Flying for Air Survey Photography.

Paper read by Captain F Tymms, M C , before the Institution in the Lecture Room of the Junior Institution of Engineers, 39, Victoria Street, London, S W 1, on 10th February, 1927 Major H Hemming, A F C , F R G S , A F R Ae S , in the Chair

THE CHAIRMAN It is my pleasing duty to-night to introduce Captain Tymms, whom you all know very well I cannot think of anyone who is better qualified to read this paper than Captain Tymms, as not only is he a practical aviator, but he is also a member of the Air Survey Committee, who are the recognised authority on air survey matters in the British Empire

We are also very fortunate in having another member of the Air Survey Committee present in the person of Captain McCaw, the Secretary

I have received letters from Colonel Edwards, Colonel Crosthwait and Wing Commander Laws regretting their inability to be present to-night

I now have much pleasure in calling upon Captain Tymms to read his paper

Capt TYMMS Flying for air photography is essentially a matter of navigation If "navi-gation," by its root, means no more than the moving of a ship, it has come to imply the moving of a ship with precision to the place desired In the ordinary process of navigating a ship or an aeroplane to a desired destination, precision is required at the point of arrival, while a considerable amount of latitude is permissible in the method and manner of arrival In photographic flying, however, not only is greater precision demanded in the two dimensional position of the aircraft, but ideally, the altitude and attitude of the machine must also be from moment to moment, under the conscious control of the pilot

If an air photograph were taken of a tract of level country with a camera fitted with a perfect lens on a perfect plate and with the axis of the camera truly vertical, it would be the pictorial equivalent of a section of a map, whose scale would depend on the focal length of the lens and its height above the ground If a second similar adjoining photograph could now be taken from the same height, one of whose edges coincided with the edge of the first, the two could be joined together to form a portion of a mosaic which would be equally the pictorial equivalent of a map

These ideal conditions do not exist The earth's surface is not level, and herein lies one of the chief of the surveyor's difficulties in air survey Neither the lens nor the plate is perfect, but the inaccuracies caused thereby are not the concern of this paper The axis of the camera is only accidentally truly vertical,

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

the reduction of the " tilt " is one of our main concerns The second and subsequent photographs are not and cannot be taken from exactly the same height, the attempt to achieve this object forms another main section of our enquiry These things being so, it is neither possible, nor desirable, to take adjoining photographs with coincident sides Both in order to avoid gaps and to enable the detail on adjoining photographs to be accurately connected up, it is necessary that there should be an overlap on all sides of each photograph To achieve economy in flying time, and in what is of comparatively minor importance, photographic material, it is desirable to regulate this overlap so that it is neither more nor less than is necessary for the purpose in hand, herein lies the third main section of the problem

Air photographs may be either "vertical" or "oblique," the former being those in which an attempt is made, with varying degrees of success, to keep the camera axis truly vertical at the moment of exposure, the latter are those in which the camera axis is definitely tilted—usually at an angle of at least 60° from the vertical The majority of air survey methods depend on vertical photography, the problems of flying in oblique photography are in the main, less precise, and are not dealt with in this paper

Type of Aircraft

Before proceeding further with the discussion of methods it may be as well to refer to the type of aircraft which is envisaged The old idea that, although one might want speed, load carrying capacity, climb and good performance generally for an air transport machine, any aircraft would do for air photography has been definitely exploded In order to achieve commercial success one must have an aeroplane of good performance, and in order to achieve success in flying accurately one must have certain special features of construction The main desiderata in the machine are —

(*a*) Pusher, twin engine or three engine, but no engine in the nose —

The pilot can only fly really accurately if he has a clear view ahead Twin engine or three engine type is desirable, because air survey usually has to be carried out in close country difficult of access and therefore usually dangerous for forced landings

(*b*) Interchangeable wheels, floats and skis —

The air survey operator has to be prepared to proceed with his machines to any part of the world He cannot build his fleet for one set of conditions

(*c*) Metal construction —

For robustness and durability which are necessary for the same reason

(*d*) Cruising speed not less than 100 m p h —

For economy in time, particularly where photographic weather is scarce

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

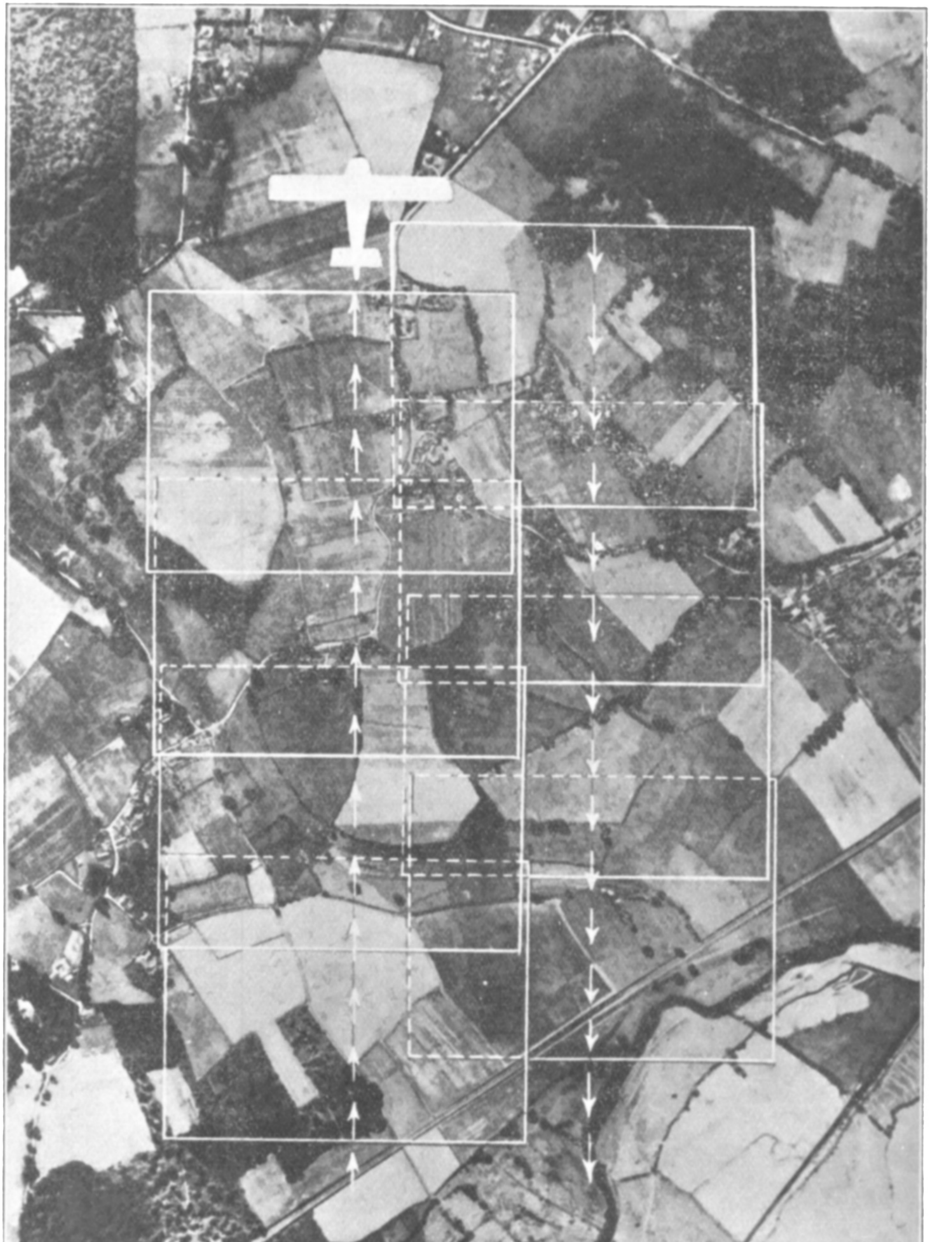


FIG 1 CORRECT OVERLAP

By courtesy of Aerofilms Ltd

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

(*e*) Service ceiling at least 16,000 feet —
The greater the height, the larger the area covered at one exposure and therefore the greater the saving in time both on the ground and in the air

(*f*) Quick get off and slow landing speed —
For operation on improvised aerodromes or restricted areas of water

(*g*) Petrol for six hours —
Brief spells of photographic weather must be taken full advantage of, and time is wasted in coming back to the base

(*h*) Disposable load, excluding petrol, oil, etc , 1,000 lbs (Including crew of two, camera, plates, sights and emergency gear)—
In certain conditions, emergency kit must be carried in case of forced landing

(*i*) Ample space for fitting vertical camera and for its easy manipulation and removal , preferably also a forward cockpit from which oblique photographs may be taken in a forward and both lateral directions —

(*j*) Stability in flight —
Both to reduce tilt and variations in course steered

Such a machine does not exist, but with the enormous potential demand for air survey which exists, those companies which undertake air survey will find it essential to specialise in their equipment, and a machine of somewhat similar characteristics will inevitably come into existence

In this paper we are only concerned with a few of the characteristics—those dealing with the view of the pilot and photographer chiefly Since these have to be referred to, it appears advisable to explain fully the situation with regard to the machine

The usual method of covering the area with vertical photographs is to fly in a series of parallel lines of convenient length, the distance between the lines of flight depending on the focal length of the lens, the size of the plate, the altitude of the machine and the amount of overlap desired The ideal result is shown in Fig 1 A greatly exaggerated version of the effect of departure from the ideal is shown in Fig 2

