Survey of India.

PROFESSIONAL PAPER—No. 19.

EXPERIMENTS IN AEROPLANE PHOTO SURVEYING.

BY

MAJOR C. G. LEWIS R.E.,

AND

CAPT. H. G. SALMOND (LATE R. A. F.)

PUBLISHED BY ORDER OF THE GOVERNMENT OF INDIA.

Dehra Dun:

PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY.

1921.

Price Rupee One Annas Eight or Three Shillings.

Survey of India.

PROFESSIONAL PAPER—No. 19.

EXPERIMENTS IN AEROPLANE PHOTO SURVEYING.

BY

MAJOR C. G. LEWIS R.E.,

AND

CAPT. H. G. SALMOND (LATE R. A. F.)

PUBLISHED BY ORDER OF THE GOVERNMENT OF INDIA.

Dehra Dun:

PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY.

1921.

Price Rupee One Annas Eight or Three Shillings.

CONTENTS.

PART I.

CHAPTER I.

Inception and Scope of the Experiment.

1. In view of the great development of air-photo mapping during the war, the Surveyor General and the Air Officer Commanding the Royal Air Force in India, were anxious to ascertain to what extent the method could be employed with advantage for ordinary peace time surveys. An Officer of the Royal Air Force, (Captain Hamshaw Thomas) experienced in the applications of ærial photography, had been deputed to visit India in the cold weather of 1918-19 with the object of inquiring into the possibilities of the method in this country. His report formed the basis of subsequent discussions resulting in the experiment carried out at Agra early in 1920.

Origin of the experiment.

2. The suitability of ærial photography for all classes of survey requires to be investigated, *viz:*—

Classes of Survey.

Topographical Surveys of 1-inch scale or larger.

Large-scale City Surveys.

Cadastral Surveys.

Special Surveys, *e.g.* of mining or forest areas, and river surveys, scale 4 inch to 1 mile and larger scales.

Topographical Surveys are in progress throughout the *plains* of India and it would be a comparatively simple matter to organise the existing field parties for the new method of Survey, should it prove superior in point of time and cost, (Air photo surveying in *hilly* country offers problems not practicably soluble at our present stage of experience). An increasing demand for surveys of the cities of India has arisen of late years; local authorities have however usually been deterred by the great cost of ordinary methods; it is here that the air photograph seems to have the best prospect of immediate success. It is obvious that, provided the requisite accuracy is obtainable, the greater the amount of detail required to be surveyed the more advantageous will the air method prove. Revenue Surveys should also offer a great future, they involve however a third department entailing difficulties of administration and organisation better left alone until further experience is gained. Moreover there is no urgent demand in this field. Special Surveys on intermediate scales are of an incidental nature, and could be suitably taken up after a Survey party has been organised for systematic air mapping work.

It was decided to deal with the 1-inch topo. and city surveys in the experiment.

3. At the outset Colonel E. A. Tandy, R.E. was in charge of the experiment, the preliminary work of which was commenced about the end of August 1919. In October, however, he had to abandon it as his services were required elsewhere. The Surveyor General considered it very desir-

able to obtain the services of an Officer of the Royal Air Force who would be conversant with the capabilities of aircraft and assist the coordination of the work of the two departments. Captain H. G. Salmond, late R. A. F., was accordingly attached to the Survey of India on deputation. Captain Salmond had been employed on experimental work with the Royal Air Force in England and was able to make valuable recommendations with regard to the apparatus and equipment which might be required by the Royal Air Force for their part of the work.

4. The aim of the experiment was to ascertain :—

Aim of Experiment.

(*a*). Exactly what standard of completeness and accuracy is attainable both in one inch and City Surveys in the plains.
(*b*). The minimum precautions necessary to give the required accuracy.
(*c*). Whether the method possesses sufficient advantages, (if any), over the ordinary practice either in time, cost, or results, to warrant its adoption.
(*d*). The best means of arranging for the co-operation of the Survey Staff in carrying out big programmes of such work in the future.

Locality.

5. The area selected comprised the four south-eastern sheets of 54 E. These formed the south-east portion of No. 2 Party's programme of normal surveying. This area seemed the most suitable, as the assistance of No. 2 Party would be available in arranging for the ground work, and also because it would help in normal programme by relieving the topo party of several sheets. The city of Agra was selected as the head-quarters, it is conveniently situated on the eastern edge of the proposed area and would be suitable for the City Survey Experiment. It was also the headquarters of No. 2 Party.

The 1-inch Survey.

6. The ground work in connection with the 1-inch topographical survey may be classified as follows :—

(*a*). Alignment.
(*b*). "Pointing."
(*c*). Supplementary field work (classification of detail etc.).

The original proposals had also included a plane-table test survey. It was however decided to omit this for the following reasons :—The only problem presented in small scale air mapping is that of placing the photos in their correct position relative to the graticule, this can be done by fixing a large number of points on which to base the compilation and subsequently to recompile using only a few points; a comparison of the two compilations would give an idea of the amount of "pointing" necessary to ensure accuracy. A plane-table survey, however carefully carried out can never be as rigorously accurate as a photograph in minor detail. The interpretation of photographs on the ground (supplementary field work) should present no difficulties to an average Indian surveyor, and should only require the same degree of checking and supervision as is the practice in ordinary surveys. Consequently a comparison between an air photo compilation and a plane-table survey would be a test of the planetabling rather than of the air photo work.

(*a*). *Alignment.* The only systematic way of covering an area is by a series of overlapping parallel strips, each strip consisting of overlapping photographs. The problem of maintaining a series of parallel straight courses with a fixed lateral interval without assistance from the ground is one which the most skilful pilot finds insuperable. With the compasses at present in use in æroplanes, flying on a compass course is liable to large errors in direction which would be useless for our purpose.

It was proposed therefore to locate helios at intervals along the centre line of each strip, and by sending flashes in a vertical plane in the line of flight to provide a guide for the pilots. This idea was carried out in the experiment; the results however were most disappointing as will be shewn in Chapter II of this report.

(*b*). *Pointing.* The provision of points fixed on the ground and identified on the photos for the compilation of the mosaic may be done in two ways—(*i*) Points may be fixed and so marked before photography as to be recognisable in the photos ("Prepointing") or, (*ii*) they may be fixed and identified subsequently when the photos are taken on to the ground ("Post-pointing"). The first method involves going twice over the ground and entails expenditure in materials for marking points, there is moreover nothing to be gained by it—the second can be carried out without much extra labour at the same time as the supplementary field work. It was accordingly decided to adopt the latter method except in the case of the helio stations which could conveniently be marked by cloth "ground strips"; these would at the same time be useful marks for the pilots, as the latter would not be likely to see the helios when immediately over them.

(*c*). Supplementary field work requires no comment at this stage.

City Surveys.

7. Col. Tandy proposed experimenting on two branches of this subject:—City guide maps and City Surveys. As a very complete and successful experiment had been carried out at Baghdad in 1917 in the preparation of a guide map on the scale of 12 inch to 1 mile, it was considered unnecessary to repeat this class of work at Agra.

A large-scale City Survey however presents very different problems. Owing to the short time at our disposal, the absence of proper camera equipment with the R. A. F., and to the fact that no officer was available to carry out a test survey of a small portion of the City, the experiment could only partially be completed.

Aeroplane equipment.

8. *The camera.* Ever since air photos have been used for map making, the necessity has made itself felt for a camera mounting which will maintain the optical axis of the camera in a truly vertical position during flight. During the War no mounting which was automatic in its operation was in general use. All the early work aimed at correcting distortion in photos rather than at eliminating the cause of the distortion. In Mesopotamia we were particularly badly off in this respect; the "L" type camera with a rigid mounting being the only type available for the greater part of the time. For surveys of the kind now attempted, the first essential is to obtain photos free from distortion—(For city work, as will be shown later on, no satisfactory results are obtainable, if there is any perspective distortion in the photos). Other necessary items are—automatic plate changing, resetting, and exposing; self capping; large plates and large magazine capacity.

Lenses. For small scale survey a lens of short focal length is required to avoid climbing to a great height; whereas for City work the longest possible focal length is desirable. Lenses of 6 inch and 36 inch focal length were therefore asked for.

Other necessary æroplane equipment recommended by Captain Salmond included:—

The statoscope, a sensitive instrument for indicating departure from a horizontal course—This instrument was particularly necessary to ensure a uniform scale, as the ordinary aneroid scarcely indicates small variations of altitude and has a considerable lag.

The recording barograph.

The bomb sight—For estimating ground speed and for indicating the point vertically below the machine.

The camera obscura.—For plotting the course of a plane and so calculating ground speed.

9. Early in September full details of our requirements were made known to the Air Officer Commanding the Royal Air Force in India who applied to the Air Ministry for a camera embodying the features laid down in our specification. By the end of November no reply had been received from the Air Ministry, and the operations in Waziristan were keeping all the available photographic staff and equipment of the Royal Air Force fully occupied; prospects of any experimental work during the current cold weather were dwindling. At the beginning of December the Air Officer Commanding in India repeated his request to the Ministry and with his concurrence the Surveyor General cabled direct to the makers of the Willamson Stabilised camera, which had been in use experimentally in 1918. Their reply that this camera was no longer being manufactured finally disposed of any hope of obtaining an instrument suitable for our purpose. At this juncture I was of opinion that the greatly diminished value of the experiment would scarcely warrant its being proceeded with; Headquarters of the Royal Air Force however strongly urged that it should be undertaken with such resources as were available in India, with which view the Surveyor General concurred. The results have certainly been of value, if only in narrowing the field of future experiment.

CHAPTER II.

TOPOGRAPHICAL SURVEY.

A. Narrative Report of Experimental Work.

10. Late in December 1919 I received orders from the Superintendent of the Trigonometrical Survey to take charge of the work in connection with the air mapping experiment and for this purpose to organise No. 13 Party, of which the normal work had been suspended owing to the War.

Major E. O. Wheeler, M. C., R. E. and Captain E. A. Glennie, D. S. O., R. E., who had recently joined the department were detailed to assist me in addition to Captain H. G. Salmond who had been engaged on preliminary work since August 1919.

11. During October Captain Salmond had carried out experiments with heliotropes with a view to ascertaining the best method of directing flashes in a vertical plane on any given bearing—(Details of the helio equipment actually employed are given in Appendix I). In November he proceeded to Ambala and explained to the Royal Air Force Officers of the 114th Squadron (now 28th Squadron) the method of ground control it was proposed to adopt. As there was no means at Ambala of laying out two helios a considerable distance apart on the same azimuth, which was the method proposed for giving a line to the pilot, a single set only was sent there, and pilots practised flying on the point indicated by the flash. It was found that the helio was easily visible from a distance of 25 miles.

Captain Salmond and myself proceeded to Ambala on 22nd January to confer with the Officer Commanding 114th Squadron. The R. A. F. Officer who was to be in charge of the photographic side of the work had arrived at Ambala and we were able to obtain details of the type of camera and lenses available of which we had been in ignorance up to that time. 20th February was decided upon as the date for commencement of photography at Agra. As it was now so late in the season the Surveyor General consented to a reduction in the programme, by which only two sheets, 54/E/12 and 54/E/16 would be taken up.

12. The following details were then worked out based on the type of camera to be used.

Camera—L. B. type with adjustable cradle—Lenses, 8½ inch (and 20 inch for city work).

Scale—It was considered that a scale of about 3 inch to 1 mile should be aimed at; anything smaller would be liable to difficulties in interpretation.

The flying officers however considered that they should not attempt to fly at much over 12000 feet at that time of year. The altitude fixed on was 13000 ft. giving a scale of 3·5 inch to 1 mile. The cameras were to be fitted with the short side of 5″ × 4″ plate parallel to the direction of the flight. The two 1-inch sheets were taken together as a single area 31 miles east and west by 17 miles north and south, to be covered by 20 parallel east and west strips, giving a centre to centre distance of 0·86 mile and 40 % overlap between strips. Allowing for a 33 % overlap between successive photos, at a ground speed of 90 miles per hour, (no wind), the exposure interval works out at 30 seconds. This allowed sufficient time to change plate magazines (18 plates) between two exposures without interfering with the continuity of the strip. It would thus be possible to obtain a continuous strip 31 miles in length. The east and west direction was selected, as being most suitable for the helios, in a north and south direction a strong enough flash cannot be thrown southwards towards midday (using the auxiliary mirror necessary for flashing in a vertical plane).

Helios—It was decided to locate helios at the beginning, centre and end of each 30-mile strip. Owing to the narrow angle of dispersion of the beam, pilots had experienced difficulty in keeping the flashes continuously in view and it was pointed out that the helios were only intended as a guide in picking up the line before the commencement of a run, and that they must endeavour to locate natural objects on or near the helio line during the few moments that flashes would be visible. Experiments were also made in photographing ground strips from a height of 13000 ft. It was found that a T, the elements of which each measured 30 feet by 52 inches, was easily visible in the photographs. In the actual work at Agra, owing to the difficulty of obtaining sufficient cloth of the above width, unbleached "*dasuti*" 36 inches wide and 36 feet long was used, with good results.

13. During January the necessary menial staff was enlisted and helio squads were organised. Major Wheeler and Captain Glennie projected and plotted the plane tables. The purposes for which these were required were threefold. (*a*) The location of helio stations. (*b*) Fixing points throughout the area. (*c*) Survey of any gaps that might be left in the photo mosaic—The 2-inch scale was selected as most suitable, this being the scale on which the mosaic would subsequently be compiled. The trigonometrical data available consisted of (*a*) In British territory:—All village trijunctions fixed by traversing between 40 and 50 years ago—(*b*) In Bharatpur State:—Traverse work for topographical survey executed during the current field season by No. 2 Party—The traverse data were plotted by rectangular coordinates (in blue), the spherical graticule was then plotted in black and the helio lines in red.

14. The party arrived at Agra on the 4th February—It was arranged that the work of laying out the helio lines and flashing the helios, along the eastern centre and western meridians of the area, should be carried out by Major Lewis, Captain Glennie and Major Wheeler respectively. During the next few days, experiments were made as to the best method of locating helio stations and laying out the East and West lines, in which only a very small margin of error was admissible. This part of the work is described in an Appendix. The surveyors lent by the Officer in charge No. 2 Party were practised in the interpretation of photos, for which purpose a strip of a dozen photos had been taken previously, close to Agra, by the 114th Squadron, Royal Air Force.

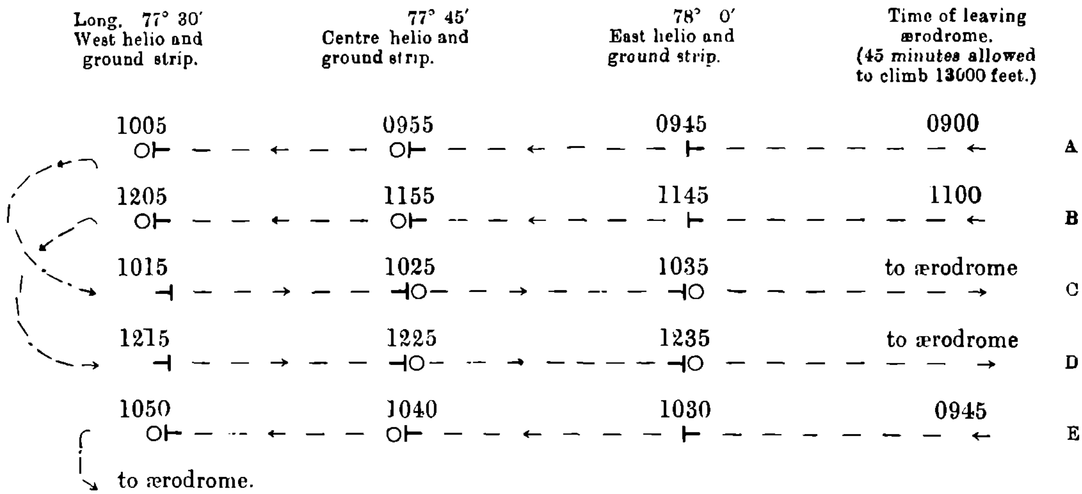
It had been anticipated that 6 Surveyors would be available. The Officer in charge No. 2 Party could, however, only spare two men, (without seriously interfering with his programme)—so that the original proposal to carry out supplementary field work on the photos in sheet E/16 as well as E/12 had to be abandoned. Sheet E/16 was being surveyed in the ordinary way on the 2-inch scale by No. 2 Party and it was intended to compare the results of the air photo method with the ground survey, as a test of the correct interpretation of photos and of the completeness of detail*. The arrangements for the photography of both sheets were adhered to, as the method of helio control was worked out for two standard sheets taken together.

15. Major Wheeler with Surveyor Fateh Muhammad Khan and Captain Glennie with Surveyor Gaj Bahadur Singh left for their respective grounds on the 11th February. They had thus only 8 days before the commencement of photography for laying out the helio lines. It was only by uninterrupted labour during the day and considerable night work that they were both able to be ready for the aeroplanes on the 20th. I was more fortunately situated in having the assistance of Mr. Muhammad Husain (Upper Subordinate Service) and two traversers, who were lent to me for a week by the Officer in charge No. 2 Party. It was impossible to postpone the photography

* But not as a test of accuracy (*see* para 6).

even by a day, as Headquarters, Royal Air Force had intimated that the Flight would be withdrawn at the end of February.

