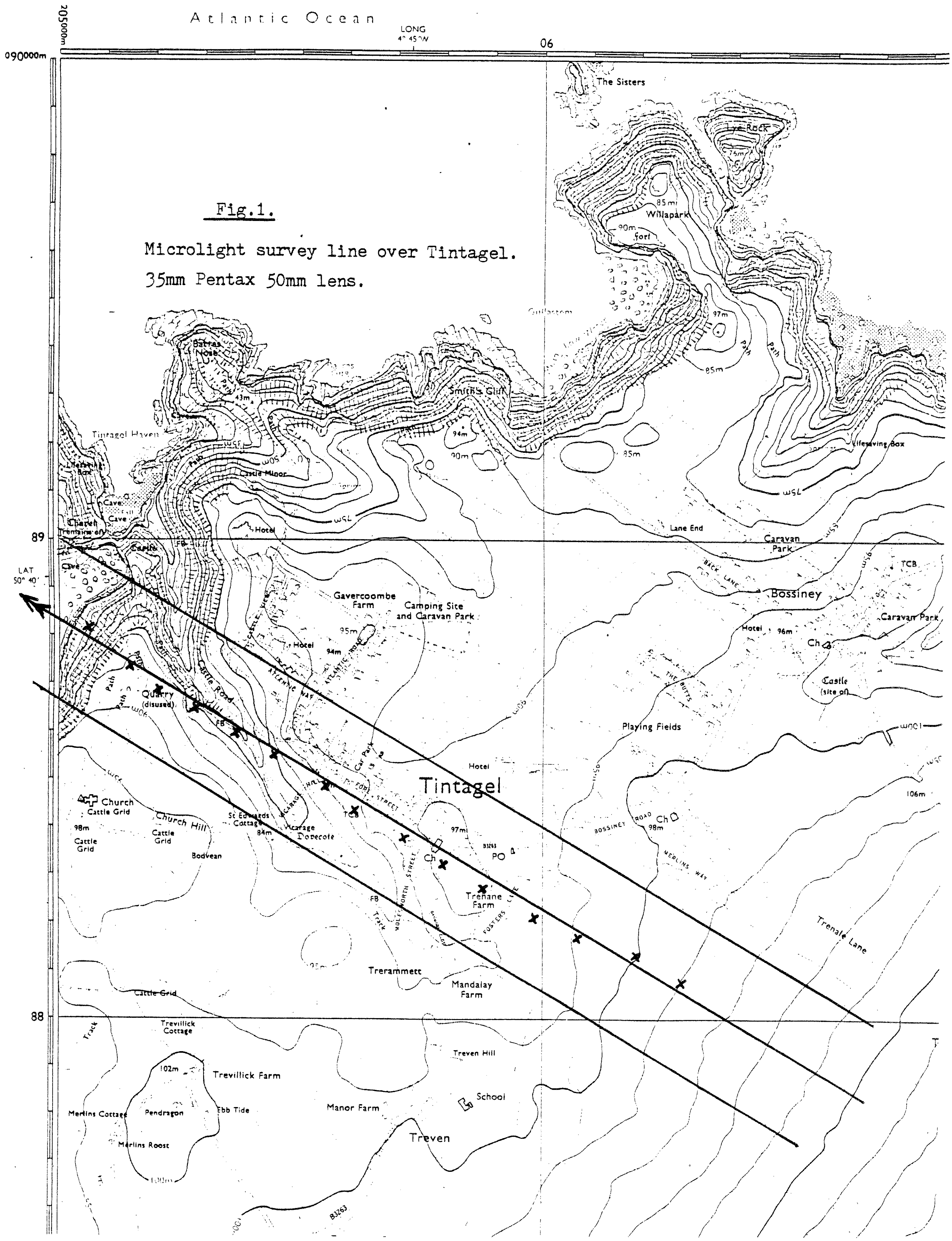

Fig.1.

Microlight survey line over Tintagel.
35mm Pentax 50mm lens.

The VR range of negative colour film supports this wealth of av ailable materials and, more importantly, has a world wide comme rcial processing back-up to provide a fast and efficient print service. The range of available materials in 35mm is indeed quite surprising and for MSP research (multispectral photograph y) we have monochrome infra-red as well as false-colour infra-red material.