Length of Photographic Strip

A point of obvious importance in the success of this operation is the size of the area to be covered in one unit, and, more important still, the length of the strips The former is frequently governed by the incidence of control points which may for example follow the line of some waterway It is convenient to have control points at each end of a strip of photographs and, apart from this, such a landmark as a waterway forms a conspicuous starting and finishing point This, in itself, therefore frequently decides the issue The area can, in fact, be made indefinitely large subject to the provision that the length of the strip has a definite limitation If it is made too short an inordinate amount of time is wasted in dead flying during the turns between each strip If it is made too long there is a serious danger of not keeping a straight course and thus giving rise to gaps

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

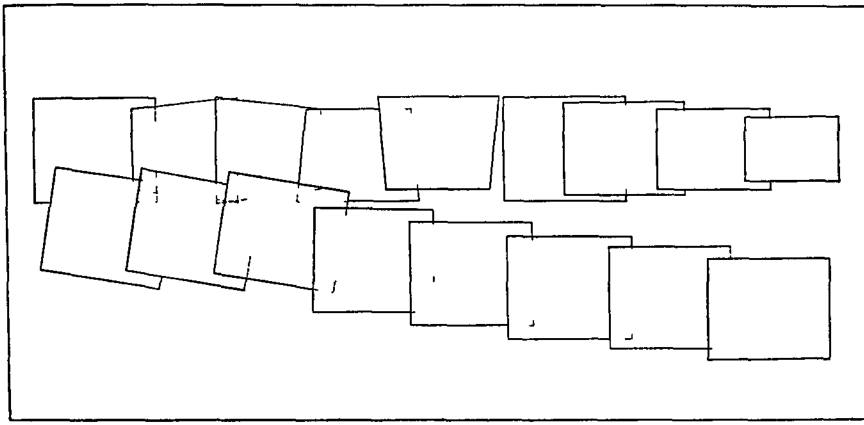


FIG 2
INCORRECT OVERLAP

General opinion puts the minimum length at about ten miles Even then, with the best possible flying at the turns, dead flying amounts to 5 per cent , and is much more likely to amount to 10 per cent Cases have occurred where strips as long as ninety miles have been photographed These are exceptional, and have been confined to the continental climate of Canada and similar places

To express the stability, or lack of stability, of conditions in this country, the Meteorological Office use the following formulae* giving the average vector change of wind with time and space —

Space	Velocity change	=	$55\sqrt{d}$	d = distance in miles
	Directional change	=	$2\,2\sqrt{d}$	
Time	Velocity change	=	$3\,5\sqrt{t}$	t = time in hours
	Directional change	=	$10\,9\sqrt{t}$	

Curves may be constructed from these formulae from which it may be deduced that in a flight of thirty miles, taking say twenty minutes, the average lateral displacement of the aircraft, assuming that no allowance had been made for change of wind, would be about one mile This would be a serious discrepancy, but it must be remembered that the average is made up of days when violent changes associated with bad weather are taking place, and other days when little or no change occurs Photography is usually carried out on the latter, so that the figures derived from the above formulæ are of less significance than might, at first sight, be supposed For this reason the curves are not shewn, and the formulæ are quoted merely to illustrate an aspect of the problem

* *See also* " Wind Structure in Relation to Air Navigation " Capt F Entwistle, B Sc Institution of Aeronautical Engineers, 10th December, 1926

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

From general considerations and experience gained by operators, it appears safe to say that, by suitable methods, strips of from 25 to 30 miles in length can be accurately flown

Direction of Flight

There have been operators who maintained that photography should only be carried out while flying up and down wind Cameras are now fitted with rotatable mounts which allow of the elimination of the effect of drift Others have thought it necessary to photograph in one direction only for a reason of a similar nature With modern equipment, there is no justification for either of these views

The direction of the strips may be sited to conform with local conditions The only factor which gives any bias in favour of a particular direction is the northerly turning error of the compass, which makes it preferable to fly in an east-west direction if this instrument is being used

Figs 3 and 4 shewing the lay-out of the strips and the actual mosaic of the photography of the Isle of Wight carried out by the Royal Aircraft Establishment, illustrate the points discussed in this and the preceding paragraph

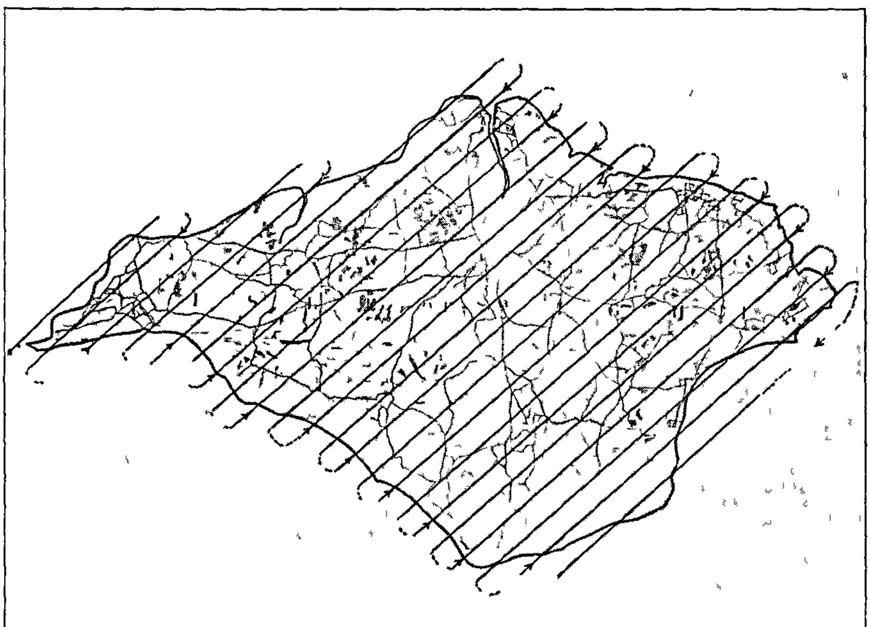


FIG 3

STRIP MAP OF ISLE OF WIGHT

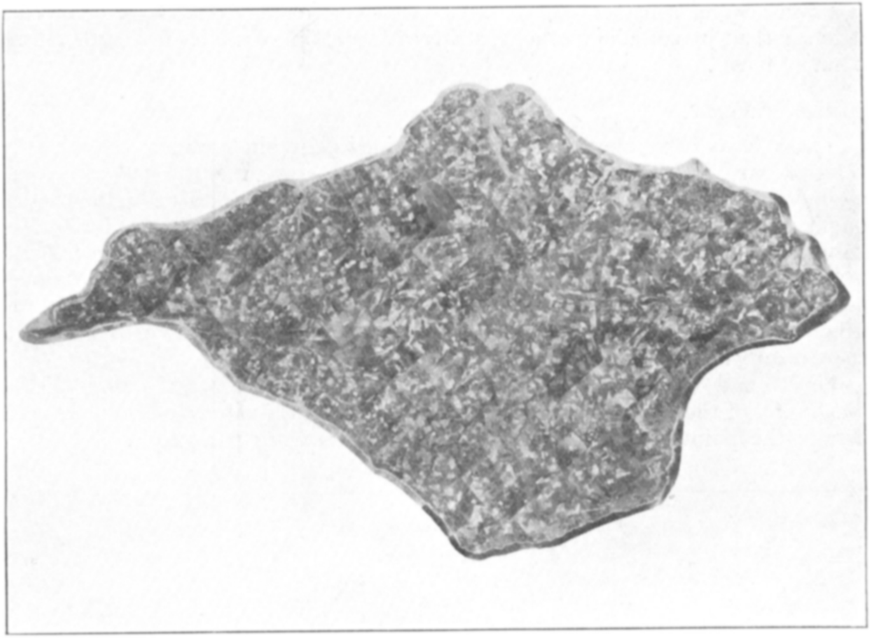
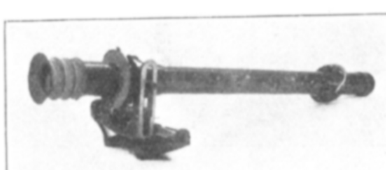


FIG 4
MOSAIC OF ISLE OF WIGHT

Determining the Course to Steer

There is considerable divergence of opinion as to how the course to steer should be determined and as to whether it should be determined by the pilot or photographer Obviously, the method depends on the method of steering adopted, and we can dismiss at this stage those methods which do not depend on the compass for steering the course, because in such methods the determination of the course and the steering of it are identical operations In these cases the pilot must carry out the whole operation



ALDIS CAMERA AIMING SIGHT

Where the compass is used in any form, it is necessary to calculate or measure the allowance to be made for drift This can most conveniently be done by the photographer, who is better able to use a drift indicator The type of drift indicator is still largely a matter of choice in the absence of one with outstanding advantages

The Aldis Camera Aiming Sight, an optical sight in the form of a vertical tube, projecting through the floor has been much used in this country with considerable success The sight has several functions, one of the most important of which is the measurement of overlap, but here we are concerned only with drift measurement The sight is mounted near the camera in a mounting which permits of its adjustment to the true vertical In the optical system is incorporated a rotatable drift line and certain transverse lines, which may be used for ground speed measurement The normal angle of view in the sight is 74°, but two prisms mounted fore and aft of the object lens are rotatable so as to bring both the forward and aft horizons into the field of view If desired, these may be used as auxiliaries in the determination of drift, but they are not normally necessary for this purpose.