16. 'B' Flight 114th squadron, with Captain C. C. Durston, R.A.F. in command, arrived in Agra on the 17th February. On the following day a programme was drawn up. There were three cameras available and Captain Durston proposed to send up three machines daily, keeping the fourth standing by in case of a breakdown. There were also three sets of helios controlled by each of the three "Ground Officers"—(nine in all). The twenty strips were divided into four groups of five, each group representing one day's flying. Taking the first five strips A, B, C, D, E, the helios first occupy their stations on A, C and E. The first plane flies from East to West along A and returns from West to East along C. As soon as the plane has passed over a helio, the latter moves to its station on the next line to the South so that the helios on A and C move to B and D and are in position for the second plane which flies in a similar manner to the first. The third plane has only one strip to do—from East to West along E, after which it may be used in filling up any gaps that have been left in previous day's work. The helios at the beginning of strips were found to be of little value, and it was decided not to use them. This programme is shown diagrammatically below :—*



17. The area would thus be completed in four days, if no mistakes were made. It was decided to carry through this four-day programme, without interruption. Any attempt to break off in order to fill in gaps due to deviations in flying or to failures in functioning of the cameras might result in confusion in the movements of helio squads owing to the difficulty of communication with ground control officers. Gaps were to be filled in after completion of the programme.

A 1-inch map showing the positions of all helio stations and the centre lines of strips (helio lines) in red was issued to each pilot. Without attempting to describe the experiences of the pilots in detail, it is sufficient to say that the helio method of ground control proved almost a complete failure. In about 54% of the strips no helios at all were seen, in spite of careful reconnoitring of the ground while climbing. On many occasions only a single flash was observed, and once or twice a pilot was able to keep the flashes in view for several minutes at a time, but on no occasion were two helios seen simultaneously. This was possibly due to inaccuracy in direction of the helios, but all possible precautions had been taken and I do not think it would be a practical proposition to ensure greater accuracy in this respect. When seen, the helios were of considerable assistance to

* Helio.........O Ground Strip...........⊣

the pilots and with further practice, better results might be obtained. But the cost and labour of the ground work necessary for their use is, and always would be, out of all proportion to the benefits derived. Captain Durston suggested the use of smoke bombs and some of these were sent for but failed to arrive in time. It would be worth while trying them.

18. The work of the ground parties during photography was not as simple as might be expected. An æroplane flying at 13000 feet is not an easy object to see from the ground; but for the faint hum of the engine which advertised their presence some 5 minutes before actually passing overhead it is doubtful whether any of the planes would have been seen at all. When planes were off their course and possibly behind time owing to wind or other causes, the helio squads were frequently in doubt as to which plane of the three they were observing and thus had difficulty in deciding when to move. On several occasions, through failure to detect the return flight of the plane they were obliged to continue flashing the helios till late in the afternoon on the chance of their being required.

Permission was obtained beforehand from the Maharaja of Bharatpur for ærial survey work to be carried out over his territory. It might confidently be asserted however that, to this day, none of the inhabitants are aware that any aircraft passed over their State during the experimental work at Agra.

The ground strips in the form of T's of white cloth placed at the helio stations at the beginning, centre and end of each strip were of great assistance and should form the most suitable means of ground control for future work; they were easily visible at a height of 13000 feet.

19. The failure of the helios placed the flying officers at a considerable disadvantage; had helios not been used, the time wasted in searching for them would have been profitably employed in locating the line by means of the ground strips and the map alone, and the attention of the pilots would not have been divided between the two methods. The resulting strips except in the case of one pilot seldom coincided with any portion of the area they were supposed to cover. The time table was well adhered to, as few cases of engine trouble occurred; the cameras on the other hand gave constant trouble, the chief fault being double exposures, which occurred on 112 plates. The following table gives details of the failures during photography :—

Number of plates exposed			1757
Double exposures		112	
Under exposed		101	
Blanks		47	
Broken plates		2	262
" Jams "	16		
Number of negatives available for use			1495

After the completion of 4 days' programme (20th, 21st, 23rd and 25th Feb.) only half the area had been covered. The remaining time was occupied in filling in the numerous gaps, this took six days up to the 3rd March. The Flight left Agra on 4th March. At the end only very small areas remained unphotographed, amounting to a total area of about 10 square miles. It is uneconomical to attempt to cover small gaps (say less than 1 square mile)—these are best left for ground survey.

20. The work of photography was handicapped by lack of the necessary equipment, several items of which, though available in India, could not be obtained. These were the camera obscura, the bomb sight, and the recording barograph; the latter though not essential would have been a useful adjunct. Observers thus had no means of estimating ground speed, with the result that some strips had excessive overlaps and others consisted of a series of isolated photographs.

At the altitude of photography strong north-westerly winds were encountered exceeding

30 miles per hour on several occasions, which added greatly to the difficulties of the flying officers both in keeping to the course and in judging ground speed. Considering the difficulties the estimation of exposure interval was extremely good.

Development printing and numbering of photos.

21. This was carried out by the Royal Air Force photographic officer who had improvised a dark-room in one of the military buildings near the ærodrome. His staff, very much undermanned, were required to work overtime every day in order to keep abreast of the photography. On several occasions, men were employed for over 12 hours in the dark-room during the day. The method of numbering adopted was to give each negative the index letter corresponding to the strip it was *intended* to cover followed by its serial number in the strip—Our work was considerably increased owing to mistakes in numbering. These possibly arose from failure to number the plates before development. (In view of the difficulties under which the photographic staff were working the foregoing remark is not intended as a criticism). I think that the only satisfactory way of numbering photographs, is to scratch the figures in a corner of the negative. The number will then appear on every print (a temporary number may be entered in pencil before development). Any other method involves sorting out the prints after drying and entering the numbers on the back, much time is wasted and it is easy to make mistakes. In comparison with those met with on service during the War, the quality of the photographs was on the whole disappointing. This was due partly to the poor condition of the plates and paper. It cannot be too strongly emphasized that correct exposure and good definition are essential, the ease and rapidity of subsequent field work is dependent upon them.

Preparation of photos for field work.

22. Two copies of each photo were received from the R. A. F. One set were pinned together in strips by overlaps. The strips were kept at the party headquarters for reference and were filed in large envelopes. Each envelope contained the strips appertaining to the area allotted to a particular surveyor, and was marked with his name. The areas covered by the strips were plotted by proportional compass on a 1-inch map and distinguished by shades of different colours. A second copy of the map was kept up for the information of the Flight Commander. The second set of photos were pasted down in strips on pieces of 4-ply bristol board and sent out to the officers and surveyors for the supplementary field work on the ground. It was found that these "field board" should not exceed about 15 inches in length, otherwise they were cumbersome to handle. Owing to differences of scale it was not as a rule possible to make up mosaics of two or more strips, which would have been more convenient for field work. Paste should be applied with care so that none remains on the surface of the photos as this interferes with the inking in of detail. The first field boards were sent out on 25th February. The last were not completed till 13th March, as the R. A. F. were not able to develop the plates exposed on 3rd March until after their return to Ambala. A separate index was kept on a 1-inch map showing areas covered by the field boards, which were numbered serially for each surveyor.

Field Work.

23. Sheet 54/E/12 was divided into four quarters, Major Wheeler, Captain Glennie and the two Surveyors, each being allotted the area of a full 2-inch plane-table section. The supplementary field work comprised—

(*a*) Pointing.
(*b*) Inking up on the field boards (photos) all detail necessary for a 1-inch map.
(*c*) Preparing village lists.
(*d*) Colour traces.

(*a*) *Pointing.* In order to be on the safe side as regards the number of points fixed for compiling the mosaic, orders were issued to cover the whole area with points averaging about 1½ miles apart. In the eastern portion of the sheet (British Territory) this merely meant identifying the positions of all village trijunctions which were fixed and plotted on the plane-tables and fixing a few points by plane-table intersection in the centre of the larger village areas. In Bharatpur State (the western part of the area) no cadastral traverse data were available, and traversing for topographical work had been carried out by No. 2 Party in the early part of the season. The available points were comparatively few and shewed considerable discrepancies when used in conjunction with the old work. Over this area pointing had to be carried out entirely by plane-table resection and intersection, and owing to the discordance in the data, this took up an undue proportion of the time.

Fixed points were given serial numbers or letters which were entered on both the plane-tables and the field boards. The numbers of the field boards were also shown against each point on the plane-table. Thus b/7-9 indicates that the point b occurs on field boards 7 and 9. This was found very useful afterwards in compilation.

(*b*). *Detail.*—All necessary detail was inked up on the photographs in the usual symbols in black, red and blue in waterproof indelible inks. State, district and tahsīl boundaries were followed out field by field. Heights of hills (there were several low ridges) were obtained by the clinometer, the scale of the photos being known; these were entered as relative heights above the general level of the country, and form lines were shown. It was not possible to give heights above mean sea-level, as the data did not include any. Where the photos were clear and the definition good, it was easy to identify, on this scale, (3·6 inches to 1 mile) small bushes, individual clumps of tall grass, and with practice, the different kinds of crops. Shadows cast by objects such as telegraph poles and stone posts of fences do not appear at all.

The total and average daily out-turn of each officer is given below:—

Officer.	Total area in square miles.	Average daily out-turn in square miles.	Number of points fixed and identified.	Remarks.
Major Wheeler ...	66	3·3	98	
Captain Glennie ...	54	3·2	67	*a* see para 30.
Fateh Muhammad ...	68	2·6	120	*b* see para 33.
Gaj Bahadur Singh ...	78	3·0	123	
	266 sq. m.	*a* 3·0 sq. m.	*b* 408	average 1·5 points per square mile.

(*c*) *Village Lists.*—These were prepared in accordance with the usual Topo. party practice.

(*d*) *Colour Traces.*—Colour traces were kept up on tracing cloth on the scale of the original photographs, differences of scale were approximately adjusted during tracing, so as to form a combind trace covering the whole area.

Major Wheeler and Captain Glennie have written separate reports dealing with the helio arrangements and supplementary field work.

The field work of Sheet 54/E/12 took one month, and by the 28th March the field staff had returned to Agra.

24. Photographs may be brought to the scale of the mosaic in two ways:—

Compilation. (*a*) By scaling individual photos from the original negatives in an enlarging lantern.

(*b*) By scaling strips of photos made up of contact prints.

The area of photographic paper involved is usually the deciding factor, so that as a general rule (*a*) would be employed for compilations on a larger scale than the original photos and (*b*) for compilations on a reduced scale. In this case the photos were to be reduced from 3·6 inch to 2-inch scale so that (*b*) was suitable. There are also two methods of carrying out (*b*):—

(i). Each strip is reduced to its correct scale in the copying camera, and prints are made from the resulting negative.

(ii). Several strips together are reduced to a small scale on to a negative of a size that can be used in the enlarging lantern. Each strip is then enlarged separately to the required scale in the lantern.

(i) is much slower but very little detail is lost; if the scale of the reduction proves to be incorrect, which occurs not infrequently, the whole process must be repeated. (ii) is rapid, and rescaling if necessary can be done in a few minutes, its only disadvantage is in loss of detail. It was the method used in Mesopotamia, where a large copying camera was not available, and gave good results.

In the present work method (i) was adopted, as the enlarging lantern was not available at the commencement of the work.

25. There are three possible methods of obtaining the necessary line work of the final map.

(i). Inking up detail in waterproof ink and bleaching out the superfluous photographic detail before reduction.

(ii). Inking up detail before reduction, (without bleaching out).

(iii). Reduction of the strip without previous inking in, which is carried out subsequently on the completed mosaic.

(i). was ruled out for two reasons, based on experience in Mesopotamia—(*a*). The pouring of bleaching solution over prints pasted down on a board results in cockling. (*b*). Photographic detail which may be required for the adjustment of overlaps, is lost. If feasible this method saves much subsequent trouble in obtaining blue prints for fair drawing.

(ii). This may be employed when the original field boards are suitable for direct reduction. If duplicate strips have to be prepared, this method should only be adopted if the detail is likely to be difficult to follow on the reductions. A considerable amount of touching up on the mosaic will in any case be required, and much unnecessary work is done on strips, only parts of which are afterwards used.

(iii). Is the best method when original field boards are not available and when the detail on the reductions is clear. It gives better results than (ii) in the later process.

26. On the completion of the field photography at Agra, Captain Salmond who had been engaged on the preparation of the field boards there, returned to Dehra and took up the work of preparing the photos for compilation of the mosaic. In the case of sheet 54/E/16 no field boards had been made, so that the second set of photos supplied by the R. A. F. were available for this purpose. It was proposed to prepare a mosaic of this sheet by using combined prints of the ground survey on the 2-inch scale as a basis. This mosaic could then be used by No. 2 Party in the fair.

mapping of the sheet as an improvement on the detail of the plane-tabling. As regards 54/E/12 it was thought that the original field boards had not been sufficiently accurately prepared and that their condition after rough handling in the field would not be good enough, to be used as originals for reduction to scale. Consequently a third set of photos obtained from the R. A. F. after their return to Ambala were used to prepare duplicate strips. It was afterwards recognised that this intermediate step was quite unnecessary and a waste of time. The field boards should be carefully pasted down in the first instance and carefully inked up in the field so that they may be used as the originals for reduction. Procedure (ii) of the preceding para was adopted for the North half of the mosaic, detail being inked up in black from the field boards, the size of the symbols on the 3·6 *inch* scale being regulated so as to be in accordance with symbol table on reduction. The reductions shewed up all detail very clearly, so that the method of inking up first was abandoned in favour of procedure (iii) for the south half of the sheet. In this case it was necessary to ink up all fixed points for scaling the strips in the camera. As already stated however it would have been better to have used the original field boards throughout especially as they also contained the surveyed blanks not covered by photos.

Mosaic.

27. The mosaic was built up in two halves (North and South) on stout mill boards mounted with drawing paper. All the fixed points contained on the plane-tables and identified on the photos were plotted and numbered as described in para 23 (*a*). The first few strips were scaled by tracing all the points contained in them on celuloid and making the ground glass image in the camera fit the points as nearly as possible. Afterwards it was found sufficient to use a strip of paper cut to the length of the distance between two of the extreme points of each strip. If there was much alteration of scale in the photos it was necessary to reduce the strip in two halves or to make the correction by tilting the plan board and plate holder. A certain proportion of the points (a large number in the case of Surveyor Fateh Muhammad) had been inaccurately fixed or wrongly identified, so that it was always necessary to check with proportional compasses the relative positions of points on the plot as compared with the photos, before selecting points for scaling. On receipt of the reduced prints from the photo office they were pasted down in position by points and overlaps. Practically none of the photos were free from distortion, which resulted in big accumulated errors in azimuth, so that it was necessary to cut each print into small sections and to correct the error by slewing each section through a small angle. As an example of the amount of distortion which occurred :—a strip of four photos contained a straight line of railway parallel to the direction of flight; when correctly fitted by overlap the railway line had changed direction by 8° at the 4th photo. This would be caused by a constant lateral tilt of about 6° in the axis of the camera, in the direction towards which the railway appeared to curve.

Owing to distortion the number of points fixed was by no means excessive, and the labour of compilation was greatly increased. The mosaics of 54/E/12 and 54E/16 were compiled by Major Lewis and Captain Salmond respectively, the former took 3 weeks from commencement of scaling.

Fair-drawing.

28. The completed mosaics with all the field boards, plane-table sections, spare photos and other material connected with them, were made over to No. 2 Party for fair-mapping.

Before drawing can be commenced it is necessary to obtain suitable prints on drawing paper. This may be done either :—

(*a*). By tracing the detail from the mosaic and preparing photo reductions of the tracing on drawing paper on the 1½-inch scale, or (*b*). By obtaining a negative on the 1½-inch scale of the inked up mosaic as it stands, from which ferro-type prints on drawing paper are prepared.

(*a*). Introduces the extra tracing process, which is difficult to do owing to the dark tint of the photos, but results in a print containing only the required detail in line work, whereas in (*b*) the line work is somewhat confused by the reproduction of the photographic half-tones and junction lines of the mosaic.

B. Results and proposals for future work.

29. The conclusions to be drawn from the experiment are discussed in the following paragraphs :—It is assumed that in future work an up-to-date camera will be employed such as that about to be supplied by the Air Ministry—Its specification is briefly as follows :—

(i). Gyrostatic stablization.
(ii). Adapted to take lenses of F. L. 4″, 6″, 8″ and upwards.
(iii) Plates or films 8″ × 8″.
(iv) Magazine capacity :—Plates ? —Films, rolls of 100.
(v) Automatic changing, resetting and exposing with adjustable exposure interval.