Naturally the question of metric accuracy has to be considered, and the Hasselblad has a good reputation in this respect, but f or most users the question of photogrammetry will not be entert ained with SFMS systems, and so the use of such cameras rapidly falls from favour. Nevertheless, we continue to experiment in this area and are now testing both 70mm and 35mm imagery from SFMS for photogrammetric possibilities. From one set of line-overlap photographs taken with Panatomic-X and a 50mm lens on a Pentax ME camera an excellent mosaic was produced, without recourse to rectification, and with a photo-index that would not have shamed a conventional air survey crew. See Fig.1. The flying height, above ground, for this mosaic was 1,500 feet, providing a photo-scale on the negative of 1:9,000 which was easily enlarged to a laydown scale of 1:1000 for map intensifi cation purposes. The area was the small west of England coast al town of Tintagel and the last pair of the twenty frames pro vided a stereoscopic model with 61% forward overlap. The avera ge overlap was 59%. From the last stereo-pair of the run, the height of Tintagel Castle above the sea-level was determined by parallax-bar as being 104 feet, quite a reasonable value which compared reasonably with the nearest trig point of 112 feet.

The small 35mm frames require every possible chance to provide accurate imagery and so only the best of lenses should be emplo yed for SFMS work. And if the print is to reveal the quality of the negative it is of the greatest importance that the enlar ger should also be of the highest quality. Fortunately the one great problem associated with 35mm negative quality - correct exposure has been largely eliminated by the incorporation of fu lly automatic exposure systems in the high quality 35mm cameras such as the Canon and Pentax we employ. Both of these cameras operate with an aperture priority system such that, when the operator selects a given aperture (which should be undertaken with some care, considering flying height and expected exposure and camera vibration) the exposure sensor automatically selects the correct shutter speed - up to a value of 1/2000 second.

In practical terms 35mm format has the distinct advantage of be ing inexpensive, lenses are of good quality, filters, autowind accessories, remote controls, etc are easily available, and the entire system can be duplicated at low cost with low weight for MSP purposes. But there are two other advantages that should be mentioned, and both have been found by experience. The 70mm Hasselblad camera offers greater bulk to the airflow than the Canon or Pentax and we have found this to be a problem with in-flight vibration. Even with an aerofoil housing the 70mm magaz ine has produced problems leading to a number of 'lost' mission s, whereas the 35mm cameras suffer not at all in this respect.