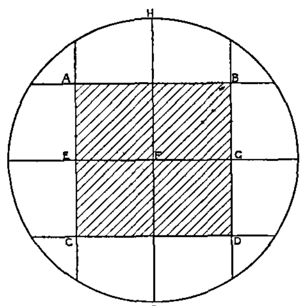


FIG 6

ALDIS GRATICULE

CAMERA AIMING SIGHT GRATICULE

Having determined the drift, the camera is set at the same angle to the fore and aft line, so as to secure uniform overlapping

The form of drift sight which I favour is one which makes use of the double drift problem, as does the Wind Gauge Bearing Plate This instrument has several times before been described, and it is not proposed to describe it again here Suffice it to say that by the observation of drift alone on two or more courses, the wind is determined and, with a simple setting, the course to steer for any other desired track and the ground speed on that track are given

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

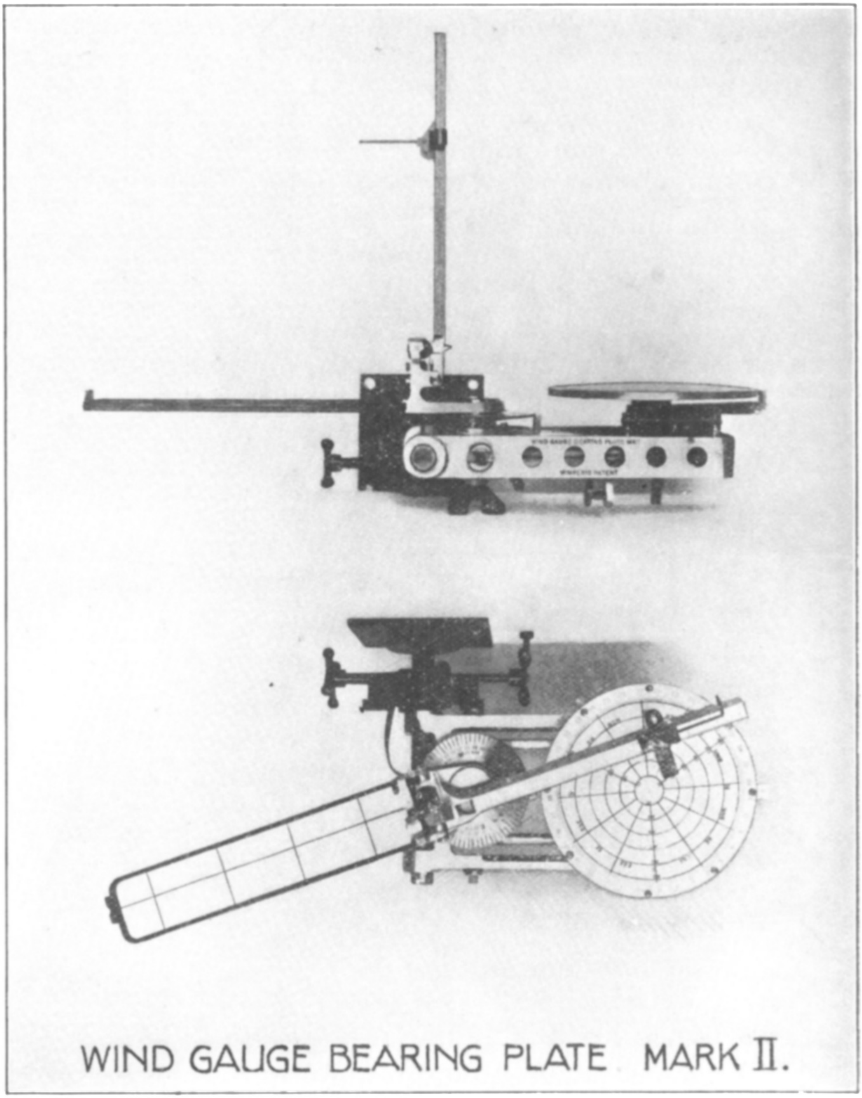


FIG 7

WIND GAUGE BEARING PLATE

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

The advantage of this instrument is that it gives the data necessary, not only for the orienting of the camera, but for the setting of the exposure interval on the camera, and that it does it with reference to drift alone, which can be accurately measured, and without the timing of ground speed, which cannot be accurately done

Major Cochran Patrick is engaged in making up a greatly improved form of the Wind Gauge Bearing Plate, which is both simpler and lighter and which gives a more direct solution of the problem

It has been maintained that it is necessary to make a trial flight in each direction along the photographic strips in order to determine the course to steer and the overlap interval It is obviously not necessary to do this with a Wind Gauge Bearing Plate, nor is it really necessary with any form of drift indicator and a calculator It is most economical to carry out the operation on the way to the photographic area, and a double flight along the photographic strips may be looked on as rather a waste of time At this and all other stages in the operation it is necessary to resist vigorously the encroachments of " dead " flying It is the flying time spent in actual photography which alone brings in a return

Getting into Position and Steering the Course

At first blush, it would not appear to be difficult to take an aeroplane to any desired position, but regarded as an operation of precision the difficulties are considerable The effect of failure is to vary the lateral overlap, and this may reach the extent of actually leaving a gap between strips Whatever method of flying be adopted, it is necessary to select some topographical feature lying on the centre of the first strip and preferably near the beginning This may be selected from an existing map or it may have to be selected in the air The problem then is to pass over this object while flying on the desired course, whether predetermined or otherwise

To attempt to do this by looking vertically downwards and trying to adjust the position of the machine is to make certain of failure to steer the correct course, at least in the early part of the strip , neither is the resulting position of the aircraft very accurate Experiments carried out in America have shewn that the average error in the determination of the vertical by judgment is 5°, equivalent to an error of 1,000 feet in the position of the plumb point at 12,000 feet Professor Melvill Jones gives the 50 per cent tilt of the camera axis in a series of " vertical " photographs as $\frac{3}{4}°$ * This therefore, gives the figure of error if a sight attached to the aircraft is used This is equivalent to about 150 feet error in the plumb point at 12,000 feet The chief disadvantage of this method, however, if it is carried out by the pilot, is that it inevitably leads to a disturbance of the equilibrium of the machine and so, not only defeats its own ends, but upsets the course being steered

Considerably better results can be obtained if it is possible to observe the object ahead of, instead of below the machine The extent to which this is possible depends on the design of the machine With the type of machine postulated for

* "Aerial Surveying by Rapid Methods " B Melvill Jones Camb Univ Press

air survey the problem becomes easy, and in fact the whole problem of steering the course may be reduced to a variation of the well-known two-point method In this case, given that it is possible to select two points on the photographic line, the pilot gets his machine in line with these points and adjusts his course until his track coincides with the line joining them Clearly the machine must then pass over the correct starting point Given that only one point can be selected, a modification of this method can be carried out with the aid of the compass, but rather less conveniently The pilot has to ensure, while steering the course determined by the observer, that he keeps the object selected on a constant bearing with reference to the fore and aft line The method requires some practice, and is not at all easy without some form of sight

The Aldis Camera Aiming Sight has a prism fitted, which gives a view forward to the horizon Where the pilot has no forward view therefore, this sight may be used in a similar way by the observer, either with two points or with one point, but it definitely introduces an additional link into the chain, and a short chain is stronger than a long one

Various attempts have been made to provide an optical sight for the pilot where he is so situated as not to have a good view forward Notably, Major Cochran Patrick of the Aircraft Operating Co is trying out one model in the survey which the Company is about to carry out in Northern Rhodesia I do not propose to discuss this class of sights, because there is none which can really be said to have solved the problem, and I foresee great difficulties, not least of which is that it is wrong in principle to make the pilot put his eye to a sight, instead of leaving him free to look at his instruments and the horizon A large prismatic sight, which is being developed by Aldis Bros , of Birmingham, to give a great degree of eye freedom may prove to be an eventual solution

From the question of sights, however, one returns to the position that if the real air survey machine existed, no optical form of sight would be necessary for the operation under discussion One could then design an open sight which would impose no strained position nor restriction of vision on the pilot The idea of the sight I am about to describe was arrived at in discussion with Major Cochran Patrick

In Fig 8, CC is a rail in the form of a segment of a circle mounted on the coaming of the pilot's cockpit, and having its centre at P, the normal position of the pilot's eye It is calibrated in degrees right and left of X, PX being parallel to the fore and aft line Mounted on the rail and adjustable to any position on it is a horizontal rod AB, so mounted as to be always at right angles to the circumference CC, or in other words so as to lie always in the direction of a radius of the circle CXC At each extremity the rod AB carries a vertical arm

The principle of this sight is self evident The arm AB, and therefore the angle XPA, is set to the angle of drift which has already been determined for the desired track OO_1 If two objects are available such as OO_1, the pilot has only to get in line with them, then set a course such that they lie on the line of sight AB Two vertical arms are provided, merely as a check to the position of the pilot's eye If one object such as O alone is available, the pilot gets into such a position

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

that it lies on the line of sight AB, when he is steering the course already determined by compass Further objects may be picked up as leading marks by means of the sight, once the course is set, and so the use of the compass becomes almost unnecessary By trial, the drift may be determined by the pilot with a sight of this description, but not conveniently, unless two objects on the photographic line are available It will be seen that the main function of the sight so far described is an aid to the distant landmark method of steering, commonly employed by pilots The opinion may be expressed with some confidence that where this simple, almost direct and almost sub-conscious method of steering is practicable, and is applied with the proper precautions, it is the best