It may be mentioned here that neither a 4-inch nor a 6-inch lens is capable of completely covering an 8″ × 8″ plate. The extreme angle from the axis to a corner of the plate is about 55° and 43° respectively, whereas the maximum covering power of any modern lens within the limits of accuracy and definition necessary for air photo work does not exceed 30°, so that with these lenses, the edges and corners of the photo cannot be made use of and overlaps must be regulated accordingly.

Ground work by the Survey.

30. The use of heliotropes as guides for æroplanes has proved a failure. Ground strips placed at each end and at intermediate points along the line of flight will probably prove to be the most suitable form of ground control. Smoke bombs used in conjuction with ground strips may be of valuable assistance. The most suitable unit of area for ground control is that covered by two adjacent (East and West) standard 1-inch sheets.

The following organisation of a field party is suggested for carrying out large programmes, should it be decided to continue with this work in view of the conclusions arrived at in a later paragraph.

PERSONNEL.
Officer in charge.
6 Assistants.
30 Surveyors.
Tindals, khalasis etc. not less than in an ordinary field party.

Headquarters section.

One officer and 4 surveyors, for the preparation of field boards, indexing and filing of photographs. After completing this work the section would proceed to Dehra for compilation of mosaics.

Ground control Section.

One officer and 10 surveyors—Each unit area of two standard sheets, would be covered by 12 east and west photo strips (see para 32). Each strip to contain 5 control points (ground strips) 7½ miles apart. Five surveyors in each area working a few days ahead of photography would fix the positions of the ground strips, and possibly at the same time intersect a few additional conspicuous points which would be certain of identification on the photos. The bulk of the "pointing" would thus be completed before photography and very little additional "postpointing" would be necessary during supplementary field work. Each surveyor should be responsible for the placing of ground strips during photography along one of the five North and South lines in each area. It would be necessary to employ two groups of five surveyors on this work, so that the photography would not be held up while the ground party moved off to and prepared the next area. On completion of the programme the ground control section would take up supplementary field work with the rest of the party.

With the improvements in instruments and training of airmen it may be found, in country where maps already exist, that the best method of photography will be to break up the area into sections bounded by conspicuous natural features and to allot each section to a pilot to be photographed in any way he may choose, without providing any form of artificial ground control.

Supplementary Field Work.—Three officers and 16 surveyors and eventually 4 officers and 26 surveyors.—This work would be commenced within a few days of photography as soon as the first field boards had been prepared. The average outturn during the experiment was 3 square miles a day. Owing to the reduced amount of pointing that would be required, an outturn of 4 square miles might be expected, but it is doubtful whether this will ever be greatly exceeded as it is limited by the time taken in moving over the ground. If (as is proposed in para 32) the scale of the photos is reduced, the outturn will be adversely affected on account of the increased difficulty of interpretation.

Photography.

31. The results of the photography show very clearly that the qualifications of the flying officers are a most important factor in the ærial part of photo surveying. Of the four pilots engaged in the experiment, one possessed the topographical sense in a marked degree, and was able to follow very accurately a given line by reference to the existing map. For topographical surveys satisfactory results will only be obtained by selecting and training officers who have a natural aptitude for this work.

There is little doubt that the attention which is being devoted to the subject in Europe and America will result in a rapid development on the ærial side. Machine will be specially designed for the work. The introduction of completely automatic photographic apparatus and instruments of precision for navigation purposes will to a certain extent do away with the personal element; while at the same time the standard of personal performance will be raised.

The ærial part of the work, in matters relating to æroplane design and equipment has been dealt with more fully by Captain Salmond in his report.

Scale

32. Apart from questions of altitude and focal length, the necessity for ease and rapidity in the interpretation of photos imposes a limit to the reduction of scale. It is clearly desirable to obtain as small a scale as possible consistent with this requirement. The scale of 3·6 inch to a mile adopted in the experiment was fully large enough, and it is probable that a smaller scale, say 2·5 to 3 inches would be sufficient provided that the quality of the photos were good. The latter is essential, photos on such small scales are useless, if the definition is not quite perfect. With a 6-inch lens at 12000 feet a scale of 2·7 inch to 1 mile would be obtained. Each photo, 8″ × 8″, would cover 9 square miles and allowing an overlap of 33 °/₀ the working area would be 4 square miles. 140 photos in 9 strips would be required to cover the area of two standard sheets (540 sq. miles). Actually, the covering power of the lens would probably not extend beyond about 3½ inches from the centre of the photo, so that an extra margin of overlap would be allowed—(unless an 8-inch lens were used at 16000 feet). Further allowances would have to be made for gap filling—say 50 °/₀, or 210 photos in 12 strips—*i.e.*, 105 photos for each standard sheet. In actual

practice it is probably that this figure would generally be exceeded. Original photos on this scale would be suitable for topographical maps on all scales up to ¼ inch to 1 mile.

Compilation.

33. The use of larger plates will greatly simplify compilation of the mosaic. The number of photos involved would be about 100 per standard sheet as against 600 in the experimental sheet. The absence of distortion will effect a reduction in number of fixed points necessary—up to a certain point. When fitting strips of photos together by overlaps it is impossible to avoid certain errors; with some individuals there is a tendency to accumulate an azimuthal error, so that even if both ends of a strip are fixed the central photos may be displaced laterally. It is therefore necessary to have fixed points at intervals along each strip. Ground strips would provide points at intervals of 7½ miles, it will probably be desirable to fix an additional intermediate point in say every alternate strip. The total number of points required for a standard sheet will thus be 80 to 100 (1 point to 3 square miles)—400 points were fixed in the experimental sheet.

Cost.

34. On the basis of the proposals for future work outlined in the foregoing paragraphs, it is now possible to work out an approximate forecast of the comparative cost of the air photo method.

(*a*). *Cost of ground work*—

Take the average of the last three years for 1-inch survey by No. 2 Party.

Year.	Outturn square miles.	Outturn per man per month of 24 days.	Cost per square mile Rs.
1914—15	844	50·9	10·2
1915—16	1602	47·0	7·6
1916—17	1092	42·0	10·4
Average	1179	46·6	9·1

Taking the organisation of the æro party described in para 30, the programme for a field season would be as follows :—

Party reaches field headquarters	... 1st November.
Photography commenced	... 10th November.
Supplementary field work commenced	... 15th November.
Photography completed	... 10th February.
Field work closed	... 20th April.

Month.	No. of men on field work.	Total "men-months".
November 15th to 30th ...	16	16 × ½ = 8
December ...	16	— — — 16
January ...	16	— — — 16
February 1st to 10th ...	16	16 × 1/3 } = 23
„ 11th to 28th ...	26	26 × 2/3 }
March ...	26	— — — 26
April 1st to 20th ...	26	26 × 2/3 = 17
		Total 106 "men-months"

Ordinary field party of same strength
30 men from 10th November to 20th April 160 "men-months"

Outturn per man per month of 24 days.						Total outturn.				
					sq. m.					sq. m.
Æro party	24	×	4	=	96	96	×	106	=	10176 (say 38 standard sheets)
Ordinary party					47	47	×	160	=	7500

Note—The above figures are only comparative, and are not an estimate of probable outturn.

Assuming that the total cost of an æro party would be about the same as that of an ordinary party of the same strength, if the cost rate per square mile for ordinary 1-inch survey is Rs. 9·1, then the cost rate for the ground work by the æro party would be 7500÷10176 × 9·1 = Rs. 6·7 per square mile.

(*b*). *Cost of compilation of mosaics in Dehra*—

Actual cost for 54/E/12 was Rs. 370/-.

Probable cost per sheet Rs. 200/- or Re. 0·8 per square mile.

(*c*). *The cost of the R. A. F. share of the work* is based on the following figures supplied by the 28th Squadron for the Agra experiment :—

Initial (i).—Movements of machines and personnel, provision of an extra hanger etc.–Rs. 1370.

Recurring and maintenance.
(ii). Ordinary—Pay of personnel, cost of rations, normal petrol and oil (Rs. 1200/-) etc.— Rs. 8230.
(iii). Extra—Officers detention allowance, extra petrol and oil (Rs. 2700/-) photographic stores (Rs. 1462/-)— Rs. 6290.

For the present analysis it is assumed that items (i) and (iii) are debitable to the Survey and only these have been taken into account in calculating cost rates. The above figures do not include any depreciation of the machines, which would amount to a very large sum.

1750 photos (excluding city) were taken at an average interval, during photography, of 30 seconds. Had 8″ × 8″ plates been used (scale 2·7 inch to a mile) the interval would have been 80 seconds. Consequently the number of plates exposed in the same flying time would have been 30 ÷ 80 × 1750 = 660.

The cost of photo stores for 1950 plates was Rs. 1460
The cost per 5″ × 4″ plate = Rs. 0·75
Therefore the cost per 8″ × 8″ plate (arbitrarily assumed to be proportional to area of plate)
= 0·75 × 64 ÷ 20 = Rs. 2·4

The cost for 660 plates = 2·4 × 660 = Rs. 1580
Actual cost = Rs. 1460
Difference = Rs. 120

Hence had the new camera been used, the total of item (iii) above would have been increased by Rs. 120/- making it Rs. 6410/- or Rs. 9·7 per plate (8″ × 8″).

The estimated theoretical outturn for the æro party is 38 standard sheets. At 105 plates per sheet the total number of plates = 3990.

Total cost of flying and photo stores = 3990 × 9·7 = Rs. 38700
Add initial charges – item (i) 1370
Rs. 40,070

Cost per sq. mile = 40070÷10176 = Rs. 3·9

(*d*) *Summary—Total cost rate.*

Ground work	...	Rs. 6·7
Compilation	...	Rs. 0·8
Photography	...	Rs. 3·9
Total cost rate	...	Rs. 11·4 per square mile.

If the total cost of the R.A.F. is taken into account (including depreciation, pay of personnel, and cost of rations) then the cost rate would probably exceed double the cost of survey by ordinary methods.

No mention has been made of the cost of triangulation and traversing. In the greater part of the areas suitable for air photo surveying, trigonometrical data are already available-where they are not, the difference in the amount of work necessary for the two methods would not be very great, the cost of traversing for æro-work might be Re. 1/- per square mile cheaper.

Another consideration which would affect the cost of photography is the distance of the work from the ærodrome. In a programme embracing two degree sheets, the outlaying sheets would be a considerable distance from the headquarters, possibly as much as 100 miles; operating at this distance would be most uneconomical.

35. Conclusions. The chief aim of the experiment has been to ascertain whether surveying by ærial photography is superior to ordinary methods for 1-inch maps, either as regards speed, cost or results.

Speed—The comparative rate of outturn is in ratio 4 : 3.

Cost—The cost of the new method is considerably greater.

Results—For a 1-inch map, about 90 °/₀ of the detail available on the photos has to be cut out. The remainder has to be generalised and passes through several processes before reaching the fair sheet. For these reasons the resulting map is not greatly superior in accuracy to that produced by grouud surveys.

It would appear then that there is nothing to be gained by adopting the air method for normal 1-inch surveys in the plains of India.

For larger scales however, as 2-inch and 4-inch, especially the latter, the new method should eventually prove superior in every way.

Mountainous country—In India and Burma there are large areas of densely wooded hilly country which for purposes of forestry or mining may require to be accurately surveyed. Such surveys are very expensive; the cost of surveying minor detail is usually prohibitive. Until precise air photo methods are developed, very satisfactory results could be obtained by a combination of ærial photography with ordinary ground surveys. Main features and heights would be obtained by the planetable while the photos would provide minor detail and hill forms.

River and Delta Surveys—Suggestions for this class of work have been made in previous notes in response to specific demands from the Bihar-Orissa and Burma Governments.

CHAPTER III.

City Survey.

Photography.

36. The outlying Lohamandi ward of Agra City was selected as the most suitable area for the experiment. Photographs were taken on the 27th February and 4th March, with a 20-inch lens at 3000 feet, giving a scale of 150 ft. to 1 inch. The area was well covered in spite of very adverse conditions.

Triangulation.

37. It was proposed to carry out a roof top triangulation by which to fix a sufficient number of points to ensure an accurate mosaic. A preliminary mosaic (this may be termed the triangulation "chart mosaic") was prepared by pasting down the contact prints supplied by the R. A. F. on a bristol board, without reference to any fixed points. For this purpose it is necessary that all the photos (in the area covered by each chart mosaic) should be as nearly as possible of the same scale. They were so in this case. Considerable care is required in building up the mosaic, otherwise errors are liable to accumulate in one place. This mosaic formed a fairly accurate map of the area, it was mounted on a plane table and used as a triangulation chart. A central portion of about 50 acres comprising the most congested area was selected.

Municipal assistance.

38. Application was then made through the Collector of Agra for the assistance of the municipal authorities in obtaining permission of occupants to enter their homes and make theodolite observations from the roofs. The official actually detailed was the Sanitary Inspector of the ward, who accompanied me on the first day's work when the triangulation stations were selected and interviewed the house owners concerned, none of whom offered any objection. In England the Ordnance Survey has statutory powers under act of Parliament empowering its surveyors to enter private property for purposes of survey. (It is presumed that similar powers will be taken in India, they will certainly be required for town surveys and must have been exercised during the Bombay Survey for example). The highest houses are clearly the most suitable for stations, and they are also the most strongly built and therefore the most free from vibration. From the first house visited it was possible with the aid of the chart mosaic to select five others necessary to cover the area.

Reconnaissance.

39. A reconnaissance was then carried out from the houses selected as stations. It was possible to fix an almost unlimited number of points which could be easily identified on the mosaic and on the ground, having first orientated the mosaic by aligning the sight rule on some distant recognised point. The mosaic was naturally not quite accurate but sufficiently so to enable any particular roof to be identified. All roofs are flat and usually surrounded by a low parapet one corner of which could be chosen as a point to be fixed. The metal spikes at the centre of mosque domes form useful points. The mosaic was inked up as a triangulation chart in the usual way. It is necessary to take ink on to the roof tops as pencil will not mark on the photo prints. A base line was selected along the railway embankment running through the area, giving a suitable connection with the triangulation. All stations were marked with a circle and dot, the centre of the roof was usually selected, (some were inconveniently restricted in area), and the distances from the parapet were entered in diagrams at

the edge of the chart. Points were evenly distributed over the area without reference to individual photos, the number fixed ensured that at least 4 occurred in each photo, one contained 9. The reconnaissance occupied three days.

Observation.

40. With the assistance of Major Wheeler the base was measured (1191 feet) with a 330′ steel tape. Four measures were taken. For the observation of angles it is necessary to have a suitable signal. That designed by Dr. J. de Graaff Hunter for traverse work in Bombay would do well. As no signals were available one corner of the parapet of the station roof was selected in every case to observe to. This necessitated the calculation of two corrections to every angle, which made the computations very laborious. Owing to the rough nature of the signals only two measures of each angle were observed, one on either face. When using proper signals and extending the triangulation over a large city it would be advisable to take four measures for station triangles and two for intersected points. It would probably be necessary to measure two bases at opposite sides of the city.

Vertical angles were observed as the heights of points were required.

A sun azimuth was observed at one of the stations. The observations were completed in 4 days, two stations each day. In cool weather it would be possible to observe at three stations every day.

The staff employed consisted of the triangulator (Major Lewis) and seven khalasis. With signals, 15 khalasis would be required.

The area covered was about 50 acres—requiring 5 stations to fix 30 points—*i.e.*, 1 station and 6 points per 10 acres. It will probably be found that the same number of stations and points are sufficient for 15 acres for a mosaic on the scale of 75 feet to 1 inch. Thus the city of Agra containing 1600 acres would require about 110 stations and 600 or 700 points. The photography would take about a week and two triangulators would complete the triangulation in, say, two months.

Computation.

41. On the return of the party to Dehra the computations were carried out by Captain Glennie and one computer. Points were computed in rectangular coordinates.

The results were as follows :—

No. of stations.	No. of triangles.	Triangular error in seconds.	Average difference between common sides per 100 ft.	No. of intersected points.	Average difference between common sides per 100 ft.
7	17	11·1	ft. 0·0039	30	ft. 0·0093.

Errors in the photographs.

42. We must now consider to what extent the photo departs from a true plan of the ground. Most writers on the subject have discussed the question from the standpoint of air mapping generally and not with reference to large scale town surveys. If we make the warrantable assumption that the lenses employed produce images free from perceptible distortions within the area of the plate, there remain three contributing factors—

(i). Tilt of camera axis.

(ii). Distortion due to focal plane shutter.

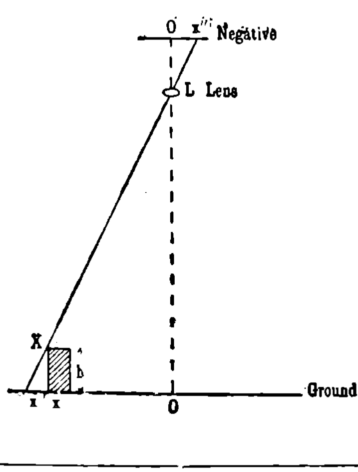
(iii). Displacement due to height of buildings and variations of ground level.