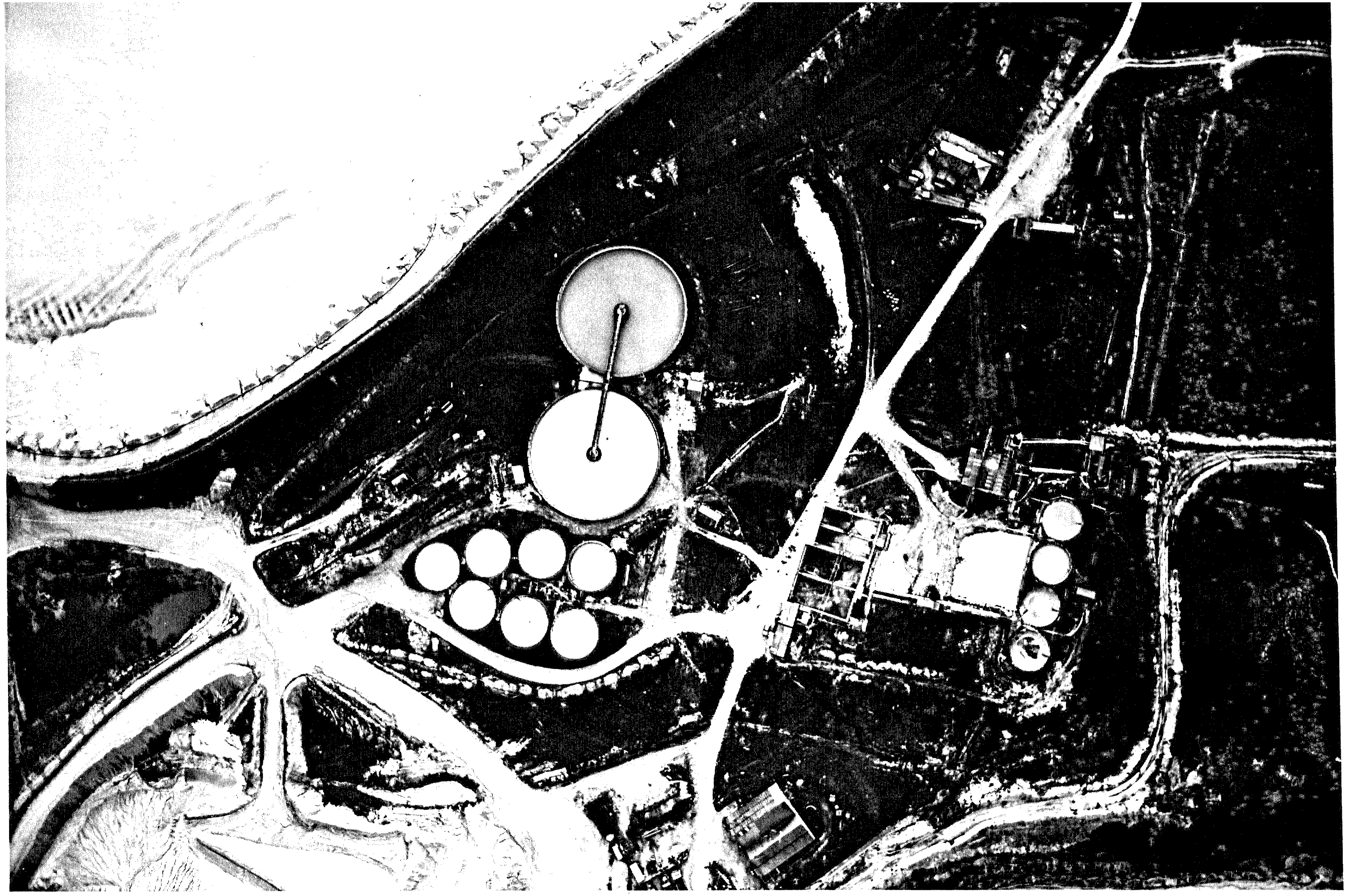

Fig.2. China Clay Works. Cornwall, England. 28/12/84.
SFMS f = 35mm. Kodak 2415 film.

This is not to say that one should not be careful with vibratio
n and 35mm cameras, far from it! But the 35mm camera is much
easier to mount and isolate against vibration than the Hasselbl
ad with a separate 70mm magazine. The second advantage we foun
d was the almost forgotten question of film processing! The 35
mm processing being simple compared to that of the 70mm film,
particularly when quality is at such a premium.

As mentioned above, the range of 35mm films now available for
aerial work allows SFMS to be carried out in low light levels
throughout the entire day, and throughout the entire year. A
typical example is shown in Fig.2, which is a 1:1000 print made
from a 1:20,000 negative on Kodak 2415 film. It should be reme
mbered that this particular film is a high-resolution low-speed
emulsion (ISO 32), yet it was still possible to fly a mission
as late as 1500 hours in late Decemeber, simply because an aper
ture of f/2 was available, and at a cruise of 32 knots in a 3-a
xis Mistral microlight very little translated image motion was
present. Flying at 2,300 feet the Canon camera was fitted with
a 35mm focal length lens to record the clay pit works in Cornwa
ll, England. The camera was operated in automatic mode to prov
ide a line-overlap mosaic at 1:20,000 scale of the entire clay-
pit area. During this mission, which ended at 1530 hours, and
was flown under a complete cloud cover at 12,000 feet, the Pent
ax ME camera was also employed with a 50mm lens and VR 1000 col
our film to provide oblique cover of the area in low light cond
itions beyond the capabilities of the 2415 film. These results
although 'grainy' were still very useful, the small areas of co
lour being differentiated well under such low-light low-contras
t conditions. Used in this way it is possible for SFMS users t
o fly the microlight close to the mission area, from any conven
ient field, and take advantage of short-term meteorological win
dows as they arise. Yet another advantage of the SFMS concept.

Although widening the possibilities for obtaining localised, di
rected aerial surveys, the microlight aircraft has its limitati
ons. Early models (1st and 2nd generation) suffer from operati
onal constraints due to wind conditions. Turbulence and crossw
inds can make the slow microlight susceptable to an impossible
range of gusts which, if not exactly dangerous, are certainly n
ot acceptable in a camera platform.

New microlight designs are now being developed however, and the
new types are capable of being operated in much wider condition
s. The performance of these 3rd generation machines are now ak
in to that of present day general aviation aircraft such as Pip
er and Cessna trainers. Indeed, most of the new microlights ha
ve enclosed fuselages making cold weather and high altitude fly
ing much more bearable. Thus, the microlight is being accepted
in the aviation world as a regular member of the aircraft famil
y. A number of countries have established appropriate legislat
ion and licensing procedures which not only specify the aircraf
t, but also control registration, certificates of airworthiness
flying tuition, and pilot qualifications. In general the microl
ight is an aircraft with an empty weight not greater than 150kg
and a wing-loading of less than 10kg per square meter, it has a
limitation of a crew of two people, and must have a wing area
not less than 10 square meters.