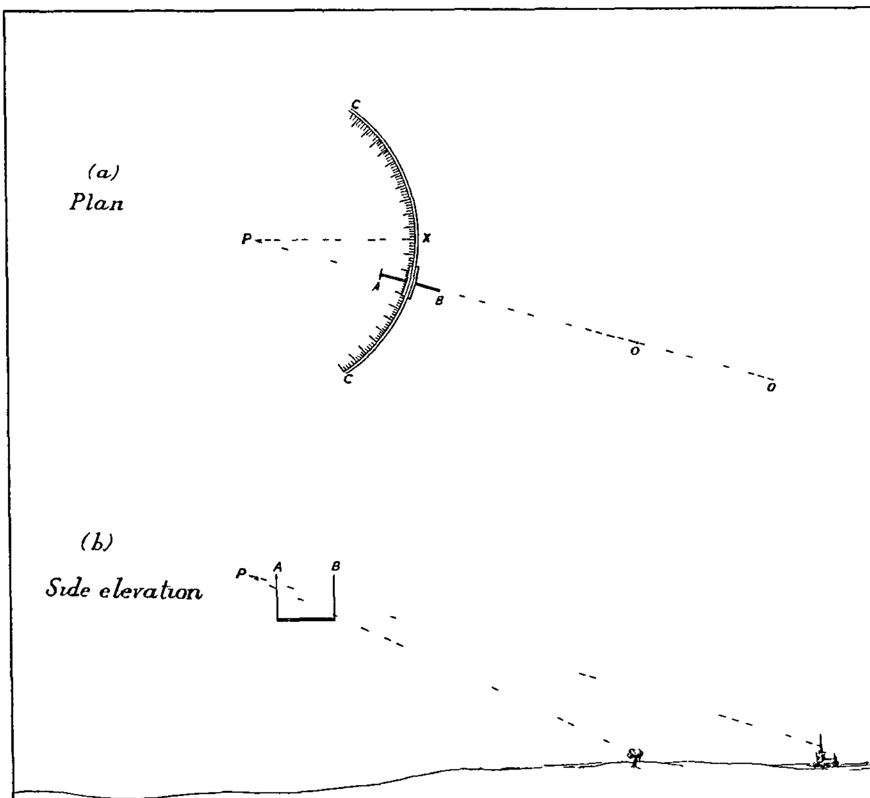


FIG 8

PILOT'S STEERING SIGHT

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

Conditions may occur however, where the method is quite impracticable, either on account of the construction of the aircraft, or on account of the nature of the country In such cases, one is forced to a greater use of the compass Experience shews that this can be done with considerable accuracy Various aids are available Probably the most useful is the gyro azimuth, which eliminates oscillatory errors set up by roll or pitch, and northerly turning error It has its own error of precession but this can now be reduced to 1° in 10 minutes or less, and is readily compensated by reference to the magnetic compass, when the aircraft has flown on a steady course long enough for the compass to settle down The gyro azimuth is most useful when making the 180° turn between two adjacent strips Here it eliminates the long approach run of several miles, which is necessary when using the magnetic compass alone, in order to give it time to settle down

The aid of the gyroscope may be extended with advantage to the actual control of the rudder This has an immediate advantage in reducing fatigue to the pilot and leaving him free to devote more attention to the other controls The only data available further shews that the course steered by the gyro rudder control is more accurate than by any other method Professor Melvill Jones found that the maximum variation in the course steered by the gyro rudder control was 2° * This compares with a variation of 9° on a course steered by compass alone There is reason to believe, however, that this result with the gyro rudder control is unduly favourable

As far as data is available, steering by compass and turn indicator appears to be a little more accurate than steering by compass alone, but there does not seem to be sufficient reason for the use of a turn indicator in air survey The instrument was designed for use in fog, when no horizon is visible Air survey is not carried out in such conditions, nor is there any aircraft which gives no view of the horizon Watching a turn indicator definitely takes away part of the pilot's attention from other things, and gives him insufficient compensating advantages

Two other kindred methods of steering may be referred to, one of which has and the other has not been used in air survey I refer to the shadow method, consisting of watching the movement of the shadow of a portion of the aircraft on, say, the dashboard, and the solar compass method The former records the movement of the aircraft about all three axes, but is uncompensated for the movement of the sun in azimuth and altitude Since, however, not less frequently than at the beginning of each strip, the aircraft has to be set on its course and adjusted to the true level by extraneous means, this disadvantage is minimised The method is purely relative, not absolute The solar compass may prove to be of great value, and to fulfil the functions of the gyro azimuth without its complications, but there is insufficient experience as yet on which to base an opinion

Lateral Overlap

Much argument has centred on the question whether lateral overlap should be observed by the pilot or the observer Since the observer can do nothing to affect it, except through the medium of the pilot, and since it involves immediate

* "Aerial Surveying by Rapid Methods " B Melvill Jones Camb Univ Press

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

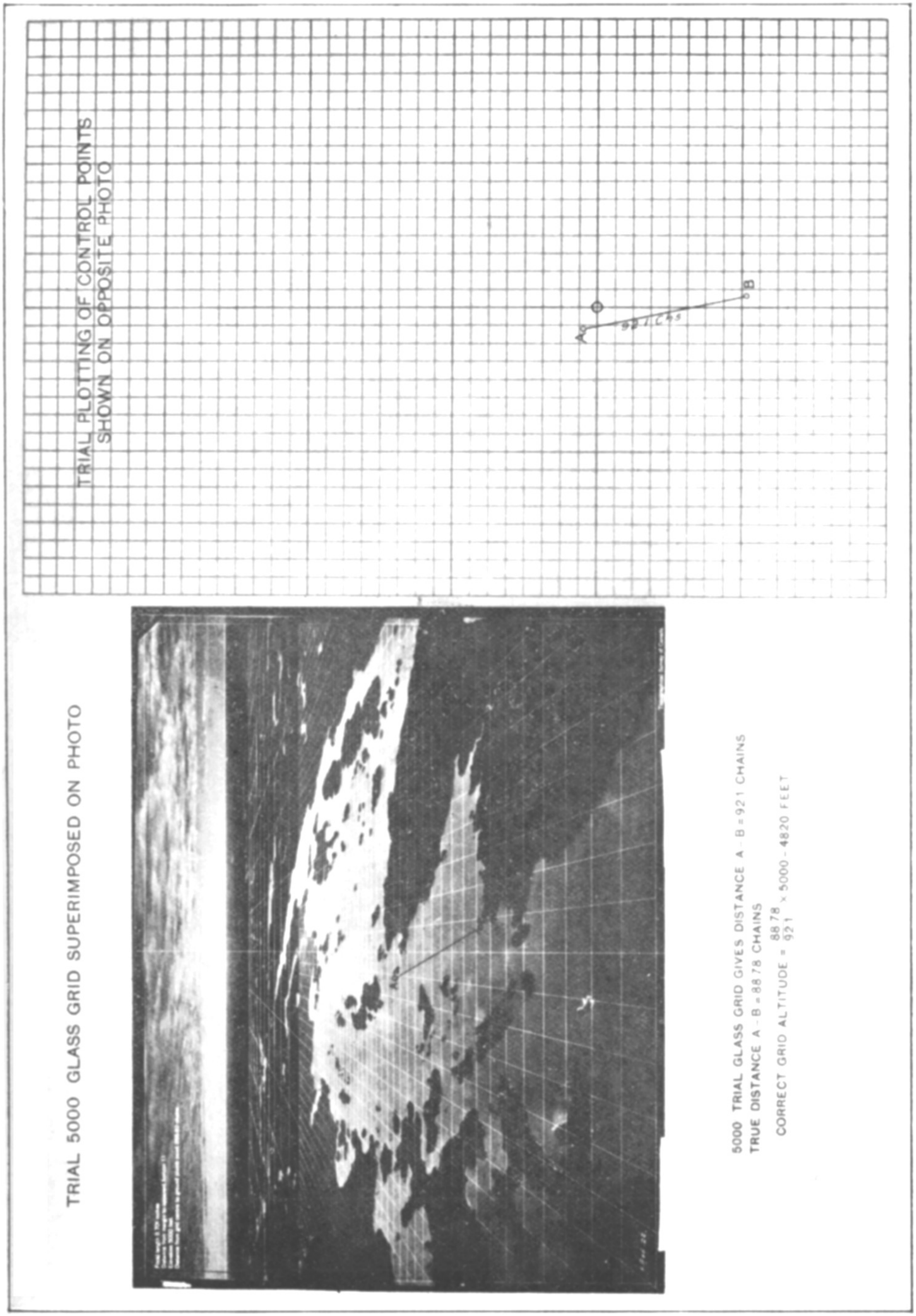


FIG 9 ILLUSTRATING CONVERGENCY OF TRACKS

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

action to rectify faults, there is in my opinion only one answer In an efficient system, the pilot must observe lateral overlap

I propose now to describe a further addition to the open sight referred to earlier in this paper The central lines of each strip of photographs are parallel straight lines, each of which is in turn the track of the aircraft The meeting point of these parallel lines, as viewed from the aircraft, is the point on the *true* horizon where the track of the aircraft intersects it This is conveniently illustrated in the oblique photograph reproduced in Fig 9, one of the Canadian photographs bearing the perspective grid, which forms the basis of the well known Canadian method of plotting The plan view of this grid is a series of rectangles The converging lines are therefore representations of a series of parallel straight lines The apparent horizon is visible, but by reason of the altitude of the aircraft, the true horizon lies above this It is marked on the photograph at H The converging lines may be taken as representing successive tracks of the aeroplane It will be seen that they meet at H, the point of intersection of the true horizon and the centre track