(i). The general question of *tilt* has already been touched on in this report. Air photo surveying cannot be considered a method of precision until it has been eliminated. If the elements of tilt are known, absolute correction may be made; but in the absence of an arrangement for recording tilt, it is not possible to correct the distortion due to it in the case of large-scale work, as will be shewn in the discussion of item (iii).

(ii). *Focal plane shutter distortion*—This is due to the distance travelled by the plane during the time occupied by the shutter in travelling across the plate. Distances parallel to the direction of flight are elongated or compressed according as the shutter travels with or against the motion of the plane.

If the velocity of the shutter is 40 inches per second and width of plate is 4 inches, then the time taken by the shutter to cross the plate is 1/10 second. During this time the plane moving at 80 miles per hour travels 12 feet. On topographical scales this is negligible, but on a scale of 150 feet to 1-inch it is a very serious matter, amounting to a percentage error of 1/50 (in the present instance the distortion was not so great as this). The distortion may be eliminated by the use of between-the-lens shutters. Such shutters are however subject to mechanical limitations. Definition requires that the exposure shall be proportional to the ratio $\frac{\text{altitude}}{\text{focal length}}$. Large scales therefore demand short exposures beyond the speed at present attainable in between-the-lens shutters, which is of the order of 1/100th second. The distortion may also be eliminated by the use of a film camera in which the film moves continuously during exposure at a speed which will maintain the image stationary upon it. It is not known whether such an arrangement has been tried. In the meantime the distortion may be *corrected* by the use of a barrel lens (such as the one devised by Lieut-Col. S. W. S. Hamilton, R. E.). This could be introduced into the enlarging lantern and might prove satisfactory. If the distortion is present the error introduced by it may be dispersed by cutting the prints into sections and drawing them out or compressing them in the required direction. This may be done in conjunction with the dispersal of other errors to which the photo prints are liable (see para 45).

(iii). *Displacement*—On a large scale the displacement of housetops with reference to the ground is very apparent, and as all fixed points are situated on the roofs, it must be corrected. The displacement is directly away from the point vertically below the camera. Its amount varies with the distance from this point and with the height of the building. It is easy to calculate provided the position of the point vertically below the camera is known; *i.e.*, it is necessary to know the direction and amount of tilt of the camera axis. If the axis is vertical the point will be at the centre of the photo.



By similar triangles, if x x′ is the displacement of a point X

$$\frac{x\,x'}{h} = \frac{O\,x'}{O\,L} = \frac{O'\,x''}{O'\,L}$$

whence *displacement* = (*height of house*) × (*distance in inches of point from centre of photo*) ÷ (*focal length of camera*).

As it is believed that there is no satisfactory method of recording tilt in an æroplane camera,* it follows that the problem is insoluble where photos have been taken with a camera liable to be tilted, since the error in the position of points on the photograph (apart

* The Survey of Egypt have made experiments with a tilt recorder on the principle of a simultaneous photo of the horizon taken with an auxiliary lens; it is not known whether the results were satisfactory.

from shutter distortion) will be due partly to perspective distortion and partly to displacement of the house tops containing the points. The only practical solution then lies in the use of a stabilised camera.

The scale of the original photos being fixed, the displacement described above may be minimised by using a lens of greater focal length and flying at a higher altitude. Thus if instead of a 20-inch lens at 3000′, a 40-inch lens had been used at 6000 feet, the same scale would have resulted but the displacements would have been halved. These displacements are a great draw-back in all phases of the work, it is therefore advisable to obtain lenses of the longest possible focal length. 48-inch lenses are in use in the United States.

Plane of reference.

43. In compiling the mosaic it is necessary to select a horizontal plane on to which all points on the photos must be projected, for while house-tops are displaced outwards, points situated in depressions in the ground are displaced inwards towards the centre of the photo, so that when there is much variation in the general level of the ground, it may be difficult to obtain sufficiently accurate results. This of course only applies to slopes or changes of level within the area of one photo, level areas at a different altitude to the general surface, would present no difficulty. If all the fixed points on house tops were at approximately the same altitude it would be simple to make the mosaic with reference to the plane containing the points, but then it would be necessary to correct the position of detail at ground level, and it is only this detail that is required in the survey. It is therefore more convenient to select the mean level of the ground as the plane of reference. The majority of Indian cities are situated on fairly level ground, and only such should be selected for experimental work.

Preparation of negatives.

44. A point was selected at the mean ground level of the area triangulated and the heights of all fixed points were computed with reference to this point as zero. It was assumed that the photos were free from tilt distortion (the excellent coincidence of overlaps showed that they were nearly so) and the centre of each photo (on a spare set of prints) was marked as the point of no displacement vertically below the camera. On the back of each print the displacement of each point falling in it was calculated thus :—

d = displacement in feet, h = height of point in feet above datum.

D = distance in inches from centre of photo.

f = focal length of lens in inches = 20

then $d = \frac{D \times h}{20}$.

The greatest displacement amounted to 6·0 feet, given by a height of 58 feet near the edge of a photo. This is equal to 0·039 inch on the scale of the photos (155 feet to 1 inch) and 0·080 inch on the scale of compilation (75 ft. to 1 in.). The average was about two feet.

The correct position of the points in plan was then pricked through on each print by measurement along a line joining the point to the centre of the photo and the negatives were similarly marked with a fine point. This is not easy to do as the distances are so small. All points were plotted by rectangular co-ordinates on a millboard and the points contained in each individual photo were transferred from this on to separate pieces of paper to be used for scaling.

The average number of points contained in each photo was 5.

Errors of the mosaic.

45. Even if shutter distortion is eventually eliminated or corrected, the mosaic will always contain certain errors which will depend very largely on the skill of the compiler; they will be due to :—

(i). Errors in marking the displaced points on the negative,

(ii). Plotting errors,

(iii). Expansion and contraction of the photo print, resulting in inability to obtain an exact fit in all of the many overlaps. Consequently in any particular print forming a component part of the mosaic there may be an error accumulating gradually towards the edges and cancelled by a sudden jump at the junctions with the adjacent prints. By cutting prints into sections the jump may be reduced in magnitude. I anticipate that the maximum error should not exceed 2 feet (or 3 feet if shutter distortion has to be dispersed mechanically) *i.e.*, that the distance between any two points measured on the mosaic (at ground level) will not be in error by more than 2 feet, but that this error may occur when the two points are only a few yards apart if they are on either side of the junction of two prints. These local errors may be slightly dispersed when inking up the mosaic.

The component prints will be fitted with regard to detail in the plane of reference (usually ground level), so that at first sight the mosaic will appear most inaccurate, owing to displacement of house tops in various directions.

The errors described above are those incidental to the mosaic alone. Further errors may occur in the interpretation and inking up of photos on the ground. It is impossible to say what accuracy will be obtained in this part of the work.

Scale.

46. The various errors to which the air photo method is liable, set a limit to the scale of survey. At the present stage of development I should be inclined to place the limit at 1/1000, though this may prove unduly optimistic. Colonel Robertson, in his paper on the practice of Town Surveys, was of opinion that the scale for Indian Cities should not be larger than 1/500, while the scale of 1/1000 would probably meet all requirements. A smaller scale would probably suffice for the majority of the uses to which a town survey is put. It might be found advantageous to make the compilation on a scale of about 1/1000 and to reduce for publication to say 1/1500. The smaller the scale of the original photos, the less will be the percentage of shutter distortion. The scale adopted for the mosaic of the experimental area was 75 feet to 1 inch (1/900). This meant an enlargement to double the scale of the original photos. Good negatives can well stand such an enlargement.

Mosaic.

47. The scaling of the photos was carried out in the enlarging lantern at Dehra. Owing to the combined effects of the distortions due to the focal plane shutter and to tilt of the camera axis it was impossible to make the points marked on the negative fit the plotted points exactly. As close an approximation as possible was obtained and the mosaic was compiled by cutting the prints into section and so distributing the errors. It may be noted here that the tilting board used in conjunction with the lantern was a temporary construction with a ball and socket movement which is unsatisfactory; fine adjustments cannot be made. The usual arrangement of frames with slow motion screws for movement in both directions is preferable.

Result of experiment.

48. The experiment was thus only partially completed. The results show merely that triangulation will be a sufficient and a rapid process as compared with the traversing required by ordinary methods. When a stabilised camera is available, further work will be necessary to ascertain :—

(*a*). The nature and amount of the errors to which the mosaic will be liable.

(*b*). The extent of the ground work necessary to interpret the photographs and the best method of carrying it out.

(*c*). Cost.

49. To complete the experiment I would make the following suggestions :—

Suggestions for future work.

Mosaic.—The experimental area at Agra should be rephotographed with the new stabilised camera which is being supplied by the Air Ministry. 36 inch and 48 inch lenses should be asked for. Photos should be taken at 6000 or 8000 feet according to the lens used, giving a scale of 1/2000, to be enlarged to 1/1000. If it is decided that a smaller scale than 1/1000 is sufficient then the altitude should be increased, so as to minimise shutter distortion and displacement. With an 8″ × 8″ plate or film a 50 % overlap should be allowed so as to utilise only the central 4 inch square of each photo, the displacement at edges of this square will then amount to only 1/18th and 1/24th of the height of the houses with a 36 inch and 48 inch lens respectively. The mosaic may then be recompiled using the points fixed this year.

Ground work—Duplicate enlargements of the photos selected for the mosaic will be prepared and mounted on bristol boards separately. On each of these prints the area to be used in the mosaic plus a margin of say ½ inch all round will be enclosed by a line by the compiling officer. The prints will then be taken on to the ground and the detail within this line inked up. This will require intelligence, and for the experimental area an officer of the Upper Subordinate or Provincial Service should be selected. In streets and alleys that run in directions other than radially from the centre of the photo, the inner side will be obscured by the displacement of the houses. It may be inserted by calculation from the height of the buildings and their distance from the centre of the photo (for this purpose a graph or tables could be prepared) or, by actual measurement of the width of the street, the opposite side of which appears on the photo. The latter method will probably be preferable. The nature of the detail required to be shown must be ascertained. In addition to all detail occurring in streets and open places it may be necessary to show :—

(*a*). Party walls of ownerships or occupancies.

(*b*). Open areas of courtyards and gardens away from streets.

(*c*). Municipal and ward boundaries.

(*d*). Spot heights and bench marks fixed by levelling.

Walls should be shown by single lines, representing the centre line, excepting in the case of walls facing on streets whose outer surface should be shown.

The detail from the completed field boards will then be transferred to the combined mosaic by copying with reference to the photo detail, adjustments being made where necessary at the junctions of prints.

Alternative method

50. An alternative method should be tried which would obviate the necessity of preparing a mosaic. All fixed points are plotted on a piece of tracing cloth. The inked up detail from each field board is then traced by adjustment to the fixed points. The adjustment between adjacent prints may be found difficult, but if feasible this method would be much quicker.

Test.

51. For the experimental ground work at Agra I would suggest that two copies of the field boards be prepared and that two surveyors should enter up detail of the same area independently so as to compare their results. At the same time a part of the area should be accurately surveyed by ordinary methods.

Organisation for City Surveys.

52. While it would be possible to complete the triangulation and ground work of a city in one season, it would be preferable to carry out the triangulation and preparation of the mosaics in one year and the ground work and fair mapping the following year. With a party consisting of six triangulators and fifteen surveyors, the survey of three cities might be undertaken each year. The party headquarters would remain at Debra.

Personnel.		Duties.
1	Officer in charge	General supervision and supervision of triangulation.
1	Provincial officer	In charge of computation and compilation at Dehra.
1	" "	In charge of ground work in three cities.
6	Provincial officers or Upper Subordinates	Triangulation and computation—2 in each city.
3	Computers	Computation of triangulation.
15	Surveyors	Ground work—5 in each city.
3	Levellers	Providing heights of bench marks.
180	Khalasis	

Fifteen surveyors is perhaps an excessive number for one man to supervise; they are however concentrated in three groups, so that the supervising officer would be able to spend at least a full day with each man in the month.

Photography—This would be carried out first and as early as possible in the season, each city being taken in turn. Town guide maps could be issued to the Royal Air Force showing the area to be covered and it would probably be unnecessary for a Survey Officer to be present. The R. A. F. could then send the negatives to Dehra together with two complete sets of contact prints. Photography should not take mare than one week for each city.

Triangulation—Triangulation chart mosaics would be prepared at Dehra by the triangulators under the compilation officer. 10 or 12 charts would be required to cover the area of a city. As soon as two or three charts were ready, the triangulators would proceed to their ground, the officer in charge going to each city in turn to select base lines, make the necessary arrangement with the local authorities and start the triangulators on their work.

Ground work—In the meantime the ground work of the towns triangulated during the previous season would be in hand.

Levelling—This would be done at the same time as the detail ground work; the triangulation mosaics might be used for indicating the position of bench-marks and spot heights.

Recess work—On completion of the field work the triangulators would return to Dehra, complete their computations and then prepare the final mosaics and the field boards for the following season, each man dealing with his own area. The surveyors would undertake the fair-mapping of the cities of which they had completed the ground work.

Cost.

53. An approximate forecast for the cost-rate per acre is obtained from the following assumptions :—

Cost of party per year Rs. 70,000/-

Area surveyed each year, 6000 acres.

Cost-rate per acre including all operations up to, and including fair-mapping 12/-

The cost of photography by the R. A. F., on the basis of extra expenditure over normal, is very small, amounting to a small fraction of 1/- per acre.

So that the cost-rate may be taken as not likely to exceed say 15/- per acre.

Photographic Section.

54. Before any extensive photo surveying can be undertaken it will be necessary to organise a separate photographic section at Dehra. A separate building will be required with accommodation for

(*a*). Enlarging lanterns, one lantern will be sufficient at the outset, but as the scope of the work expands it may be necessary to instal a second one. This should be allowed for.

(*b*). Compilation rooms—Two or more large well lighted rooms will be necessary.

(*c*). Store rooms for negatives, photographic stores, etc.

I would recommend that all the photographic work of the various classes of air photo surveying that may be undertaken in the future should be concentrated under one officer at Dehra. The members of the different parties responsible for the field work and fair-mapping would be under his supervision for the time being while mosaics were in the course of preparation.

APPENDIX I.

Heliotrope Equipment and Method of Aligning Helios.

1. *Equipment.* Each heliotrope set consisted of the following :—

Two 12-inch heliotropes. The auxiliary helio, for directing the sun's rays on to the flashing helio, had no special fittings. The flashing helio was fitted with sights screwed into its rim at either end of the diameter perpendicular to the horizontal axis of the mirror; it also had milled headed screw for clamping the mirror as regards movement in azimuth.

Two helio stands. 3′ 6″ and 2′ 6″ in height for the flashing helio and auxiliary helio respectively.

A level.

A plumb-bob.

An "aligning board". This was a light board, 3 feet by 2 feet, fixed to an iron-shod stake. A shade flap was hinged to the upper edge, quadrants of canvas being nailed to the side edges of the board and flap. The inner surfaces were painted black and three white vertical lines were painted on the board, one central and two outer 2 feet apart.

2. *Setting up.* The following procedure was adopted for setting up and flashing the helios on a given line, previously marked by two pegs about 40 yards apart, the exact aligning being given by nails driven into the pegs.

The aligning board is set up by driving the stake into the ground against its peg, (the peg nearest to the approaching æroplane) so that the board faces the helio, with the centre white line coinciding with the nail in the peg. The shade flap is raised.

The flashing helio is centered over the other peg (on the taller stand). The horizontal axis is then carefully levelled and the movement in azimuth clamped after aligning the sights on the centre line of the board. The axis of the mirror is now at right angles to the alignment.

The auxiliary helio is then set up about 3 feet from the flashing helio (between it and the board) its centre being brought into the alignment with the aid of the sights on the other helio. If the sun's image is now directed from the auxiliary mirror on to the flashing mirror oscillating about its horizontal axis, the rays reflected from the latter will move in a vertical plane on the required alignment.

The two operators take their stand at their respective helios. The man at the auxiliary helio brings his reflected center "spot" on to a small piece of white paper stuck at the centre of the flashing mirror. The second operator then rotates his mirror till the image rests on the black surface of the aligning board, and directs the other to make any necessary adjustment of the auxiliary mirror which may be required to centre the image exactly between the outer white lines on the board (the width of the image at 40 yards approximately fills the space between these lines). The exact position of the centre "spot" reflection is then marked with a black dot on the patch of white paper. The helios are now in adjustment for flashing. The routine adopted was to flash ten times,—each swing taking about a second—then to stop the flash on the board, correct for the sun's movement, and commence flashing again. A squad of four men was required for carrying the outfit, and by taking turns, flashing could be kept up continuously for several hours.

3. *Alignment.* The problem consists in locating the positions of three helio stations on a straight line and in laying out the direction of that line sufficiently accurately on the ground. The beam thrown by a helio with a plane mirror has an angle of dispersion corresponding to the angle subtended by the sun's diameter at the earth, viz;—about 30′. Hence, should the alignment of two helios be in error by 15′ or more in opposite directions, the paths of the two beams would nowhere overlap, and the airman would be unable to see both flashes simultaneously. To ensure this necessary coincidence of the flashes, the permissible error in alignment must be fixed within limits, say 5′. Now the error in laying a helio on a mark some 40 yards distant, as described in the preceding para, can, with care, be kept with 3′ or 4′; consequently the error in the alignment of the marks themselves must not exceed 1′ or 2′.