To date testing has been carried out with three different types
of camera, 70mm and 35mm. Four different focal lengths of lens
and a comparison made between two wide-angle 35mm lenses, each
of f=35mm, in order to establish the role of lens quality with
high resolution film. Seven different monochrome 35mm films an
d three 70mm films have been explored, with five different type
s of developer. In addition, five types of negative colour fil
m have also been investigated.

So far we have only been able to test fly 1st and 2nd generatio
n microlights, but we have been able to fly and operate our cam
eras from five different types of machine including at least on
e of each of the three basic types of aircraft. Our operations
have been conducted from three different sites, two in England
and one in The Netherlands, under a joint programme of research
between ITC and AIS Ltd, England. We present a short review of
this programme, its aims and objectives, results, recommendatio
ns and future developments.

Microlight Aerial Photography Test Programme.

The two principal aircraft used in the early test programme wer
e the American Aerolights Eagle, and the Eipper Quicksilver MX
II. Various engines have been used on the Eagle, but the type
employed in the test programme was the Xenoah, considered to be
the most powerful and reliable of the available range. The two
aircraft represent the best of each type, the Eagle being an ex
cellent example of the hybrid type of microlight where control
is mediated through a mixture of weight-shift and 2-axis flying
control. The Quicksilver is possibly the most popular microlig
ht aircraft in the world at this time and, unlike the single-
seater Eagle, can be flown as an optional two-seater, and is a
more conventional aircraft employing conventional 3-axis contro
ls.

Comparative performance figures for these two aircraft are:

	EAGLE	QUICKSILVER (2 seat)
Engine:	Xenoah G.25B1 245 cc. 20HP at 6500 rpm.	Cuyuna 430 RR. 430 cc. 45 HP at 6500 rpm.
Max speed:	44 kts at 6500 rpm.	45 kts at 6500 rpm.
Vne: (velocity never to exceed)	48 kts.	63 kts.
Service ceiling:	12,500 ft. amsl.	10,000 ft amsl.
Rate of climb:	600 f.p.m.	390 f.p.m.
Cruise speed:	28 kts at 75%.	36 kts at 75% power.
Landing speed:	22 kts.	24 kts.
Stalling speed:	18 - 20 kts.	21 kts.
Take-off roll:	10-30 meters.	20-30 meters (single) 100-150 meters (dual)
Landing roll:	less than 25 meters.	30 meters plus.
Sink rate:	325 ft per minute.	390 ft per min (single)

	EAGLE	QUICKSILVER
Glide ratio:	9:1 (at 25 kts)	6:1 (dual) 8:1 (single)
Fuel capacity:	2.7 gall. 8 gall (long-range)	4.4 gall.
Duration:	1.75 hours (2.7 gal)	1.75 hours (4.4 gal)
Range:	97 km (still air)	80 km (still air)
Empty weight:	77 kg.	136 kg.
Max T.O weight:	197 kg.	317 kg.
Payload:	120 kg.	181 kg.
Wingspan:	10.67 meters.	9.75 meters.
Wing-loading:	10.9 kg/M^2.	21.3 kg/M^2.

Both aircraft were equipped with fixed camera mounts, each mount being provided with a means for setting-off drift compensation during flight. The Eagle mounting system went through five different experimental phases in order to attempt a universal assembly suitable for verticals and obliques, but with each variation there were problems concerned with engine vibrations and the final system followed that employed in the Quicksilver - a 'soggy' type of anti-vibration suspension protected from wind buffeting.

The cameras, Hasselblad (80mm and 100mm lenses), Pentax ME Super (50mm and 35mm), and Canon(50mm and 35mm), were each fitted with electrically operated auto-wind systems remotely controlled from the control column of the aircraft.

The principal aim of the programme was to establish the feasibility of the concept, the degree of pilot experience required to fly acceptable flight lines, the optimum camera/mounting configuration, focal length of lens, photo-scale,altitude, film and processing combination, flight strategy with respect to the prevailing wind vector, and camera sighting technique. In order to establish these closely linked variables the required programme simply implied putting together as many experiments as possible in each flight, and using four different pilots of varying experience over an entire range of flying conditions.

The objective was simple enough, to provide a viable, and economic system of SFMS with the best and safest combination of aircraft, camera, mounting, film and flying technique possible.