If now, one of the vertical arms of the sight, preferably A (Fig 8), is made adjustable vertically, it may be set so that its top is level with the pilot's eye in level flight It therefore marks out, when set for drift, the meeting point of all the tracks on the true horizon

It hardly needs emphasising that though there are many methods of steering in a particular direction, there is only one of steering along a particular line Some point or points on that line have got to be observed from the air The pilot's requirement in an overlap sight is therefore one which will mark out for him the centre line of the next adjacent strip of photographs

The arm A therefore, carries two horizontal arms D and E (Fig 10), set at such a distance below the top as to subtend angles of dip at the pilot's eye of, say, 30° and 45° Arms D and E are made adjustable in length from the centre, and calibrated in terms of the angle of the lens and the amount of overlap required

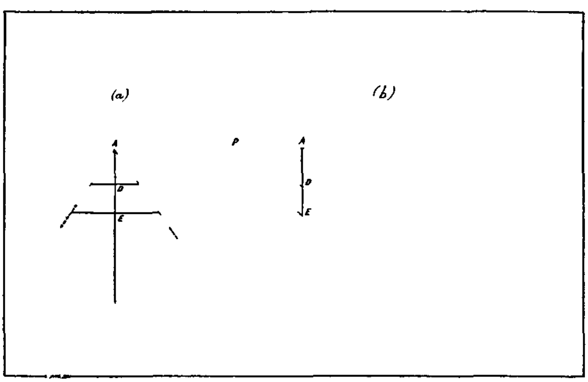


FIG 10

PILOT'S STEERING SIGHT LATERAL OVERLAP

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

These two factors decide, irrespective of height, the angle subtended in the vertical plane at the aircraft by the perpendicular distance between two successive strips They therefore also decide the apparent width of the strip interval at any angles of depression such as at D and E As previously shewn, at A, the horizontal, the apparent width of the strip is zero

Lines joining A to the extremities of D and E therefore mark out for the pilot, through the whole range of his vision right up to the horizon, points on the next preceding and next succeeding strip centres

The pilot can now, while steering with the aid of rod A on the landmarks already selected, without moving his eyes from the sight and his reference line, the horizon, select new landmarks for his next line of flight, and at the same time if desired, check up on the landmarks of the preceding strip

The sight can be modified by hingeing two stiff wires at A and the extremities of D or E, and doing away with the other horizontal bar

When working in a tractor aeroplane, or one without the open view forward required for the above operation, the next best alternative is an open type athwartships sight, that is, one fitted on the side of the cockpit in such a way that the pilot can observe the next strip immediately on his beam Several forms of this sight have been developed In this country, one has been produced by Captain Durward (though not commercially) and in France there are two examples, the Brager and the Chretien sights, described in L'Aéronautique, of December, 1925, and in the Bulletin of the Directorate of Scientific and Industrial Research and Inventions (Ministry of Public Instruction and Fine Arts), May, 1922, respectively

The principle of any such sight is simple in the extreme It is required only to set the sight at such an angle to the vertical in the athwartships vertical plane, as is subtended by the perpendicular distance between strip centres This angle again depends only on the angle of the camera lens and the amount of overlap desired It is independent of height, as in the forward type of sight, and it may therefore be set before the aeroplane leaves the ground

An essential feature of the design of such a sight, if it is to meet with general approval, is that it should be so mounted as to be usable with the pilot's head in its normal position In other words, it must not require the pilot to lean his head over the side of his cockpit

On the question of lateral overlap, it remains to examine the utility of optical sights Optical sights should not be designed for the pilot's use At the same time, lateral overlap is the pilot's concern It follows, though I express it as a personal opinion, that there is no real demand for an optical sight to govern lateral overlap Optical sights have been used, however, for lateral overlap by the observer The only example I need cite is the Aldis Sight Reference to Fig 6 will shew the graticule which marks out the area of the photograph and hence its lateral limits By making an estimate of the overlap on the graticule, the edge of the succeeding strip of photographs is indicated to the observer, who can then note its position on the graticule on the return flight Instructions have then got to be conveyed to the pilot, and for this purpose inter-communication telephones are recommended

The graticule of the Aldis Sight is at present not adjustable, and it is therefore only suitable for one particular angle of lens, and for use with any other lens or camera, an estimate has to be made The sight is commonly made up for the F 8 (or Eagle) camera, *i e*, a 7 inch × 7 inch plate and a 10 inch lens

Fore and Aft Overlap

Except in the rare case when the pilot flies solo and manipulates the camera himself—an event almost unknown at present—the control of fore and aft overlap is entirely in the hands of the photographer From this and what has just been said about lateral overlap, the conclusion may be drawn that a combined lateral and forward overlap sight is not required, though a number of sights on this principle has been made

Both the Brager and Chretien instruments, previously mentioned, are provided with fore and aft overlap sights The former incorporates the principle of observing fore and aft overlap not immediately below the machine, but on the succeeding strip, so that it does not involve the pilot (or observer) leaning over the side of the machine to make the observation In so far as the sight may be used by the observer, this principle is sound

A further criticism of this class of sight which occurs to one, however, is that a fore and aft overlap sight should be near the camera and not fitted on the side of the machine The Aldis Sight comes nearest to filling the demand This, being an optical sight, is fitted through the floor of the cabin, in a convenient position for the photographer to manipulate both sight and camera The only drawback at the moment is the fact that the graticule is standard and fixed, so that either a further calculation or an estimation is required when observing the exposure time interval

It is common and sound practice to calculate the exposure time interval from the factors—length of plate (fore and aft), overlap required, focal length of lens, height of aeroplane and ground speed When the Wind Gauge Bearing Plate is used for the observation of drift, the ground speed is read directly in the form of time (t) to cover one mile The formula to give T, the exposure interval, then becomes —

$$T = \frac{h\,s}{f} \times \frac{n-1}{n} \times \frac{60\,t}{5280}$$

where T = exposure interval
h = height of aircraft in feet
s = fore and aft dimension of plate in inches.
f = focal length of lens in inches
$\frac{1}{n}$ = desired overlap
t = time to travel one mile, in minutes

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

A number of these factors are constant for the flight —

$$K = \frac{60\,s\,(n-1)}{5280\,f\,n}$$

so that the formula for use in the air becomes —

$$T = K\,h\,t$$

Elimination of Tilt

Professor Melvill Jones has established the interesting fact that the tilts occurring in a series of supposedly vertical photographs are "random"*

His results also give us quantitative ideas The maximum tilt discovered was $3\frac{1}{2}°$, while 80 per cent of the tilts were less than 2° While there is no other source available which gives such extensive data, such evidence as there is tends to confirm the conclusion that these figures represent approximately the standard attained by a good pilot, consciously trying to fly level on a day of good photographic weather

The problem then is to reduce these figures—ultimately to zero It may be tackled in a number of ways —

(*a*) Automatic stabilisation of the aircraft (camera fixed)

(*b*) Automatic stabilisation of the camera

(*c*) Pilot levelling up the machine with the camera fixed

(*d*) Photographer levelling up the camera

The first two methods contain possibilities of a complete solution I do not propose to deal with them in detail Progress depends on the development of the gyrostat At the moment, no gyrostat is available which will do what is necessary, and it is obvious that the solution of (*a*) is more remote than (*b*)

Neither (*c*) nor (*d*) can ever give a perfect solution, because of the inevitable lag of the human brain The first of these methods is the one which has been most commonly used It involves the levelling of the camera in the machine by means of the bubble levels provided, either with the machine trued up on the ground, or with the machine in level flight at the altitude of photography While the former is more definite, the latter is more correct, in that it takes account of any alteration in the trim of the aircraft After photography has been commenced, the camera is not touched, and the whole of the levelling depends on the skill of the pilot in flying the machine His datum marks may be the horizon or they may be Cross Level, and fore and aft level in the cockpit The air speed indicator as a guide to fore and aft level suffers too much from lag for this purpose The shadow method may also be used

The fourth method has also been used, but when, as is the case to-day, the only datum, to which the photographer can level the camera, is the position of two bubble levels, the principle is unsound Bubble levels are subject to acceleration, and while, over a period, they serve to indicate the mean position, they cannot be used for the "snap" determination of level for an individual photograph It

* 'Aerial Surveying by Rapid Methods" B Melvill Jones Camb Univ Press

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

seems a possible solution that a small gyro should be mounted on the camera to indicate the vertical to the photographer If a suitable gyro were available, which maintained the direction of its axis over a sufficiently long period, this method would then have as its main disadvantage, only the lag of the observer's brain

The problem may also be tackled from the point of view, not of eliminating, but of recording tilt This has received considerable attention The gyro which would indicate the vertical to the observer could equally be made to record the vertical on the plate An interesting alternative to the gyro for this purpose is being developed by Santoni in Italy He uses the altitude and azimuth of the sun, which are determinable, as his datum, and, by photographing an image of the sun through an auxiliary lens, obtains thus a measure of the direction and amount of the tilt

Obviously there is considerable development work ahead in the matter of eliminating tilt

Maintaining Constant Height

To deal with this problem properly it would be necessary to write a small pamphlet, and in a paper which is already far too long, it is essential to summarise Two courses are open —

(*a*) To maintain the aeroplane at a constant altitude as far as possible

(*b*) To record on the plate, changes of height

As a matter of fact, it is advisable to do both The problem of maintaining constant height differs from the others we have considered, in that the pilot has to depend entirely on the indications of an instrument in his cockpit No visual observation of external objects gives a guide