It is impossible to obtain this degree of accuracy by plane-table orientation, it was therefore necessary to resort to theodolite traversing combined with frequent astronomical observations. To avoid computations, graphs were prepared showing the azimuth of Polaris at the mean latitude of the work (the arguments being standard mean time and date). An error of two or three minutes in time made no appreciable difference in the resulting azimuth. By this means an East and West line could be laid out to within 30″ in a very short time, the only disadvantage being that observations to Polaris entail night work.

4. Let X, Y and Z represent the West, centre and East helios on any line. This line must be a "great circle", and for symmetry it was made the prime verticle of Y. The latitude of X and Z being considered fixed, that of Y is obtained by applying a correction equal to the arc-versine of a 15′ arc (about 85 feet in lat. 29°). The azimuth of the helio line at Y is due East and West, but at X and Z a correction equal to the convergency of the meridians must be applied. In lat. 27°, this correction is about 7′ subtractive from azimuth 270° at X and additive to azimuth 90° at Z.

5. *Location of helio stations.* Lines representing the helio alignments were ruled of the plane-table sections, and their computed northings (or southings) at the three helio station meridians were entered. Helio stations had to be fixed at some point on the line reasonably near these three meridians. In British territory, were numerous fixed village trijunctions existed, the procedure was to select a fixed point near the line and to chain the requisite distance either due north or south, which at once gave a point on the line. If this point was unsuitable for a helio station, it was necessary to move a short distance east or west until a convenient site was found. The exact azimuth was then laid out as already described. Where, however, only a few traverse points were available, regular theodolite traversing was carried out, and it was necessary to compute the work before leaving each station, so that helio stations and aligning pegs might be fixed *en route*, the azimuth being carried forward through the traverse and checked every night by observations to Polaris.

Considerable ingenuity was required in concealing the aligning pegs in such a manner that they would not be immediately removed by the villagers. The best method was to sink the peg flush with the ground and to provide a conspicuous decoy peg a few feet away which the inhabitants were at liberty to remove. The heliotrope khalasis formed part of the traverser's squad and had no difficulty in picking up the concealed pegs subsequently.

PART II.

Report on Experimental Air Survey near Agra, carried out by the Survey of India in 1920.

INTRODUCTION.

Early in 1919 Major-General Sir G. H. Salmond, Officer in charge, Royal Air Force in the middle East, directed Captain Hamshaw Thomas, R. A. F., to proceed to India with a view to demonstrating to the Surveyor General the photographic work carried out by the Royal Air Force during the War, and to discussing its possible application to peace time survey.

The possibilities of this being conceded, a tentative proposal was made for the carrying out of an Experimental Survey during the following cold weather.

In August of that year the writer reported to the Survey of India for duty on this work and, in conjunction with Colonel E. A. Tandy, R. E., drew up a definite proposal for an experiment in October, which was approved by the Surveyor General and submitted to the Royal Air Force authorities for acceptance. They, however, stated that they were not in a position to supply the necessary machines and personnel before the end of the year, and that certain apparatus asked for was not available out here, the Air Ministry being asked to supply it from England.

In January 1920 the Air Ministry replied that the type of camera asked for was not available but that an improved type, on the lines suggested, was under trial and would be ready shortly, though not in time to be available for the proposed experiment.

The Royal Air Force authorities in India then offered to carry out the experiment, with the existing apparatus and personnel, early in February.

This offer was accepted by the Surveyor General and the preliminary ground work was at once set in hand, in order to be ready to start the actual photography by the 20th February.

Shortly before commencing work, intimation was received from Air Head Quarters regretting that, owing to urgent work elsewhere, the machines detailed for the work would have to be withdrawn on the 29th, and, in consequence, arrangements had to be made on the assumption that all photos required would have to be taken in the 9 or 10 days allowed.

[In point of fact, the "Flight" started work on the 19th February and was not withdrawn till the 4th March, and even then the area had not been completely photographed.]

The preliminary work, laying out Helio stations and lines, had also to be carried out under great pressure and in a short space of time.

The weather conditions at that time of the year were not conducive to good work, there being a strong wind (attaining a velocity approaching 30 m. p. h. at 13000 feet) during the greater portion of the time, frequent dust storms, and occasional ground haze.

The district was completely strange to the pilots and there was no time to spare for them to get acquainted with it before starting their work. The Helio system of ground control was new to them and it is believed that, few, if any, had had much practice with it at Ambala, owing to lack of machines.

No photographic lorry was available and arrangements for dealing with the prints had to be made at short notice.

The setting out of Helio stations and lines was done in country which had not been surveyed for many years, and in which many of the pillars and the points of reference had either been shifted, or had altogether disappeared, and the time available was so short that it was found impossible to complete the work by the time the "Flight" arrived.

From the above it will be seen that the Experiment was carried out under conditions the very reverse of favourable, and in considering the results obtained this fact should be *continually* borne in mind, and the experiment as a whole should not be taken as a sample of what could be done under proper conditions.

It may however be taken as a rough guide of the costs involved, and of the difficulties likely to be encountered in this form of work.

The comments in this report have been made with a view to indicating the lines on which improvements might be made, in the event of further experimental work being undertaken. The question of costs, involving as it does so many variable factors, has been dealt with somewhat vaguely, but the costs estimated may be useful in showing the *minimum* expense likely to be incurred even under the most favourable conditions.

N. B.—When the writer first reported for duty with the Survey of India, the possibility of that service equipping and maintaining its own machines and personnel was mooted, and it is with a view to such contingency that the various suggestions and comments, (based on personal experience) on machines, instruments etc., have been made.

CHAPTER IV.

Experimental Air-Survey near Agra.

1. From the *purely Civil Air Survey* point of view the Bristol Fighter is by no means the most suitable type for the purpose in that

Machines.

(*a*). The Tail Plane adjustment is very coarse, and consequently cannot be set with sufficient fineness to enable the pilot to keep his machine flying at a constant height by means of it alone, consequently the machine has to be kept level by the control stick, which involves "hunting" *i.e.*, a slight climb followed by a slight descent in order to average the correct height as shown on the Aneroid), which in turn involves changes of scale in the photos. This question is dealt with further under the heading of "Instruments".

Tail Plane.

2. (*b*). The pilot's view vertically downwards is almost completely obscured by the bottom planes, which are covered in right up to the "fuselage".

Visibility.

In consequence it is very difficult for the pilot to pick up a distant object and make certain of passing vertically over it. There is a glass window in the floor of his cockpit, but this, even when not obscured by oil or masked by bomb racks, gives a very restricted view forward, and prevents the pilot from following a distant ground mark with his eye, from the moment he picks it up, to the time he passes vertically over it.

As a result of this, the pilot is almost entirely dependent on his observer, who from the aft cockpit has a better field of view, to correct his course. In cases where the observer is busy inside his cockpit, manipulating a Camera, the pilot is more than likely to get off his course.

This point was brought out very strongly in the experiment when pilots, who believed they were over or nearly over the ground T's, were found actually to have flown a considerable distance to one side or the other of them. (In the case of one pilot who correctly picked up and passed over nearly all his "T s", the accuracy of his course was almost entirely due to the very excellent work of his observer, who achieved the apparently impossible task of being down inside the fuselage manipulating the camera and hanging over the side directing the course, at one and the same moment).

The writer is aware that very good results *have* been obtained during the war, both in bombing and photography, with these machines, but it has been done in spite of the above defects and by the united efforts of very skilled pilots and observers.

For purely Air Survey work however, it is desirable that work of this sort should be independent of individual skill, in order to obtain uniform results.

3. (*c*). The air endurance of the Bristol Fighter is very short, 3 hours at the outside, much of which is occupied in climbing to the desired height. This means that, where the landing ground is any appreciable distance from the area to be photographed, the amount of ground that can be covered in one flight is very limited.

Air Endurance.

4. (*d*). Owing to the smallness of the radiating surfaces and the type of engine, the use of this machine in the plains during the hot weather, would be very inadvisable, if not impracticable. However, as presumably all air survey work would be done during the cold weather, this point is not of much importance. It may be mentioned however, that at Agra, at the end of February, it was found necessary to allow ¾ hour for climbing to a height (which *could* be attained in about 20 minutes) in order not to overheat the engines.

Radiators.

5. In the opinion of the writer, the most suitable type of machine at present for purely air survey work would, if water cooling difficulties could be overcome, be a "Pusher" of the F. E. 2c type (pilot in front of observer, engine and propeller behind both), which would give both pilot and observer a very clear and extensive field of view forwards and downwards. Failing this, an air cooled Radial Engined Tractor machine, with both bottom planes left uncovered near the fuselage, to give the pilot a clear view downwards, would be suitable; either type should have a wheel and cable adjustment for the tail plane.

6. Assuming however that it is not found practicable to obtain a special type of machine for this work, and that the Bristol Fighter is the only type available, the following arrangements and alterations are strongly to be advised:—

(1). The lever and rack Tail Plane adjustment should be altered to wheel and cable: or the pilot should be provided with some instrument, a good deal more accurate and sensitive than the present aneroid, to enable him to fly level on the "Stick".

(2). The fabric covering the lower planes near the fuselage should be removed for a couple of bays on each side so that the pilot could see forwards *and* vertically downwards. Or

The observer's work with the camera be so reduced that he can devote almost the whole of his attention to directing the pilot, (see also remarks on "Instruments").

(3). A temporary emergency tank of about ¾ hour capacity should be fitted to balance the time used in climbing and enable a longer time to be devoted to the work of photography.

This is not of great importance in city work etc. but in the case of a long River survey a short Air Endurance would necessitate a considerable number of landing grounds in order to enable the area to be covered.

7. *Aneroids.* The Standard Aneroids as fitted to R. A. F. machines are very unsatisfactory, from the civil Air Survey point of view, in that they cannot be read to within the required limits of accuracy, they are by no means sensitive, have considerable "lag", and are graduated between too extensive limits of height.

Instruments.

(In the Agra experiment a large number of strips showed a change in scale due to a constant rise or fall or a mixture of both, which, apart from the cases due to partial engine failure, can only be ascribed to the aneroids, or the pilot's inability to read them to within the required limits of accuracy; also overlapping parallel strips, taken at a constant height, differed in scale, showing that the aneroids in the different machines differed in their readings. Of course strips of a *constant* scale can very easily be enlarged or reduced to any scale required, but an exact, or even very close, agreement in scale of the overlapping strips would enable two or three to be pasted down together on the "Field Boards", and would simplify the work of the surveyor doing the Identification work. It would also help to prevent "directional" errors in the pasting down).

8. If Air Survey is to be used extensively certain fixed scales would be used for certain types of work and consequently the heights at which the photos were to be taken would also be fixed. In which case the type of Aneroid to be desired, in addition to the standard type, would be somewhat on the following lines:—

(*a*). Reading between the limits of 0—1000 feet, *i.e.* 500′ below and 500′ above the required altitude, to be set in action by the Pilot on reaching approximately the lower limit, as shown by his Standard Aneroid.

(*b*). To be graduated in units of 10 feet and accurate to this limit.

(*c*). As free from "Lag" as possible, to enable the Pilot to start work as soon as possible after reaching his height.

(*d*). A sufficient number for the work required should be specially built and looked after, so as to obtain a minimum variation in their collective readings between the limits of altitude specified.

(*e*). The Detachment carrying out the Air Survey should have a portable "Air Pump" for testing these Aneroids before and after each flight.

9. If such instruments could be designed and constructed and used in conjunction with a wheel and cable adjusted Tail Plane (or even without it) they should enable all pilots to fly at, and maintain, the same height over level ground.

Failing the acquisition of such instruments, a "Statoscope" would enable a pilot accurately to maintain any given altitude, though it would depend entirely on his aneroid as to whether that altitude was the same as that of other machines carrying out the Survey.

One or the other of these two instruments or a fine adjustment Tail Plane is greatly to be desired if a truly constant height above level ground is to be maintained.

10. Providing that either the pilot or observer has the necessary field of vision to use it, some form of Bomb Sight is highly desirable.

Bomb Sights.

This "Sight" should be so designed and constructed as to fulfil a double purpose, viz:—

(*a*) To enable the pilot (or observer) to fly on, and vertically over, a distant landmark and

(*b*) to enable him to ascertain his "ground speed" (*i.e.* the speed with which he is passing over the ground as opposed to the speed with which he is passing through the air), and so to estimate correctly the "exposure interval" of his camera to give the desired overlap to the photos in each strip.

11. For the Agra Experiment Air Head Quarters had hoped to be able to provide a "Camera Obscura", and it had been proposed to send up one machine to fly over this at the required height and to obtain the ground speed of the machine and wind direction at this height. From the results obtained the "exposure interval" of the cameras for all machines would have been fixed before leaving the ground. This instrument, however, failed to materialize, and, as a matter of fact, would have been useless on at least four of the days in which photography took place, since on these days the wind velocity varied very considerably while the machines were in the air. Standard Bomb Sights would have made a useful substitute, but unfortunately were also not available. In consequence it was left to individual observers to *guess* their ground speed and make their "exposure intervals" accordingly, with the result that, although in some strips the overlap of successive

photos approximated very closely to specification, in others, owing doubtless to the very strong winds encountered, it varied between gaps (*i.e.* no overlap at all), and an almost complete duplication of the previous photo—which in the latter case involved the exhaustion of the supply of plates before the strip was finished.

Gaps so caused required a number of extra flights to fill them and were very wasteful of plates and Flying Time.

12. The above troubles could be almost entirely eliminated by the fitting of a form of "Sight" as suggested. With a standard size of plate (or film) and a lens of standard focal length, a sliding scale could be arranged on the sight itself for the correct "exposure interval" for any given "ground speed", or, if this is deemed an unnecessary refinement, the observer could be given a set of tables from which, having taken his ground speed (in the direction required) by stop watch and ordinary Bomb Sight, he could read off the necessary "exposure interval". On days when the wind velocity was perceptible and varying he would have to check his ground speed before starting each "strip".

An arrangement of this sort would occupy very little space and is considered by the writer to be absolutely essential.

13. The results, obtained from the particular specimens of the L.B. type camera used, were not as satisfactory as had been hoped.

Cameras.

(*a*) *The flexible drive* for plate changing and the Bowden wire shutter control, which usually accompany this type of camera (the "L B" type) were not fitted, the reason given for this by the Photographic Officer being, that the flexible drive would twist up and jam and was completely unreliable.

In this case it would seem desirable that the matter should be reported to A.H.Q., R.A.F. at once, as it is believed that the latest type of camera is being similarly fitted.

As a result of the absence of the automatic drive etc., the observers had to spend most of their time bending over the camera inside the fuselage, and were unable to direct their pilots at all.

(*b*) *The Mounting* for these cameras, in at least one machine, was not quite correctly adjusted for holding the camera lens-vertical at the height flown, and in consequence all photos taken by this machine were slightly distorted. It was anticipated by the writer that this would occur, as was also distortion due to the machine being flown one wing or the other "down" (*i.e.* not on a dead level laterally). Both these defects will, it is hoped be overcome by the latest type of camera which is to be mounted on gimbals and gyrostatically controlled.

(*c*) *The Shutter and Plate Setting Control* on one of the cameras proved unexpectedly defective, there being no less than 112 cases of double exposure, an occurrence which with this type of camera is theoretically impossible, and which completely baffled the Photographic Officer at the time.

This question will doubtless be investigated and settled by the R.A.F. as soon as possible, as double exposures in a strip of photos not only make the strip difficult to scale up or down afterwards, but also render the detail in the area covered by it difficult to pick out. There were also 16 cases of jambing.

Whilst on the subject of shutter setting it may be mentioned that at least 6 strips were spoiled by being under or over-exposed, and in many others the detail was not nearly as sharp as it might have been for this reason.

This of course was no fault of the cameras, but it is a point that should be borne in mind in future work of this sort, as it necessitates the strips being re-taken,

(*d*) *The Magazine Capacity and size of Plates* are both improved in the latest R.A.F. type of camera, there being a roll of 100 films each 8″ by 8″ as opposed to the present 18 plates each 5″ × 4″. This, if available for the Survey of India, would be a great improvement and, on the scale adopted at Agra, would enable at least two 30-mile strips to be taken without recharging. With the existing arrangements the observers had considerable difficulty in changing boxes of plates (magazines) between two exposures so as not to break the continuity of a strip. This was particularly so when machines were travelling down wind at over 120 m. p. h.

Apart from this difficulty, the argument of leaving the observer free to guide the pilot, applies in this case also.

(*e*) *The Lenses* used were very satisfactory, though somewhat different focal lengths might prove more suitable in future work.

That is to say a 6″ lens for country work would enable the machine to fly at a lower altitude, which would save time wasted in climbing and where the wind velocity would be less.