The prime objective was to provide continuous overlapping runs of photography over urban targets since this was considered to be the most useful and difficult operation likely to be encountered in practice. Most of the primary work was conducted at Davidstow airfield, Cornwall, England, where a number of test missions were flown against a local 'test-line' of white markers set out over the airfield at intervals of 90 meters through a distance of two km. Only after a considerable number of test-line flights were made did we attempt specific missions and, since Davidstow is 970 feet amsl, and suffers from high moorland winds, these test-line flights proved to be of great value.

Three major components of strategy were established during thes e test-line flights; the aircraft's heading with respect to the prevailing wind vector, establishing the photo-stations, and th e question of camera vibration. Each of these important compon ents will be briefly discussed in terms of our solutions to the problems incurred.

Wind Vector.

All microlights, by definition, suffer from extremes of wind an d are constrained in their performance by this singular factor. Employing all four pilots, according to their ability to fly in various strengths of wind, we established conclusiveley that th e various photo-station (set at 90 meter intervals) came up onl y too quickly, and the position of each aircraft directly over each target was not easy to execute when flying against the win d vector. Not only was it difficult to keep to the line, and place the platform over each target, but it was also difficult to maintain a constant altitude (particularly with the Eagle an d its canard wing configuration) at the same time. Flying with the wind behind the aircraft made life much easier however, suc h that experienced pilots could maintain station in 20 knot win ds, without too much difficulty.

Establishing the photo-stations: Camera sighting for overlap.

As mentioned above, wind is a principal factor is establishing a good flight-line and, as a consequence it is implicit that regular intervals are difficult to establish on the basis of a known ground-speed! It was very soon made obvious that any att empt to provide sophisticated exposure interval control would be frustrated by the irregular ground speed of the microlight. We therefore adopted the old system of 'side-sighting' whereby the operator (pilot) exposed each frame, for a given degree of frame overlap in the forward direction - say 60%, by selecting a ground feature along the flight-line, making an exposure and when this same feature appears at another point of reference on the frame of the aircraft - make yet another exposure, at this point the next ground feature is recognised against the forward reference point, an exposure is made, and when this same feature appears at the rearmost reference point....and so on to the end of the line. Naturally suitable reference points must be made on the frame of the aircraft according to the seated position o f the pilot, camera focal length, and frame size, but once this has been done the system is remarkeably reliable regardless of the aircrafts height above ground. For the Tintagel town line-overlap with the Eagle aircraft, two reference bars on the land ing frame of the machine were employed for the 50mm lens, 60% overlap, and the 24mm side of the 35mm frame leading. Over a line of twenty frames we never deviated by more than 4% from the nominal value of 60% forward lap.

Camera Vibration.

Both Eagle and Quicksilver, like nearly all of the 1st and 2nd generation aircraft, are powered by two-stroke engines. These power units operate at high revolutions and, through the tubul ar structure of the airframe, generate significant vibrations.

After a number of different types of mounting were tested it wa s found that only the suspended type of mount, well protected f rom incident vibrations and the wind could provide acceptable isolation for the camera.

Future Developments and Conclusions.

The advent of the 3rd generation microlight will see great impr ovements in terms of performance, comfort, and reliability, but these features should not override the existing advantages of the current machines. The introduction of four-stroke power un its, greater performance in 20 knot plus winds, extended range, and freedom from excessive vibration will be the main advantage s looked for in improved machines.

From our research flights we can offer the following main point s that should be considered by those interested in adopting a SFMS system:

(i) Select a single seater aircraft, such as the Eagle or Quic ksilver. These aircraft have proven capabilities and, in the event of a power failure, good glide characteristics - a very important feature when flying over extended urban areas! But on ly in the single-seater variants of the Quicksilver we would ha sten to add!

(ii) Pay strict attention to a good anti-vibration mounting.

(iii) Employ a good quality 35mm camera, such as Canon, Nikon, Pentax, with autowind control. Use both 50mm and 35mm lenses, the latter being most important with 2415 film. Lenses should be of the best possible quality.

(iv) Make sure that the enlarger is of first class quality.

(v) Operational altitudes should be in the region of 2000 to 3000 feet most of the time. At these heights it is easy to navigate, haze is reduced, winds are less of a problem.

(vi) Flying microlights, like most potentially dangerous under takings, requires correct training. With correct flying traini ng the microlight aircraft is as safe as any other aircraft whe flown within its flight envelope. In this respect the Eagle is very safe, being designed as spin and stall resistant, and is a good aircraft to start with.

-.-