The instrument is the altimeter in one of its various forms The requisite properties of the instrument are sensitivity and freedom from lag This immediately suggests that one should look to one of the various forms of statoscope which are now available, to provide a solution Statoscopes have not been used to any large extent—insufficiently to provide definite data The Pioneer Rate of Climb Indicator has been tried in Canada and America, and the Wright statoscope was tried by the late Major Griffiths in his experiments carried out at Cambridge Both are of the bubble type

Major Cochran Patrick for the Aircraft Operating Co is now testing a Wright and an Askania statoscope in the survey which he is carrying out in Northern Rhodesia The latter works on the aneroid principle, and for it is claimed an accuracy of 10 feet, and freedom from lag

The bulk of survey flying by British operators has been carried out with altimeters of the Mark V pattern, calibrated every 100 feet The Mark VII is now available, which, being calibrated according to the S T Ae Law, gives a more accurate true reading, but is still only graduated every 100 feet

Working with an instrument of this type, the results available appear to show that height can be maintained within 200 feet of the mean height, while of the photographs analysed by Professor Melvill Jones, 92 per cent were taken at a height differing less than 100 feet from the mean height of flight *

It is obvious, that however sensitive the altimeter, certain movements will occur which the pilot cannot control, but we are justified in looking for a great improvement by the use of the more sensitive statoscope

It is important to notice that for this purpose, absolute accuracy of height indication is not of prime importance—in fact it matters very little In none but the roughest of reconnaissance surveys would reliance be placed on the indications of an altimeter to obtain the scale of a photograph

It is a point of some importance in this work to ensure that the altimeter or statoscope actually records the pressure of the atmosphere and not the pressure in the cockpit, which, on account of the machine's passage through the air, is usually less than atmospheric pressure and is inconstant This can be achieved by connecting the pressure chamber to a static head

Coming to the recording of height on the photograph, this has been provided for in the Eagle camera by the photographing of a small altimeter, fitted into the camera, on the edge of the film The value of this must be clearly realised It is not an accurate record of true height, but within limits it gives the variation of height from photo to photo Clearly the altimeter so used must be as sensitive and free from lag as its small size permits Apart from the use of the record as a general guide, with which we are not much concerned in true survey photography, its use is to give the variation of scale from the scale of a key photograph, determined from ground control points

Now consider the errors to which the altimeter is liable, and their bearing on the two problems of maintaining and recording height The most serious error is that due to temperature While the Mark VII altimeter is calibrated for a ground temperature of 15° C and a lapse rate of 6 5° C per 1,000 metres (normal conditions in North West Europe), departure from the conditions may account for an error of 2,000 feet at 20,000 feet Allowance may be made, from a knowledge of the ground and upper air temperatures, with the aid of a height computer Is it worth while ? Where it is desired to photograph as near as possible to a predetermined height, and this may have considerable importance at times, then it must be done, but from a consideration of what follows, it appears only necessary to make the one computation for each flight

Other errors occur due to a variation in pressure with time, variation in pressure with space, variation in temperature with time and space and variation in the vertical temperature distribution The following table, supplied by the Meteorological Office for the assumed conditions of photographic strips of thirty miles with a flying time of, say, twenty minutes, shews that the effect of temperature variations is negligible

* "Aerial Surveying by Rapid Methods " B Melvill Jones Camb Univ Press

TABLE SHEWING THE EFFECT OF ATMOSPHERIC CHANGES ON THE READING OF AN ALTIMETER

	Great Britain		Tropics	
	Pressure	Height	Pressure	Height
(1) Change of pressure with time	0 5 mb	15 ft	Unimportant	
(2) Change of pressure with space	1 2 mb	35 ft	,,	
(3) Diurnal variation of pressure	Unimportant		0 2 mb	6 ft
(4) Change in the vertical temperature distribution with time and/or space	Unimportant in photographic weather			
(5) Change of temperature with time	Unimportant		Unimportant	
Total	1 7 mb	50 ft	0 2 mb	6 ft

Of these the only changes of any significance are (1) and (2)

Dealing first with the effect on the pilot's altimeter or statoscope, the change of pressure with time is too small to be allowed for in the course of one strip, but in the course of a flight of four hours, the change might account for an error of as much as 180 feet The conditions of the survey may make it desirable to reduce this error, which can only be done by the aid of the meteorological organisation The barometric tendency can be predicted with considerable accuracy over a period of four hours, and may be allowed for by an adjustment, at intervals, of the zero of the Askania statoscope, if this instrument is used by the pilot

Similarly, the pressure gradient can be obtained from the same source, and allowance made for the oscillating error caused by crossing and recrossing the isobars

Where no meteorological organisation is available, a good deal can be done in certain conditions by the observation of a barometer at the base

The same process can be applied to the record of height on the photograph, with the limitation that the small altimeter incorporated in the camera is not so sensitive as the larger one used by the pilot The process is, in fact, easier, since it is applied on the ground, from an actual record of the meteorological conditions at the time of the flight

Where it is desired to obtain the nearest approximation to the true height of the camera, the most accurate method available is to obtain a record of the pressure and temperature at the height of photography and on the ground by means of a microbarograph and thermograph From the records so obtained, the true height can be calculated at any time, and it is a simple matter to correlate the records with the photographs The calculation required is of less significance when it is remembered that a large amount of calculation is inevitably involved in an air survey

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

CONCLUSION

The problems considered in this paper have been related to a particular process of survey, the making of mosaics with the utmost economy of flying time and photographic material The limits of a single paper do not permit of the extension of the arguments to other processes, though, in general, the principles remain the same

The paper is based on an investigation carried out for the Air Survey Committee, and I am indebted to that body and to the Air Ministry for permission to make use of the material At the same time, I should point out that the opinions expressed do not necessarily represent the views of those bodies

I wish to acknowledge the assistance given by Flight-Lieut Porri who collaborated in the preparation of the original paper, and the part played by Major Cochran Patrick, who, in a long series of discussions on the subject, has helped to form many of the conclusions Professor Melvill Jones' book, than which there is no more valuable collection of data, has been freely drawn on for figures The original paper prepared for the Air Survey Committee will shortly be published under the same title as this paper

DISCUSSION

Capt McCAW It is rather presumptuous on my part to make any remarks I am neither a pilot nor an observer , at the same time perhaps some excuse may be offered on my behalf, because, while I occupy neither of those positions, I have been associated with Captain Tymms in the work of the Air Survey Committee

I should like to say that it is only the members of that Committee who know all the trouble that Captain Tymms has taken in compiling this paper He has acquired the information by correspondence with pilots all over the world, and has endeavoured to arrive at a concensus of opinion that is rather difficult to obtain, because in every new art such as that of pilotage for air photographic survey, there is a certainty that there will arise a considerable difference of opinion

Referring to the instruments, I shall not take up time in talking about them, because I think everyone finds that you have to use an instrument in order to understand it However, there are one or two questions which have been brought forward by Captain Tymms, and I think I may be justified in referring to them

Firstly, he has pointed out the extreme importance of sights in air survey , I think that that might almost be considered the whole burden of his paper The importance is perhaps greater than we realise in this country, because the conditions under which air survey will be carried out in the future are conditions where in many cases it will be very difficult to follow parallel alignment Air survey, to make its way, must be prepared to visit regions where the ground surveyor finds great difficulty, and it is precisely in those regions that alignment will be most difficult to maintain For instance, in the Nile Sudd region, I am afraid that to follow any definite objective on the horizon would be very difficult On the great

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

flats around Lake Bangweulu the same conditions obtain, as far as the eye can reach one can see nothing but featureless forest It is true that there are hills on its eastern border, these, however, would not be of great value as landmarks in alternating flight unless the sighting apparatus afforded a rearward view

When Captain Tymms was speaking on the subject of sights it occurred to me that I was not quite sure (nor, I think, is he) whether we have really yet attained to the possibilities in the way of optical sights I think sights might be divided into two or three different classes—the look-down, the look-in, and the look-to He has made it quite clear that the look-down sight is of little value An ordinary look-in sight will be of very little use either, because it detracts the pilot's attention from his work, but Captain Tymms has indicated that there is the possibility of and optical look-to sight, embodying some of the principles of the mechanical sight described to-night, with which he has identified his own name in a measure manifestly modest A sight, like that of Sir Howard Grubb, giving a wide field and a large ocular free from parallax, should not be beyond the skill of the modern optician, it ought to give also a view backward, for the picking up of successive landmarks foward must, in the nature of things, lead to a certain amount of loss of alignment It is a well known principle that short lines should not be prolonged too far, and " lining in " between landmarks will often be preferable

I think perhaps in reading this paper one might gather, contrary to the author's intention, that the conditions discussed do not apply in the same sense to oblique photography, because that demands a different type of navigation He has referred to obliques as a determining factor in the design of the machine, but there is no doubt that the same skilful directive craftsmanship that is required for " verticals " is also in demand for oblique photography, except, of course, in special circumstances

Mr BRAMSON I always think there are many different ways of delivering any one given lecture, but one always finds that Capt Tymms expresses his thoughts in such a convincing way that even if one knows nothing whatever about the subject beforehand, one is quite positive afterwards that one knows quite a lot, and that all Capt Tymms says must be commonsense facts May I therefore compliment him not only on the paper, but on his manner of delivering it

I feel that I now know much about air survey that I did not know before It is natural in the circumstances that there are a number of questions one would like to ask

Capt Tymms mentioned that it was very undesirable that the pilot should be forced to twist his body or head in order to look down to the sight Would it be impossible to construct an optical apparatus somewhat like a stereoscope quite close to his head, combined with a prismatic system giving a clear view of what he ought to see ?