For Town work an even longer focal length than 20″ would be desirable, though possibly difficult to obtain. The large-scale photographs of Agra city were taken at 3000 feet and the obliquity due to the height of the houses was very marked. A larger focal length, say 36″, would greatly reduce this though of course it would always be present in a greater or lesser degree.

Contact Prints.

14. *The Contact Prints* in individual strips were very frequently either wrongly numbered or unnumbered, which necessitated a careful examination of each print in order to ascertain from the detail in the overlap what position in the strip that print occupied. In cases where, owing to excessive exposure interval, there was no overlap, this could only be done by comparing the photos with a map or by the general lie of detail on them. This occupied a very considerable and unnecessary amount of time, and it is strongly to be desired that, in any further work of this sort, all consecutive plates or films in each strip should have numbers or other identifying marks scratched or stamped on them, so that they will be automatically reproduced on all contact prints.

These numbers or marks should be as fine as possible in order not to obliterate detail, or might, with advantage, be placed on the very edge, so that, owing to half the overlapping portion of successive prints being cut away, they would not appear in the final mosaic.

The contact prints should also, if possible, be always on "Matt" paper and unglazed, in order to facilitate their being inked up by the Field Party.

15. Ground Control. This was carried out by means of (1) *Heliotropes* and (2) *Ground strips*.

Heliotropes.

16. In the work at Agra not more than a dozen helios out of 40 were reported as having been picked up.

Of those seen the greater number were "Centre" helios, 15 miles from the starting point of each strip.

The small total of helios picked up may, to some extent, be accounted for by the fact that in a large number of cases the pilots picked up a "ground strip" at the starting point and having correctly identified their position, were carried over so far to one side or the other of the "T" (owing to cross winds and the difficulties enumerated under the heading of "Machines" and "Bomb Sights"), that they were outside the "angle of dispersion" of the helio flashes.

The fact that most of the pilots had had little or no experience with this form of ground control undoubtedly contributed to their difficulty in working with it at Agra.

A further contributary cause was the fact that some of the pilots did not quite understand the function of these helios, which was *not* to act as a sort of continuous beacon towards which they were to fly, but to enable them to pick up, from one or two single flashes, one or more prominent landmarks of any description on the same line as, or in the close vicinity of, the helios, the landmarks thus picked np giving them the line on which they were to fly.

However, the helios were correctly interpreted and used by at least one pilot, and even he and his observer were unable to pick up the helios on all their strips.

The fact of their seeing the centre Helios on strips, but not the far ones, is difficult to account for, as the dispersion of a helio 30 miles away is double that of one only 15 miles distant and, having successfully got inside the smaller angle, they must, in theory, have been inside the larger one and so should have seen the further helio.

The two possible explanations are that

(1). The far helios were incorrectly aligned, not working, or masked at acute angles with the ground by trees etc.

(2). That the angle the sun made with the distant helios was so obtuse that only a very weak flash was given by them.

(A third possibility is that the pilot may have picked up the centre helio and then before attempting to pick up, the distant one, got off his line and so lost it. This however may be dismissed, as the pilot's attention was particularly drawn to this point by Major Lewis, and they were warned to look ahead for the far flash the instant the near one was seen).

Cause (1)—if correct, can possibly be set right by closer supervision.

Cause (2)—can be corrected by carrying out the work only between such hours as the sun is fairly high in the sky.

Taken all together, in the Agra experiment the helios were more of a hinderance than a help, since most of the pilots were relying on them almost entirely to guide them, and, not finding them, were very naturally somewhat at a loss as to how to carry on.

The strips of photos made by them were, in consequence, possibly rather more serpentine than would have been the case had they relied entirely on their maps. However, even in the repetition of various strips where helios were not used, many of the pilots failed to get near the strips of ground to be covered—(*vide* plates at end, showing very roughly the position of various strips of photos).

The strip taken by one particular pilot were almost equally good, whether carried out with or without the helios, but he admitted that in at least two strips, where such landmarks as were shown on the map were not recognisable on the ground and *vice versa,* he would have been completely at a loss as to the course to take, had it not been for the helios, which he located near patches of dark or light ground etc., which served as the necessary guides to fly on.

As has been mentioned, the helios were used only during the theoretical carrying out of the programme of 20 strips, and not during the repetition and gap filling.

This was unavoidable as the time available was very limited, about 50 % of the area was uncovered, and it was considered that the necessary arrangements for placing the helios might cause sufficient delay to prevent the R. A. F. from finishing their work before the Flight was withdrawn.

This is greatly to be regretted, as it is believed by the writer that further experience, under the improved weather conditions met with later, would have given a more definite indication as to the practicability or otherwise of this form of ground control.

From the evidence available it is rather difficult to form a definite opinion one way or the other.

It would seem however, that *where the area to be photographed has been previously well surveyed, and where there are numerous recognisable landmarks, which can be identified on the map,* the helios may profitably be dispensed with.

On the other hand, in cases where these two conditions do not obtain, the helio system, with some slight modifications and after the pilots had a considerable amount of practice with it, might prove satisfactory.

Other forms of Ground Control.

17. Some form of controlling the direction and width apart of the strips is absolutely necessary, and failing helios, the following suggestions are put forward for use over territory that is either unsurveyed or in which the conditions, given above for the use of maps, do not obtain :—

(i). That each machine taking part in the operations be fitted—in either the pilot's or observer's cockpit with a modern form, of gyro compass, *e.g.* the "Brown", having a "multiple-repeater" enabling it to be read to within very fine limits. A "Drift Indicator" would also be required, and a number of ground strips pointing in the correct direction, would be placed, approximately in position on the ground, to indicate the starting point of the centre line of each strip, and so spaced as to allow for the necessary overlap of parallel strips.

By means of the Drift Indicator the observer, when the necessary altitude was obtained, would give the pilot a compass bearing to fly on, which would take him, as nearly as possible, along the direction of the strips (say due E or due W). The pilot would then pass vertically over his first ground " T " and fly over the strip entirely by compass bearing, and would repeat this for successive strips. By this means all strips would be parallel and overlapping, though an error in the Drift Indicator might cause the whole series to be slightly askew, thus leaving a small area in the first and last strips uncovered. But this could be easily re-taken, or could be filled in by the Ground Party and would, at any rate, be an enormous improvement on the method used at Agra. As far as can be seen this method possesses no serious disadvantages, but it is not proposed to elaborate on it here, as it is a question which remains entirely in the hands of the R.A.F., unless the Survey of India decides to maintain its own machines, instruments etc.

An alternative scheme would be to lay down, approximately on the centre line of the strips, a series of ground " Ts " some 4 to 5 miles apart.

It is believed, from the statements made by pilots at Agra, that these could be successfully picked up and used as guides.

It would however involve a lot of preliminary ground work and prove rather expensive in the matter of cloth to form the " Ts " and khalasis to stand by them.

A third possible method, for use over unmapped areas, would be to send up a machine prior to the commencement of the survey, to take a series of oblique photos at right angles to the lines of parallel strips. These obliques would then be marked with the centre lines of the strips in perspective and would be given to the pilots as guides. This method would involve the lengths of the strips being kept rather short.

The possibility of using "smoke-flares" for ground control was considered and 50 were wired for by the O.C. Flight, R.A.F. They did not however arrive in time, and in any case they are, in the writer's opinion, unlikely to fulfil the purpose required of them, unless used in great quantities, in which case the expense is likely to prove prohibitive.

Ground Strips.

18. The material, (unbleached "*dosuti*" cloth), shape (T) and size (each arm 3′ × 36′) of the ground "Ts" used at Agra seem quite satisfactory, as they were easily picked up by the pilots and quite recognisable in the photos (incidentally it was found that there is no necessity for a helio at the *starting* point of each strip, the ground "T" being quite sufficient).

19. For city work, it is doubtful if any form of ground control is necessary, though it would undoubtedly be helpful, provided the difficulties mentioned under "Machines" are overcome (*i. e.*

enabling the pilot to see downward and forward unrestrictedly, or enabling his observer to be free from all other work in order to guide him).

At Agra, the pilot carrying out the work found the greatest difficulty in covering the area of Agra city required, owing to his being unable to see exactly what portion he was over, and to his observer being fully occupied with the camera.

20. Whilst on the subject of city work it may not be amiss to mention, that an altitude of 3000 feet (the height from which photos were taken of Agra city) is rather on the low side for several reasons, among them being that over big cities this height does not allow of a pilot being certain of making a "non-house-top" landing, in event of complete engine failure, and the fact that the air is more prone to be "bumpy". The reduction in scale caused by an increase in height would however be very little disadvantage, as the photos will stand being enlarged up to about 4 times without appreciably losing detail.

21. Whatever method is used to obtain parallel and overlapping strips, it might be advisable to split up the ground to be covered into areas, and allot one area to each pilot, rather than give him every 3rd or 4th strip in a whole sheet, as was done at Agra.

"Pointing".

22. The question of pre-pointing or post-pointing (*see* Major Lewis' Report page 3, para 6 (*b*)) is a matter on which Major Lewis is better qualified to express an opinion than the writer, but it appears to the latter that post-pointing is preferable from every point of view, unless ground "Ts" are used in such profusion as guides, as to render any further "fixings," unnecessary.

Interpretation Work.

23. The strips of photos sent out to the surveyors in the Field for interpretation, identification and "post-pointing", were pasted down, roughly, on Bristol Board and were mostly in a very dilapidated condition when brought in.

Field Boards

24. It is suggested that, in any future work of this kind, the photos be properly butt-jointed and pasted down on *thick* straw boards at Headquarters, and sent out with covers, also that these strips be marked up only roughly (in ink that will wash out) by the surveyors when "in the Field," and then, neatly and fully inked in (in waterproof ink) on their return to camp in the evening.

By this means each "Field Board" of photos could be scaled down to required size without any further work, leaving only the compilation and fair drawing of the mosaic.

In the Agra experiment, duplicates of every strip were pasted down, inked up, scaled to size and put into the mosaic for fair drawing.

The method suggested would mean more work for the Headquarters staff in the Field, but would appear, on the whole, to be more economical in the end.

Mounting Paste.

25. The same remarks apply to Town Surveys. (With regard to the pasting down of photos, the "Mountant" paste used was quite good but, unless used extremely carefully, was found to cause the photos to stretch and wrinkle.

In a recent issue of the "British Journal of the Photography" a form of paste "Campbell's Cold Dry Mounting Process". 71, Prince's St. Edinburgh was advertised which *claimed* to obviate this, and to take the place of "dry-mounting" tissue. It would seem to be well worth while obtaining some of this paste for trial).

Royal Air Force. (Flying Section).

Personnel.

26. The "Flight" at Agra consisted of four pilots, one of whom was the Flight-Commander, and four observers, (and the requisite number of "other ranks" for the maintenance and minor repair of the 4 machines).

These pilots and observers took the greatest interest in the work and made every effort to obtain the required results and, under the circumstances, taking into consideration how much they were handicapped by machines, instruments, the unusual restrictions imposed upon them and the weather conditions, it may be considered that they did extremely well.

But, if this form of survey is to be made an economical proposition, there is no doubt that a very much higher standard must be attained.

It is not for a moment intended to suggest that any of the Pilots or Observers at Agra were anything but first class in their ability to handle their machines etc. in general all round work, but the execution of civil Air Survey, unless the personal factor can be eliminated, requires a specialized training and a naturally good eye for country.

It may be said therefore, that for future work of this kind, EITHER, machines, instruments, ground control, etc., must be so improved as to eliminate the personal factor in pilots and observers, and so obtain uniform results of a high standard of perfection, OR, all pilots and observers employed must have specialized in this class of work, which differs very considerably from Active Service work.

Of the two, the former seems the more desirable end to attain.

Royal Air Force. (Photographic Section).

27. This consisted of a Photographic Officer, a Corporal and, as far as can be remembered, four men.

This Section, heavily handicapped as it was by inadequate facilities and under-staffing, worked magnificently, the personnel being frequently on duty for 14 hours a day, in order to try and make the output of prints keep pace with the influx of plates.

Owing to photography being stopped occasionally they very very nearly succeeded in this, but, had the air work been carried on continuously, the Photographic Section would have been absolutely unable to cope with it. (The fact that some of the numbers of the prints were incorrect may be attributed entirely to the pressure at which the work was carried on, though the method of marking the plates is to be recommended in any case).

In future work with Aeroplane Photos it is highly desirable that the Photographic officer should have at least 10 assistants, in order that the maximum output may be obtained from the machines.

Survey of India. (Field Party).

28. The Field Parties consisted of 2 officers, for laying out the helio lines and the subsequent interpretation etc. of a portion of the photos, two surveyors for the interpretation of the remaining portion, and the necessary number of khalassies.

It is possible that in future these officers might be replaced by surveyors, but, if the helio system of ground control is again used, it would seem advisable to have an officer to check this portion of the suveyor's work.

Survey of India. (Headquarters Party).

29. This was composed of the O. C. Party (Major Lewis) and the writer. The supervision of the working of the helios and all work in connection with the preparation of "Field Boards" for the Field Party was executed entirely by these two officers, and involved a considerable amount of labour, consisting as it did, of pinning individual prints together into strips cataloguing and dividing these strips into suitable lengths for the Field Boards, marking on maps the area covered by them, pasting duplicates of them on to boards, marking on these boards the approximate North and the names of prominent villages etc., preparing tracings showing the Field Party how the various strips were interconnected etc. etc.

It is doubtful if this work could ever be carried out entirely by other than officers.

Indian Draftsmen and surveyors have since been employed in pasting down strips of photos and, although with practice they became moderately adept, they were very slow and required fairly constant supervision. However, by employing a sufficient number of them on pasting down and preparing Field Boards, the Officer in charge would be relieved of the heaviest portion of the work.

Photo Mosaic.

30. Duplicates of the strips sent out on the Field Boards were pasted down and the fixed points on the latter transferred. These points were then accurately plotted, from their co-ordinates, on the paper-mounted boards, (two boards to each 1″ sheet), on a scale of 2″ to the mile. The strips were then photographically reduced to the same scale, by means of strips of celluloid on which were marked the various points in each strip, and should, theoretically, have then formed, when put together, a perfect mosaic of the area covered. In point of fact however, it was found necessary to cut each reduced strip up into groups of three, two, and even single, units in order to get them to fit each other, and yet be in their correct relative position.

This was due to three causes :

(*a*). The strip's undergoing one or more changes in azimuth owing to the distortion of the photos, caused by the axis of the camera lens not being truly vertical at the time of exposure.

(*b*). The strip undergoing changes in azimuth due to the overlapping prints not being correctly fitted when they were pasted down.

(*c*). Errors in scaling down.

(*a*). would be practically eliminated by the new R. A. F. gyro-camera, though changes of scale througout the strips will still occur unless means are found of keeping the machine at a constant height above the ground.

(*b*). This error could be very much reduced by careful work and practice, though it is doubtful if it would ever completely disappear.

(*c*). This was mainly caused by (*a*) and (*b*), but the existing method and apparatus probably contributed towards it.

31. The Room Cameras at Dehra Dun are not fitted for this work, and there is no proper means of rapid and delicate adjustment for the strips and ground glass.

The method is also very expensive and wasteful of plates, especially if it is desired permanently to retain the negatives of the reduced strips for future reference.

The alternative method is to reduce each strip on to ½ or ¼ plates, and then enlarge to the required scale with an enlarging lantern on to Bromide Paper.

This reduces the cost of plates for permanent records and affords a simpler, more accurate, and more rapid method of scaling.

It however, involves a double process, requires "Bromide" paper of a large size (which is difficult to obtain), causes (it is understood from the O. C. P. Z. O.) a greater loss of detail, and the negatives retained for future reference are on an unknown scale.

It is nevertheless, on the whole, the better method and, with the new enlarging lantern expected from England, should give results a good deal superior to those obtained by the present method.

In future Air Surveys of Large Towns it *might*, in view of the large number of plates to be dealt with, be worth while making the prints into strips and dealing with them as such (at present individual plates only are dealt with). In which case the use of Camera Rooms,* with some improvements in the way of adjusting and focussing, might be advisable in order to save loss of detail.

Accuracy.

32. Sheet 54 E/16 (the Eastern Sheet of the two) was not "Post-Pointed", but was surveyed by the usual ground methods, on a scale of 2″ to the mile. Prints, made from the plane-table work thus obtained, were mounted on boards and used for the compilation of the mosaic. (The paper, on which these plane-table prints were made, was found to have stretched considerably and unevenly. This was corrected, as far as possible, by cutting them up into small squares and fitting them into the sheet graticules. It is probable, however, that a certain amount of error persisted at and near the junction of such squares). A certain number of points common to the plane-table and photo prints, *i.e.*, junctions of main roads—canals—railway etc., were selected and treated as "fixed for purposes of scaling down the photos and for compiling the mosaic. These "fixed" points averaged about 0·75/□ mile. Further detail on the plane-table prints was utilized as a rough guide but, *as far as possible the mosaic was built up by the detail overlap of the photos,* the fixed points serving to prevent cumulative error.

Generally speaking the detail in the mosaic was found to agree very closely with that of the plane-table prints.

It seems reasonable to suppose that, in future work, 1 fixed point per 3 square miles will be ample to secure the required accuracy of mosaic.

R. A. F. Flying and Photographing Section.

Cost.

33. An abstract of costs, submitted by the R. A. F., is attached herewith, as is also an abstract showing approximately the number of hours flown, plates exposed, etc., etc.

This abstract of costs, though showing the general and inclusive expenses incurred, is not sufficiently in detail to allow of extensive analysis, and the inferences to be drawn from it must, of necessity, be also of a general nature.

Referring to this abstract it will be seen that the total expenditure was *Rs. 14,543.*

This is subdivided into 3 Heads, viz :—

(*a*). *Initial expenses.* Such as "Movements"—Aerodrome—Photo-Stores etc., *Rs. 2,814.*

(*b*). *Running expenses, i.e.* the expenses incurred in the *normal* running and maintenance of a Flight of 4 machines for 16 days. ... ... *Rs. 8,228.*

(*c*). *Extra expenses, i.e.* running expenses over and above the normal ... *Rs. 3,501.*

Of these (*a*) and (*c*) represent the actual "out of pocket" expenses of the R. A. F.

N.B.—Photo-Stores should, strictly speaking, come under (c) Extra expenses.

The total expenditure *i.e.* Rs. 14,543, when spread over an area of approximately 540 square miles, gives a *cost per square mile of Rs. 26·9* (or, since the total time the æroplanes were in the Air was about 48 hours, a *cost per hour's flying time of Rs. 303*).

**N.B.*—The Room-Cameras referred to are simply "dark-rooms" about 30′ × 7′, each having a lens holder capable of taking various sizes of Lenses built in to the outer wall, on to which abuts a glass covered verandah. Inside each Room is wooden frame for holding the ground-glass or sensitized plates. This frame is mounted on rails, and can be moved backward and forwards in the plane of the axis of the lens for rough focussing, the final adjustment being made with a slow-motion screw attached to the frame.

Small displacements of the plate holder, in a vertical or horizontal plane, can be made by two screws on the lower edge, the upper edge being supported by, and pivoted on, an eye-bolt in the centre. The object to be photographed is placed outside in the glass verandah and mounted on a somewhat similar arrangement, except that there is no fine adjustment screw, the complete plan board being moved bodily. The Lenses used have a focal length of 54″ and enlargements up to 3 times and reductions down to ⅓ the original can be made. The inside plate-holder takes a sensitized plate 42″ × 28″.

This is considered by the writer to be abnormal and directly due to the conditions under which the experiment was carried out.

34. In drawing up an estimate for any future work of this kind the following facts should be kept in view :—

(*a*). That the flying time (*i.e.* No. of hours in the air) taken, in incompletely covering the 540 square miles, was actually about 48 hours, but the time taken, in going through the original programme of 30 strips, was only about 25 hours. That is to say, had each pilot successfully photographed the strips detailed to him, the whole work would have only occupied 25 hours, or just over half the time actually taken, or conversely, very nearly two more 1″ sheets (*i.e.* the two E. of Agra in the same Latitude as those actually done) could have been covered in the 48 hours.

This would have reduced the cost per square mile to about Rs. 15.

(*b*). That the total number of 5 × 4 plates, required theoretically to cover the 540 sq. miles, was about 840, but that, owing to gaps having to be filled , excessive overlap, under and over exposures, double exposures, bad plates etc., over 1700 were actually exposed and a further 200 or so were wasted through jams and other camera defects.

It is unlikely that work of this sort could ever be carried out with an expenditure of only a theoretical number of plates, but, with a 90 °/₀ efficiency, the number of plates used at Agra should have been enough to have almost covered a further two sheets (540 sq. miles), which again points towards a reduction to *Rs. 14 or Rs. 15 per square mile.*

(In the case of the portion of Agra city photographed, the time in the air, and the number of plates exposed, was over 3 times that actually necessary for the area specified).

(*c*). That at Agra at least 4 contact prints were made from each negative, 1 for the pinned together strips, 1 for the pasted down Field Board strips, 1 for accurate pasting down at Dehra Dun for scaling down to 2″ for the mosaics, and 1 for the extempore full size mosaic put together by the R. A. F. photographic officer at Agra.

In future work this number might well be cut down to 2 since, by pasting down the Field Board strips accurately and protecting them in the Field, the necessity for the preparation of further strips for scaling purposes would be avoided, and since no useful purpose would seem to be served by the Photographic Officer attempting to make a full size mosaic. (Except in cases where no maps exist of the area to be photographed, and in which a temporary mosaic might be helpful to show the progress of the work).

This would effect a further though slight economy in the cost per square mile.

(*d*). The new R.A.F. gyro. Camera with 8″ × 8″ films instead of the present 5″ × 4″ plates should make a further reduction in cost, though, from the figures available, it is difficult to say exactly how much.

For a given area the cost in photographic stores etc. would remain about the same, but owing to the increased width of each strip, the area would be covered in a fewer number of flights *i.e.* in less flying time or, conversely, in the same flying time a greater area would be photographed.

At Agra the machines averaged about 2 hours on each trip, covering two strips (an area of $\frac{1}{10}$ × 540 square miles = 54 square miles) and using 5″ × 4″ plates.

With 8″ × 8″ plates and the same proportional overlap, the strips covered in the same time would be roughly 8/5 of 54, or about 86 square miles.

It has been pointed out above that, with a 90 °/₀ efficiency, the open country work at Agra should have cost *about Rs. 15 per square mile.*

Providing that the various component costs were the same, the introduction of 8″ × 8″ films for a similar area in future should therefore, theoretically, bring the cost down to about Rs. *9·5 per square mile.*

However, with the somewhat meagre data available, it is difficult to estimate with any great degree of accuracy.

The figures given nevertheless serve to show the lines on which reduction in expense could be carried out, and it is the writer's personal conviction that the *Total cost* ultimately need not exceed *Rs. 9 per square mile* (for a scale of 3½″ to the mile), the cost to the Survey of India alone being proportionately less.

35. *Cost of City work.* At Agra three attempts were made before the requisite area was covered and, of the photos obtained, only a small proportion was utilized in making up a mosaic of the triangulated area.

It is therefore impossible to use the data obtained at Agra for any accurate calculations for cost.

To get an approximate idea it is necessary to consider that the two units, on which other calculations have been based, are the cost per square mile and the cost per hour's flying time.

The actual cost of the Agra experiment (Open country) works out at about *Rs. 303 per 1 hour's flying time*, about 50 % of which time was occupied in climbing to the required altitude and returning to the ærodrome after completing photography.

In City work at 3000 or 5000 feet, the time occupied in attaining height and returning should not exceed half an hour per flight (providing that the landing ground is adjacent), which, with an air endurance of 3 hours, leaves 2½ hours available per machine for actual photography.

The distance between centre lines of parallel strips was ·095 mile (theoretically).

In 2½ hours æroplane flying at 80 miles per hour would cover $200 \times \cdot 095$ square miles $= 19$ *square miles*, if flying over one continuous strip. Allowance however must be made for turning at the end of each strip and picking up the new line, which introduces a very variable factor depending on the size of the town and whether it is oblong or square in shape.

With short runs, such as might be expected over smallish towns, these turns would probably occupy *something like 75 % of the time*, so that, in 2½ hours, about $\frac{5}{8} \times 80 + 0 \cdot 095$ square miles would be covered $= 5 \cdot 9$ *square miles.*

The total flying time (leaving ground to landing) being 3 hours, this works out at *1·96 square miles per 1 hour flying time* or Rs. $\frac{303}{1 \cdot 96}$ per square mile = Rs. 155 per square mile.

In addition to this, the number of plates used, compared with the smaller scale open country work, will increase the cost of photographic stores and further add to the above estimate.

That is to say, allowing a 30 % overlap, 136 plates per square mile are required as compared with 1·5 plates per square mile of open country work (scale 3·6 inches to the mile approximately).

The cost of photographic material (at Agra) is shown as being Rs. 1462 or about 10 % of the total cost). As has been already shown, this represents the cost incurred in an expenditure of from 1700 to 1900 plates, say 1800.

Then the cost for 1800 plates, being Rs. 1462

„ „ „ 136 − 1·5 „ will be $\frac{134 \cdot 5 \times 1462}{1800}$

$= $ *Rs. 109·2.*

∴ Total cost = Rs. 156 + 109·2

= *Rs. 265·2 per square mile.*

36. The only figures available from the Agra city work show that on one occasion a machine exposed 90 plates in 30 minutes. The exposure interval being 4 seconds, the time actually occupied in photography would be $\frac{90 \times 4}{60}$ minutes = *6 minutes, leaving 24 minutes for turns, picking up the line, etc.*

The area covered (with a 30 $^{\circ}/_{\circ}$ overlap) would be *about 0·66 square mile.* (The actual overlap was however less than this, but even in this case the area covered would not exceed *1 square mile*).

The total time in air (leaving ground to landing) is not given*, but is unlikely to have under *45 minutes.*

This would give between *0·88 square mile and 1·3 square miles per 1 hour's flying time* and would make the cost from *Rs. 344 to Rs. 233 per square mile.* To which must be added the extra cost of photo meterial, Rs. 109. Total Rs. 453 to Rs. 342 per square mile. This is a good deal higher than the estimated cost, but, in this instance, photography took place in two different parts of the city, the runs were very short, there was a strong cross wind, and there may have been other factors, which make this particular case a bad example, as the proportion of 6 minutes' photography in 30 minutes flying time for city work is rather low.

37. The introduction of 8″ × 8″ films will improve matters to some extent, owing to the smaller amount of time wasted on turns, the necessary number of parallel strips being fewer.

This would make the area covered per 4 hours flying time about $\frac{8}{5} \times 1 \cdot 96 = 3 \cdot 14$ *square miles,* instead of 1·96 square miles.

The cost of photographic material would probably also be less, but without knowing the relative cost of 8″ and 8″ films compared with 5″ × 4″ plates, and that of developing printing a small number of large photos compared with a larger number of small ones, it is impossible to give any figures.

Assuming the cost to be the same, *the total cost per square mile of city work with 8″ × 8″ films would appear to be about Rs. 96·5 + 109·2 or Rs. 206.*

38. OPEN COUNTRY WORK. 3·6 inches to 1 mile.

Summary of Total Costs.

	5″ × 4″ plates.	8″ × 8″ Films.
Actual cost	Rs. 26·9 per sq. mile	...
Estimated cost under ideal conditions ...	Rs. 15 per sq. mile	Rs. 9·5 per sq. mile.

CITY WORK. 35 inches to 1 mile.

Actual cost	Rs. 340 to Rs. 450 per sq. mile	...
Estimated cost under ideal conditions ...	Rs. 265 per sq. mile	Rs. 206 per sq. mile.

39. *Cost to Survey of India.*

Survey of India's Share of Costs.

For the Agra experiment, it is believed that the Royal Air Force will be content to accept their "Out-of-pocket" expenses, which consist of "initial expenses" (such as movements, ærodrome etc.), plus any expense incurred in the use of petrol, oil, photo stores etc., which is over and above the

* In the copies of the Flying Report sheets supplied by the R. A. F. detailed times (leaving ground, commencing and ceasing photography and landing) were in many cases omitted. This is greatly to be regretted, as their absence makes any definite calculations impossible.

normal consumption in routine work. In this case this cost amounts to *Rs. 6,315* or about Rs. 11·5 per sq. mile.

In this actual case this forms $\frac{6315}{14543}$ or *43·3 %* *of the total.*

40. For future work of this sort, if the machines and personnel are lent by the R. A. F. and not provided by the Survey of India, it is however more than likely that this arrangement might not be agreeable to either the former or the latter.

The survey of India, it is believed, would object to it on the grounds that unlimited plates and petrol could be expended by pilots not tovering their area at the first attempt etc., without any penalty being incurred.

The Royal Air Force would quite conceivably object to it on the grounds that work of this sort, although for the public good, should be made to help somewhat towards the maintenance of the Force, which mere " out-of-pocket " expenses would not do. In reply to charges of uneconomical work, it is conceivable that they might point out that the special machines, instruments, and training of pilots for civil air survey under peace conditions, are not necessary for war work—(where photography forms only a small proportion of work expected of pilots, observers and machines), and that the "tightness" of their Budget would not admit of their expending the money necessary for the attainment of the efficiency required.

It would therefore appear that if greater efficiency or economy, than that obtained at Agra, is to be arrived at, then it is essential that Government should make a grant to cover the expenses involved in attaining this efficiency. Otherwise we arrive at the "non possumus" of the R. A. F. declining to do work which does not pay them, and the Survey of India declining to utilize a method which may be more expensive than their existing one, and a definite stop being put to further progress in civil Air Survey.

41. In the event of some such Government grant being given, and the requisite pitch of efficiency in men and machines being obtained, it is still rather difficult accurately to forecast the probable cost involved to the Survey of India (*i.e.* the cost per square mile that the R. A. F. would tender to work for).

The "initial and expenses above normal" theory adopted above may give results varying very greatly in magnitude.

For instance—suppose the normal routine work of an R. A. F. pilot is fixed at 3 hours per week, and suppose that 4 pilots put in 24 hours flying work (all of which is efficient) in photographing some area. These 24 hours might be flown off in 2 days (3 hours per day per Pilot) or they might (owing to weather, breakdowns or other causes) be spread over 2 weeks.

In the former case the "expenses above normal" would be proportional to 24 — $(4 \times \frac{2}{7} \times 3)$ hours ... ... = *20½ hours.*

In the latter case the "flying expenses above normal" would be 24—$(4 \times \frac{14}{7} \times 3)$ = 0 *i.e.* the actual cost to the Survey of India would be merely that of photo-stores, movements, and other initial expenses.

42. As it is the R. A. F. who would make out the necessary estimates and quote a price per square mile for the Survey of India to accept or reject, no good purpose would be served by giving a mass of statistics showing the probable costs under different conditions, but the following remarks, coupled with the rough estimate attached, may serve as an indication of the probable cost.

(1). For every 250 odd miles, that the area to be photographed is from the operating squadron's ærodrome, 1 week's normal flying expenses will be incurred in getting the æroplanes to the site, so that the full cost of petrol etc. used per week per 250 miles distance will be "extra-expense".

(2). That in future work it is possible that a full Flight of 6 machines (instead of 4) may be detailed.

(3). That in open country work (3″·6 to mile scale) of two sheets are taken at a time (*i.e.* 30-mile strips) each machine will probably do only 1 flight of 2 strips a day, and will take about 2 hours (leaving ground to landing), providing the landing ground is adjacent to one of the 4 edges of the sheets.

(4). That in city work (35 inches to 1 mile scale) each machine will possibly make 1 flight, of just under 3 hours a day, and will cover about 1 square mile.

(5). In river survey work, the area covered and the time taken, will be dependent on the position or positions of landing grounds.

(6). That all estimates for photo-stores etc. may be upset by the new R. A. E. camera, which will be charged with a roll of 100 films, the cost of which compared with plates is unknown. Any unused films in a roll cannot be utilized on another occasion, as the whole roll will be developed as a unit. This will entail a certain amount of wastage.

Rough Estimate.

43. Area to be surveyed—4—1″ sheets *i.e.*	*1080*	*miles.*
Distance of site from Squadron Headquarters, ...	say *1000*	*miles.*
No. of Machines employed	*6*	
Time taken to reach site	*2*	*days.*
Flying Time " " " 12 hours per machine	= *72*	*hours.*
Time Flight remains at site	say *8*	*days.*
Time taken to return from site	*2*	*days.*
Flying time " " " "	*72*	*hours.*
Width of strip covered by 8″ × 8″ film (3″·6 = 1 mile scale) with 33 % overlap	= *1·5*	*miles.*
∴ No. of 30-mile strips per 18-mile sheet = 13 + 10 % non-efficiency	= say *14*	*strips.*
Total strips for 4 sheets = 2 × 14	= *28*	*strips.*
Average time taken per machine per 2 strips	= *2*	*hours.*
∴ Flying Time for Photography	= *28*	*hours.*
(No. of days occupied at 2 hours per day per machine = 2⅓ say *3* *days*).		
Total Flying Time (Headquarters to site and back plus photography) = 72 + 72 + 28	= *172*	*hours.*
Deduct normal flying time = 3 hours per machine per week for 12 days =	say *30*	*hours.*
∴ *Extra Flying Time*	= *142*	*hours.*

All of which will be chargeable to Survey of India.