Another question is in connection with gyroscopic controls Has there been any attempt made to make gyroscopic controls act in terms of the angular acceleration rather than angular displacements ? The reason why the pilot is now better than any automatic instrument is that he is sensitive to angular accelerations

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

What the pilot feels on the various parts of his body is acceleration, not displacement, and the reason why he can correct quicker than gyroscopic controls is that he makes his corrections proportional to the accelerations applied

I do not know, but I am sure Capt Tymms, who has inside knowledge, will be able to tell us, if any work has been done in that direction If not, I suggest that it might be worth while trying

Capt Tymms mentioned shadow flying That is, perhaps, the only part of the subject of which I have experience in connection with sky-writing It struck me that there are some functions of the sky-writing pilot which are probably similar to those of pilots doing air survey work If you make an " H " or any other letter which involves parallel lines, you have nothing to go by except the sun You can fly dead into the sun, or you can fly dead away from it by looking at the shadows of the wing struts I can confirm the difficulty of doing two things at once, you have to choose a direction parallel to a given direction, and at the same time to choose the particular position required If, when sky-writing you make an " i " going upwards, and want to go down on the same line and dot it, you are faced with the same problem You have to be dead parallel to the first line, and also dead in line with it You are helped by the little cloud in front of you, but the survey pilot has a much more difficult job, because the lines he has to follow are far below

There was described the other day a new electro-magnetic compass, the principle of which is an armature which is kept rotating all the time, and which if it is in such a position that it cuts the lines of force in the earth's magnetic field, causes a current to flow, but if the armature is turned in such a direction that the windings are parallel to the earth's magnetic field a voltmeter connected to it will show a zero just at that moment I want to know whether such a compass would be suitable for air survey work

One of the remarks in Capt Tymms's paper made one feel sorry for the pilot Imagine flying on a line 80 miles long and having all the time to memorise the objects that he has to look at and try to catch sight of on his return journey He will need a course of Pelmanism

There is one further point to which I would like to call attention In trying to correct for tilt Capt Tymms mentioned a number of alternative methods of making the corrections at the last moment, and said that the air bubble level is useless Assume that you discard it and take a small gyroscope, one way would be to try just at the moment or a little before taking the picture, to tilt the camera to the right place The probability is that by the time you had to take the picture it would be out of the correct angle As you do take your pictures with large overlaps, why not choose ten or fifteen seconds during which you want the picture to be taken Watch, and when accidentally the aircraft becomes parallel to the level, as it is almost sure to do, then take the picture It will make the overlaps vary in size, but will that matter ?

Capt Tymms mentioned one way of trying to keep flying at the same altitude There is another way, that is, trying to fly horizontally There is something that will tell you when you are flying horizontally, and that is, the air streamlines A stable vane balanced on a horizontal pivot will take a line dead parallel with the air stream If you compare some reference point on that vane with either a spirit level or a gyroscope, you might be able to fly very successfully in a horizontal plane, and therefore would only have to make corrections for tilt

Mr C M WILLIAMSON I was very interested indeed in Captain Tymms' lecture, and quite a number of points have occurred to me

I am not an authority on air survey work, but he has gone into the mechanical side, and therefore I can make some suggestions

Mr Bramson raised a point with regard to taking the photograph when the camera is on a vertical axis It seems to me that all Captain Tymms' arguments and the apparatus described more or less depend on being able to obtain an absolutely vertical axis In the course of conversation with Major Cochran Patrick recently I understood him to say that sideways roll was the most difficult one to correct Apparently it is safe to depend on the machine maintaining a fairly level keel, and you can adjust the camera to allow for any error in this direction A sideways roll would constantly vary, and in the special mounting which we made for the Aircraft Operating Co a handle was fitted to rock the camera to a vertical position before taking the photograph In the corrections for tilt Captain Tymms mentioned two alternatives—one was levelling the machine and the other levelling the camera I think Mr Bramson has hit on what might be a very accurate way of obtaining a vertical photograph, *viz*, by moving the camera slightly by special mechanism so that it passes through a vertical axis, and then take the photograph With an automatic camera this operation seems fairly simple, because you could have a gyroscopic switch mounted on the camera, and if the camera was operated in the manner suggested the exposure would be made when the camera passed through the vertical axis We have made one or two experiments with mercury switches which were not very successful, although it is usual to allow for at least 50 per cent overlap, you have at least five seconds in which to swing the camera, and it seems as though the idea is worth developing further

I should like to ask Captain Tymms if he has had any experience or knows whether such a scheme is workable

Capt SAYERS I should like to thank Captain Tymms very much indeed for his paper, which has dealt very exhaustively with a complicated problem

It seems to me that in dealing with this question as he has dealt with it he has not made it clear that requirements as to accurate flying may be quite different under different conditions, depending upon the work which has to be done

You may use aerial surveying in order to acquire accurate photographic details, working over country which has already been very carefully surveyed on the ground In this case accuracy in flying is important, but it is important only as saving work in reducing your photographs to the final map form If you have a good control on the ground you may take photographs how you like, and correct them, but obviously the accuracy of your final results depends on the ground survey alone in such a case

Then you may have to work over country which has never been and cannot be accurately surveyed from the ground, and there the accuracy to which you

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

can fly determines the whole accuracy of your final result, which does look as if quite different methods will have to be adopted in the two cases

From what we have heard to-night, everybody will sympathise with the pilot on aerial survey, he seems to have to do almost everything, and I must say I am impressed with Captain Tymms' statement of the work which the pilot should perform The observer apparently has but a small number of functions and it ought to be possible to simplify the purely photographic operations, and wash the observer out altogether In that case you can meet the requirements of the air survey machine much more economically and thoroughly

I had hoped that Mr Raynham would have been here to-night Although I know he is in general agreement with Captain Tymms' views, there are naturally differences of opinion in actual between different authorities

Mr Raynham mentioned to me that it sometimes was better to have a really good backward view than to have to observe ahead

I should like to know quite what Captain Tymms makes of that statement I did not have time to enquire into it exhaustively, but it is obvious that if you can get a rear bearing on points you have passed over, you keep a course in the same way as from points ahead of you

Captain Tymms says the machine should be all metal It seems to be a habit of the Air Ministry to lay this down as a requirement for new machines for all purposes I should like to ask Captain Tymms what he thinks would be the condition of an all-metal machine of the type under discussion after it had done three years' survey in out-of-the-way places in the tropics It is essential that an air survey machine should be repaired on the spot, and we have no certain experience as to whether a metal machine will stand up to this type of work without needing repair

Flight-Lieut G H REID The problems presented by Captain Tymms in his exceedingly interesting paper are certainly difficult, and demand a very fine degree of accuracy in any instrument that may be designed to overcome them A great deal has been said about gyroscopes, but these have certain limitations, and must be used within certain prescribed conditions Gyroscopic problems are by no means as simple as they sometimes appear

One speaker asked if the principle of angular acceleration could be applied to the spinning of gyroscopes It could be, but it would not then be a gyroscope in the true sense of the word Stabilising the camera by gyroscopes will not completely solve the problems that have been indicated by Captain Tymms, because it will be necessary to turn the camera relative to the machine, when photographing across wind The camera should always point along the true path of the machine relative to the ground, not along the longitudinal axis of the machine

Regarding the question of sighting, this appears the best method of keeping the true straight line course, and an apparatus I have experimented with for another problem, operating on the principle of the Control Indicator, may be found useful This consists of a double framed sight mounted on an arc on the front of the

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

machine One end of this sight contains the three necessary movements to maintain control of the aeroplane in the three dimensions of movement These indications are given by a gyro and mercury bubbles, and are set very sensitively, so that in addition to sighting, the control of the machine can be maintained accurately while sighting The indicators on the end of this sight are similar to the movements of the control indicator, and are conveyed by small electric lights, which in addition can be connected to the electric circuits of the camera, so that the circuit can only be operable when the indicators are central The photographs can then be taken in these positions, and when taken are correctly aligned in space Experiments tried on the Reaction apparatus have shown that this is quite feasible, and even for fairly quick movemetns the periods available for " firing " the camera are fairly numerous I should be very glad to have a further discussion to see if something could not be done in this way to help along the problem

Mr C G COLTBROOK I think the subject itself is one of the most hopeful developments of aviation, and it is one which I am sure Captain Tymms' paper will stimulate in many directions I should like to congratulate Captain Tymms on having presented a very technical subject in such a clear and interesting way I read his paper with very great interest before coming to the meeting, and the diagrams have cleared up many points, and I feel, like Mr Bramson, that I now have some idea of the more technical aspects of air survey, or, rather, until called upon to make remarks, I felt I knew something about it

Written Discussion from Mr G H DOWTY I have read through the advance copy of this paper with much interest, and I have found it most instructive

The requirements of the ideal machine for Air Survey outlined by Captain Tymms, are most interesting It would be a comparatively easy task to design a machine fulfilling the modest performance requirements Such a machine, however, would constitute a departure from present-day practice I should like to ask Captain Tymms if the demand for such machines is likely to be a large one, and, if so, does he think that the aircraft operating companies would purchase machines at £6,000 each ? I am basing this price on the requirements specified, and present-day costs If machines at such a price are marketable, then it would seem that this is a proposition worth the consideration of our aircraft designers

It appears to me that the pilot of the aircraft has almost the whole of the work to carry out himself The pilot determines the course to steer, observes the lateral overlap, observes and corrects for altitude, levels up machine to eliminate tilt, etc I should like to know exactly what are the duties of the photographer, other than the control of fore and aft overlap, because the paper does not clearly define this point If the pilot of the machine could start and stop an atuomatically operated camera by means of a distant control, does Captain Tymms think that the whole of the operations could be performed by the pilot ?

CAPTAIN TYMMS' REPLY TO THE DISCUSSION

Captain McCaw's reference to featureless country where landmarks are not available for the two point method of steering emphasizes that in certain conditions it will be necessary to make a greater use of the compass

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

I quite agree that we are a long way from reaching finality in the design of sights The notes in this paper are more in the nature of suggestions than anything else Captain McCaw drew attention to the fact that similar conditions with regard to accuracy of flying were imposed on the pilot when engaged in oblique photography This is perfectly true as long as the conditions call for the taking of oblique photographs while flying in a straight line as would be the case when using a multi-lens camera Any distinction which I have drawn in the paper between the taking of vertical and the taking of oblique photographs refers to the case where, for example, oblique photographs of a coast line are taken, in which case the pilot is unable to fly straight

Mr Bramson raised the question of a prismatic sight for the use of the pilot I think that this can be classed with the type of sight which Major Cockran-Patrick is now trying out in Rhodesia, though the binocular eyepiece suggested by Mr Bramson has not yet been tried I think the necessity for this type of sight will clearly disappear when the suitable type of machine is produced

With regard to the use of shadow flying in connection with sky-writing, the only point which occurs to me is that in sky-writing the pilot is only flying on parallel courses of comparatively short length

Mr Bramson's question with regard to the use of an angular acceleration rather than an angular displacement as the controlling factor in a gyro-rudder control is one which I shall have to look into (Since the discussion I have made enquiries about this and find that a gyro-rudder control has been made up to depend on the rate of turn rather than the amount of displacement—in other words, controlled by a turn indicator instead of a gyro azimuth This was not quite satisfactory and, as might be expected, it merely brought the machine back to a steady course but not necessarily the course which it was desired to fly In this, it acted exactly as a turn indicator does While it is not quite clear how an angular acceleration could be used to control the gyro, the logical outcome would seem to be that it would merely bring the machine back to a steady rate of turn but not a straight course In other words, it would so adjust the conditions that the acceleration was reduced to zero

I quite agree that the earth inductor compass may prove to be of value It would certainly mean the elimination of deviation, but whether it would definitely eliminate errors of the nature of northerly turning error depends on whether or not it is possible to keep the axis of rotation vertical This is partly achieved by gyroscopic action, but tests carried out in this country show that further development is necessary before this type of compass can be considered quite satisfactory

Mr Bramson's suggestion to use a vane which would maintain itself parallel to the air stream flowing past the machine as a means of maintaining the path of the aircraft horizontal and so maintaining constant height, seems to me (after further discussion with Mr Bramson) a very valuable one, and one which will well repay further investigation

Both Mr Bramson and Mr Williamson have raised a very interesting point in their suggestion that a gyroscope should be used in such a way as to ensure that the photograph can only be taken when the axis of the camera is vertical This is a matter which certainly deserves investigation (Since the discussion

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

I have made further enquiries about this system and find that it has already been proposed by certain French operators The matter is being further investigated This same idea comes out in a different form in Flight-Lieut Reid's proposed sight)

The sight described by Flight-Lieut Reid is extremely interesting Since the discussion I have seen some experimental charts produced by Flight-Lieut Reid to show with what frequency the circuit would be completed so that the camera exposure could be made These look very promising and though there is undoubtedly a good deal of development work to be done this form of sight might still go a long way towards improving the quality of the flying Flight-Lieut Reid proposes to indicate in front of the pilot, movement about the three axes of rotation of the aircraft It is questionable whether it is necessary to indicate in this way, movement about the vertical axis since the steering sight itself will be used to maintain constant direction by reference to land-marks on the ground This is a point which will be settled by trial One essential condition of the development of this sight is that the addition of the proposed indications of tilt do not obscure the indication of lateral overlap which is required

Mr Williamson quotes Major Cockran-Patrick as having said that lateral tilt is much more pronounced than fore and aft tilt In view of the large amount of data collected and analysed by Professor Melvill Jones, which clearly shows that tilts are fortuitous, one would require a considerable amount of comparable evidence to the contrary before accepting this view

Captain Sayers suggested that under certain conditions, as for example, revision of a well-surveyed area, there is not the same need for accurate flying as exists in undeveloped country While this statement may contain a certain amount of truth as far as tilt is concerned, it is not altogether a sound conclusion Accuracy in flying is mainly directed towards economy and in any sort of photographic operation this is of vital importance It must be added, too, that there is a considerable advantage in reducing the amount of tilt in individual photographs even when there is a large amount of ground control

It is generally agreed that the day will come when it will be possible to eliminate the photographer and so arrange the camera controls as to enable the pilot to carry out the whole operation single-handed A certain amount of development work is still necessary before this can be done

I do not entirely follow Captain Raynham's idea about a backward sight, as described to us by Captain Sayers It is undoubtedly true that a backward sight is the most efficient for the observation of drift, and in consequence that it is probably as easy to maintain a certain definite direction by means of such a sight as by any other means It does not follow, however, that a sight of this description will enable you to pass over certain definite desired points Having managed to pass over the first point on your photographic line while flying in the right direction observation of this point astern will certainly enable you to continue flying on that line, but it does not entirely get over the difficulty of approaching that point in the right direction

On the question of the all-metal machine, I defer to Captain Sayers' superior judgment, but even if there is not an all-metal construction at the moment which

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

is superior to wood and fabric in its durability and ease of maintenance under very widely varying climatic conditions, it cannot be very long before this condition is satisfied The point I particularly wish to make in specifying an all-metal machine is that the air survey machine, unlike many air transport machines, may be used, during its lifetime, in all the different climates of the world

In reply to Mr Dowty's letter, with regard to his first paragraph dealing with aircraft for air survey, I certainly think that operating companies would be prepared to pay a price of £6,000 for the ideal machine As to the market for such machines, it would, of course, have to be created A very favourable factor in the creation of this market is the fact that operators in practically all countries have reached somewhat similar conclusions as to the type of machine required The amount of air survey work undertaken will inevitably go on increasing, and the question as to whether any individual operator can afford to buy special machines depends entirely on the size of the contracts he, individually, secures It is possible that Governments may be interested in this type of machine, but it has to be borne in mind that Governments usually like to put in hand their own designs, for example, Canada is already definitely tackling this problem and has produced designs for machines of this general type It may not, therefore, be possible to get orders from some of the largest users of Air Survey aircraft In addition to this, Canada stipulates that all the aircraft used by the Royal Canadian Air Force must be Canadian built In spite of this, however, I am quite sure there will ultimately be a considerable market for this class of machine, though it will be some time before they can be produced on a large scale

With regard to the second paragraph of Mr Dowty's letter, referring to the possibility of the pilot carrying out the whole of the operation himself, the duties of the photographer, working on the system which I described in my paper, are practically limited to the observation of drift and the calculation of wind speed, ground speed, course to steer, and such kindred information, with the addition of the control of fore and aft overlap and the control of exposure which may involve the changing of filters, aperture and so on

As I indicated in my reply during the discussion, I personally think that, with the machine and fittings stipulated, the day is not far distant when the photographer could be eliminated and the pilot could carry out the whole of the operation himself A certain amount of development work is necessary before we can advance to this stage, but I quite agree with Mr Dowty, there does not seem to be any insuperable obstacle in the way I believe that the most difficult obstacle to overcome will be the necessity for the photographer to watch light conditions, nature of terrain, etc, in order to regulate the exposure so as to get the best photographic results

The CHAIRMAN It is now my pleasant duty to thank Captain Tymms for his brilliant paper on "Flying for Air Survey Photography" It is a very valuable contribution towards the development of an important new science, and I have also to thank Captain McCaw and the other speakers who have contributed to this interesting discussion

On behalf of those interested in air survey I should also like to thank the members of the Institution of Aeronautical Engineers for having arranged for this

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press

ımportant subȷect to be dıscussed here I can say by doıng that they are consıderably advancıng ıts ınterest Already, as the result of that Dınner gıven by your Instıtutıon whıch I had the honour of attendıng, and of the dıscussıon whıch followed, we hear that Flıght-Lıeut Reıd has been workıng on the subȷect, and Mr Wıllıamson ıs also goıng to deal wıth the matter, so I am sure that from our poınt of vıew a great deal of good wıll come out of thıs paper

I ask you to gıve Captaın Tymms a very hearty vote of thanks for hıs most ınterestıng and useful lecture

The proceedıngs were brought to a close by warm votes of thanks to Captaın Tymms for hıs ınterestıng lecture, and to Maȷor Hemmıng for kındly takıng the Chaır

Wııtten Contrıbutıon by. Flıght-Lıeut REID Sınce the Lecture, Captaın Tymms, Maȷor Hemmıng, and I, have met and dıscussed thıs sıght and the fırıng actıon Charts were taken of the fırıng spaces avaılable per second, ın eıther fore and aft control, lateral control, and rudder control, and ın any combınatıon of the three I am makıng up a trıal sıght on thıs prıncıple, and hope somethıng useful may come out of ıt

https://doi.org/10.1017/S2976693100000612 Published online by Cambridge University Press