Cost of moving personnel and Stores by train (1000 miles)	...	say 4,000·0·0
Erecting 6 Temporary Hangars or Transporting R. A. F. Tents	...	say 625·0·0
Incidental Landing ground expenses	...	100·0·0
Officers T. A. (6 Observers and 1 Photo Officer) ...	...	600·0·0
„ extra pay (Detention allowance) 12 Pilots and Observers and 1 Photo Officer for 8 days	...	520·0·0
Petrol for photography, 28 hours at 13 galls. per hour	...	773·8·0
Oil „ „ „ „ „ 0·7 galls. per hour	...	44·0·0
Petrol for journey to and from site (æroplanes) 114 hours at 13 galls. per hour	...	3,148·0·0
Oil „ „ „ „ 0·7 galls. per hour ...	...	199·8·0
Petrol and oil for journey to and from site 1 Light Tender and 1 Motor Cycle and side car	...	368·0·0
Petrol and oil for above for daily work at site (over and above normal) say 90-100 galls. ...	...	220·0·0
Depreciation	...	say 300·0·0
Photo-Stores—cost proportional to that of 20 – 8″ × 8″ films per strip (28 strips)	...	1,400·0·0
		12,298·0·0

∴ cost per sq. mile chargeable to Survey of India $= \frac{12,298}{1080} =$ *Rs. 11·40 approx:*

i. e. cost, if carried out at *Headquarters of Squadron* ... *Rs. 3·7 per sq. mile.*

„ „ „ „ *250 miles from*
Headquarters Rs. 3·700 + 1·400 ... .. = *Rs. 5·100 per sq. mile.*

„ „ „ „ *500* „ „
„ Rs. 3·700 + 1·400 2·100 ... = *Rs. 7·300 per sq. mile.*

„ „ „ „ *1000* „ „
„ Rs. 3·700 + 1·400 + 3 × 2·100 ... = *Rs. 11·400 per sq. mile.*

Or Rs. 3·7 per sq. mile + { Rs. 1·4 per sq. mile for 1st 250 miles from Headquarters and Rs. 2·1 per sq. mile for every 250 miles above this.

N. B.—To the above the addition of a certain percentage representing profit to R. A. F. may be added.

A similar estimate can be prepared for city work utilizing the figures arrived at in the main Report.

Field and Headquarters Party. Survey of India.

41. To the above costs must be added those incurred in "Post-pointing"—Indentification and Classification—Pasting down strips of photos—Reducing or enlarging them to scale—Preparing the mosaic—Inking it up and, in the case of open country work—Preliminary field work for helio lines, ground strips etc.

Costs.

It is understood that Major Lewis is extracting the actual expenses incurred in the above at Agra.

It is expected that these will be found to be fairly high, in view of the fact that 4 officers were employed on the work, but it is presumed that possible reductions for future work will be suggested by him.

45. Speaking generally, it is greatly to be regretted that the experiment at Agra had to be carried out under the conditions previously referred to, since the conclusions to be drawn from it are of necessity somewhat vague and may easily be misleading.

Conclusion.

On the whole, it may be said that Air Survey for civil work is at present somewhat ahead of its time, and that considerable improvement, both in methods and apparatus, is necessary before it can become an economical proposition.

Unless the Survey of India carries out its own experiments with a view to effecting these improvements, and maintains its own machines etc., it will depend entirely on the Royal Air Force as to whether, and when, the necessary stage of efficiency is reached (*see* also remarks under "Costs. R.A.F.").

The question of a stabilized camera is, it is understood, being taken in hand by the Air Ministry, with every possibility of successful results.

Should the other difficulties be tackled and overcome with equal success, the following arguments, for and against the supersession of existing methods of ground survey by Air Survey, are submitted :—

46. In view of the high cost involved, and the fact that only a very small percentage of the detail shown in the photos is actually utilized, it seems probable that Air Survey will never be able to compete with existing methods for work on a scale of 1″ to the mile or less, over country which is open and easily traversable.

(1) Plains Survey.

In country which on the average is flat, but is either greatly split up by ravines etc. or thickly wooded, *i. e.* in which a plane-tabler is forced to work slowly, the possible adoption of Air Survey is worth considering, as is also its possible adoption for Revenue-crop survey.

47. Until an improved form of "Stereo-comparator" (there are about 3 at present, none of which is quite adequate for the purpose) has been devised, which will get over the difficulties at present experienced with the distortion due to change of level in single photos, survey by æroplane photos is not worth considering except for obtaining a very general idea of new country.

(2) Mountain Survey.

It is possible that a certain amount of success might be obtained by a combination of æroplane and ground camera photos, since by obtaining views of given objects both "in plano et alto" it should be possible accurately to "fix" them.

Experiment on these lines is recommended.

48. The survey of large alluvial rivers is at present a lengthy and expensive process, with the further disadvantage that it is impossible to keep maps up to date, that is to say, that by the time a river has been surveyed and the maps produced, its course, may be and frequently is, largely changed.

(3) River Survey.

It is submitted, that the employment of Air Survey, for work of this kind, is not only feasible but desirable.

An æroplane flying at 10,000 feet, and equipped with a camera with a 6″ focal length lens and 8″ x 8″ films, would in one hour cover a strip of country (or water) eighty miles long and (2½) two and a half miles wide.

This width should, in the majority of cases, be sufficient to include both banks of the river, the pilot flying vertically over the centre of the river and following the bends in it. In special cases, *i. e.* hair pin bends—alternative courses etc. a double or treble strip could be taken, but this would be the exception rather than the rule.

Points in existing traverses along the banks would be marked, preferably in stone or something permanent, with ground "Ts" which would appear in the photographs and provide means for scaling etc. After a certain amount of experience in interpreting the photos, it should be possible to dispense with the necessity of any subsequent ground party, the names of villages etc. being taken from existing maps.

The only objection to this method is the difficulty of providing and equipping "landing grounds" at intervals of 100 to 150 miles. As however most of the big rivers are fairly well sprinkled with towns along their banks this should not prove insurmountable.

49. *Town Surveys.*

These may be divided into two types, viz :—

(*a*) Guide Maps and (*b*) Property Surveys.

Guide Maps.

50. For this type it is believed that extreme accuracy is not required, and in consequence very extensive triangulation for the mosaic would not be necessary, and the error due to the displacement (*see* Maj. Lewis' Chap. III Section 42 (iii)) could be ignored.

By photographing the town on a moderately small scale say 8″ or 9″ to the mile and then enlarging up three or four times (*i. e.* to 16″ to the mile) the expense involved should not be large. The enlargement could be done either by the Survey of India at Head Quarters on the new enlarging lantern expected from England, or enlarged up direct from the films as they came in, by the Photo Section of the R. A. F.

As the R. A. F. seem to have facilities for obtaining printing paper of the required size and type, the latter course might be desirable, especially as "Field Boards" on the final scale could then be sent out to surveyors at once.

Property Surveys.

51. It is understood that a very high degree of accur[illegible] is required for this work and, in consequence, in every photo, corrections would have to be made for the errors caused by displacement (*i. e.* by the buildings having height and the camera lens having a limited focal length) and possibly for shutter speed, and as for the same reason the foot of the buildings would in many cases be obscured, a considerable amount of ground work would be involved.

It is, however, submitted that for *towns built on level ground*, a Property Survey by means of æroplane photographs could be successfully and comparatively cheaply carried out. For towns built on sharply undulating ground the utility of this method is somewhat doubtful owing to the very heavy work involved in correcting for distortion.

52. It is believed that the Coast and Geodetic Survey in America has been experimenting with Air Survey over both flat and mountainous country, though it is not known with what results. It is also believed that an American Camera called the "Brock" ("Stabilized" by Air Dampers and having a clock work movement for automatic exposure, film changing etc.) was used, and it is conceivable that the C. and G. Survey would be willing to supply the Survey of India with further particulars, and thus possibly obviate unnecessary experiment on lines that have already been "tried out".

53. This—though not directly concerning the Survey of India, may be mentioned as a case in which the employment of Air Survey might be profitable. There are in India and Burma some hundreds of thousands of square miles of Forest, which is broken up into innumerable "Blocks" of trees of one type. The majority of this Forest Land lies on hill and mountain sides, but it is understood that a very considerable area lies on level, or nearly level, ground and it is for dealing with such areas that the following proposal is submitted :—

Forest Stock Mapping.

The ordinary mapping of Forests is carried out by the Survey of India and it is doubtful if the existing methods could be improved upon. *Stock-mapping* is however carried out by the Forest Department and entails sending a skilled man into any given forest to discover and plot the delimitations of the various " Blocks " and identify the type of tree in each block for stock-taking purposes. It is understood that this is a very slow and expensive business and that moreover, the results obtained make no pretensions to strict accuracy. This being the case, there seems every reason to suppose that the method might be usefully superseded by that of Air Survey.

The limits of each "block" are demarcated by a 30-foot wide clearing and, allowing for the overhanging branches of trees on each side of this clearing, it is probable that there would be a clear air-space of at least 10 feet wide, which would undoubtedly show up in photos of a scale of 3″·6 to the mile and upward. The outline of each "block" could therefore be traced and, although it is improbable (though not impossible) that the type of trees in the different "blocks" could be identified, the expense of sending a man in to the forest, provided with a map showing the outline of all blocks, and having merely to identify and note the types, should be very small.

In large areas it would be necessary for the Forest Department to provide landing grounds not more than 150 miles apart, which would necessitate the clearing, levelling and draining of spaces at least 800 yards × 800 yards. It is believed however, that in wooded parts the timber obtained would more than cover the cost of the above operations.

It is highly desirable that æroplanes employed on such work should be equipped with gyro-cameras, sights, and other instruments mentioned earlier in this note, in order that the resulting photos should in themselves form a correct mosaic as possible, owing to the difficulties likely to be involved in pre-or post "pointing". The question of "ground control" is also rather more complicated in this case than in open country, and it is suggested that in this particular work smoke flares burnt at chained intervals on two roughly parallel lines denoting the start and finish of strips, should be employed. The cost of such flares would not be excessive in view of the wide difference between the total cost of the proposed and actual methods.

The scale of the photographs required is rather a matter for conjecture but it is submitted that 4″ to the mile, enlarged in the field to 8″ to the mile, would serve the purpose.

It is also submitted that for this work there would be no need to make a mosaic or to do any further reduction etc. by photography, each strip of enlarged photos (covering say 60 miles in length) would be pentographed to the required scale and traced on to a "key" map (based on an existing Survey of India Forest Map) mounted on rollers, any necessary slight adjustments being made during the tracing. As the only detail required would be the "Block-limits" this should be a very rapid process and should easily keep pace with the photography.

Maps thus obtained would be sufficiently accurate it is believed, to meet the purpose of the Forest Department. A rough comparison of the two methods is appended.

	Existing Method.	*Air Survey method.*
Speed.	1 man does 1/6th square mile per day.	1 machine does 50 sq. miles (on 4" scale) per day.
Cost.	On above assumption say *Rs. 180 per sq. mile.*	*Photography* (including "smoke flares" and enlarging photos to 8" scale) not more than Rs. 15 per sq. mile. *Headquarters Staff* for pantagraphing, tracing etc. say -/8/- per sq. mile. *Ground work* identification of types of trees say Rs. 3 per sq. mile. Total ... Rs. 18/8/- per sq. mile.

APPENDIX II.

Expenses Incurred.

R. A. F. SECTION

			Recurring.		
COSTS.	*Detail*	*Initial*	*Ordinary*	*Extra*	*Remarks.*
INITIAL.	1. Provision of Hangar.	...126- 7-0			
	2. Movements	1044-12-0			
	3. Photo-Stores.	1462- 0-0			
	4. (a) Water supply	94- 4-3			
	(b) Officers T.A.	86- 4-0			
		2813-11-3			
RECURRING	1. Pay ...	...	3704	...	... Officers.
			2165	...	... Other ranks.
			78	...	... Indians.
	2. Extra pay ...	...	...	680	Officers detention allowances.
	3. Rations ...	...	995		
			93		
	4. Petrol ...	...	1148	2656	1790 gallons.
	5. Oil ...	...	...45	45	40 gallons.
	6. Telegrams ...	...	...	100	
	7. Depreciation of machines.	...	...?	?	
	8. Bullock carts.			20	
			8228	3501	

Total 2814
3501
8228

Rs. 14,543 or Rs. 26·93 per sq. mile.

APPENDIX III.

8½″ lens at 13000
Air Survey Experiment at Agra.

Time in air (from leaving ground to landing)		*48 hours.*
No. of Plates *Exposed*		1715
No. of blanks	47	262
No. of Jams	16	
No. of Double Exposures.	112	
No. of Broken Plates.	2	
No. of Underexposed.	101	
No. of useful plates		1453

Time and Plates used in Agra City. Not included in above.

Area covered	540. sq. miles.
Map Area covered	512 „ „
Time of Flight at Agra	16 days.
Plates exposed per square mile	3·17
Plates theoretically required to cover area	*820*
„ „ „ per sq. mile ...	1·52 app.

DIAGRAM

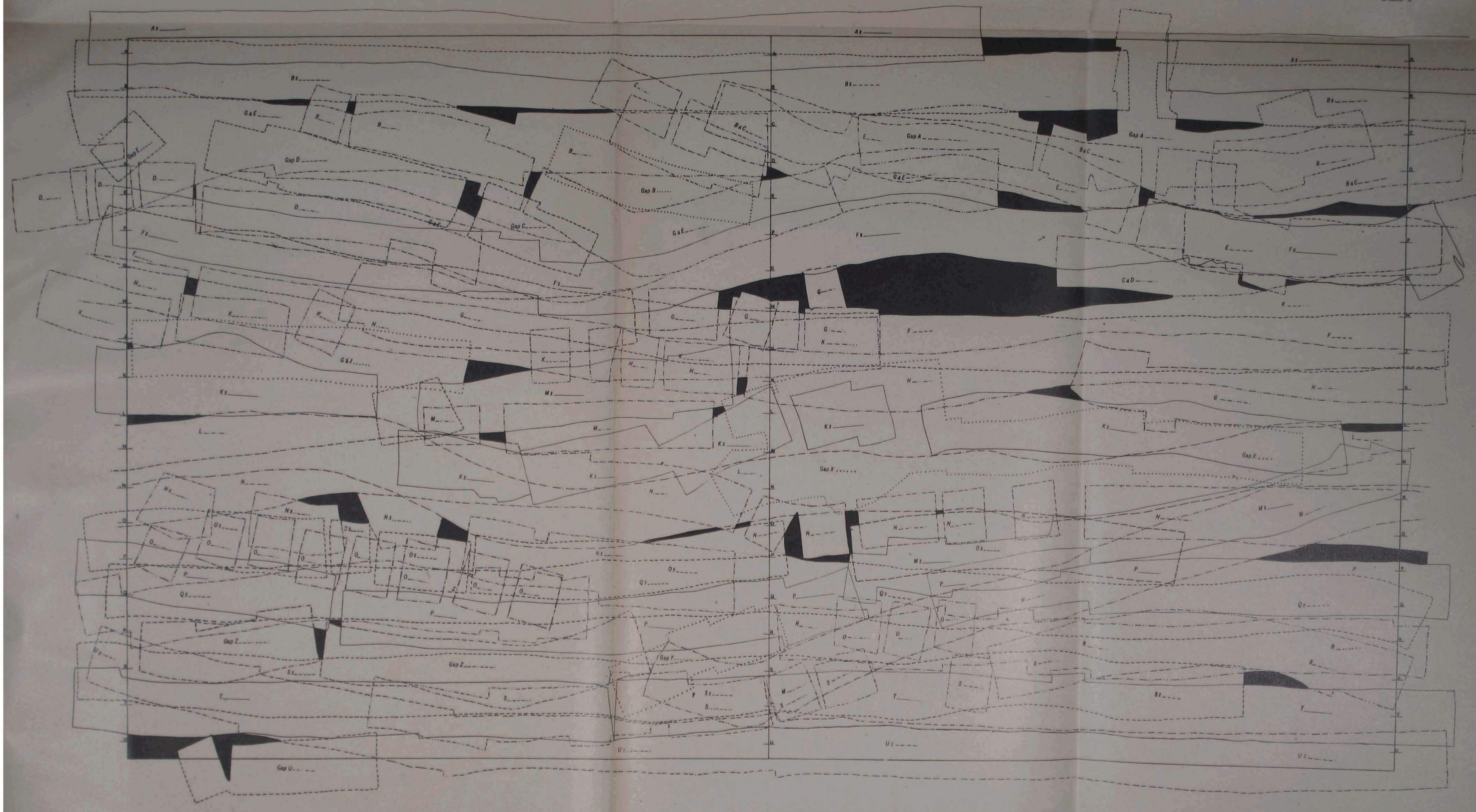
showing roughly

Courses of Aeroplanes & Areas covered by them

Sheet No. 54 $\frac{E}{12}$

Sheet No. 54 $\frac{E}{16}$

Plate I



Single letters (e.g. A, B, C etc.) indicate 1st attempt, the letter denoting the strip the pilot intended to cover.

Letters with the figures 2 after them (A 2, B 2 etc.) indicate 2nd. attempt at the strip denoted.

Combined letters (A&B, G&E etc.) indicate 3rd. attempt to fill gap between the strips denoted.

Scale 1 inch=2 Miles or 1:126,720.

Furlongs 8 4 0 1 2 3 4 5 6 7 Miles

Letters preceded by the word Gap (Gap A, Gap Z etc.) indicate attempts to fill remaining gaps - the letters having no connection with the strip letters. (4th attempt)

The letters down the vertical graticule lines show the centre lines of the courses the Pilots SHOULD have taken.

Final areas left uncovered, blocked in black.

DIAGRAM

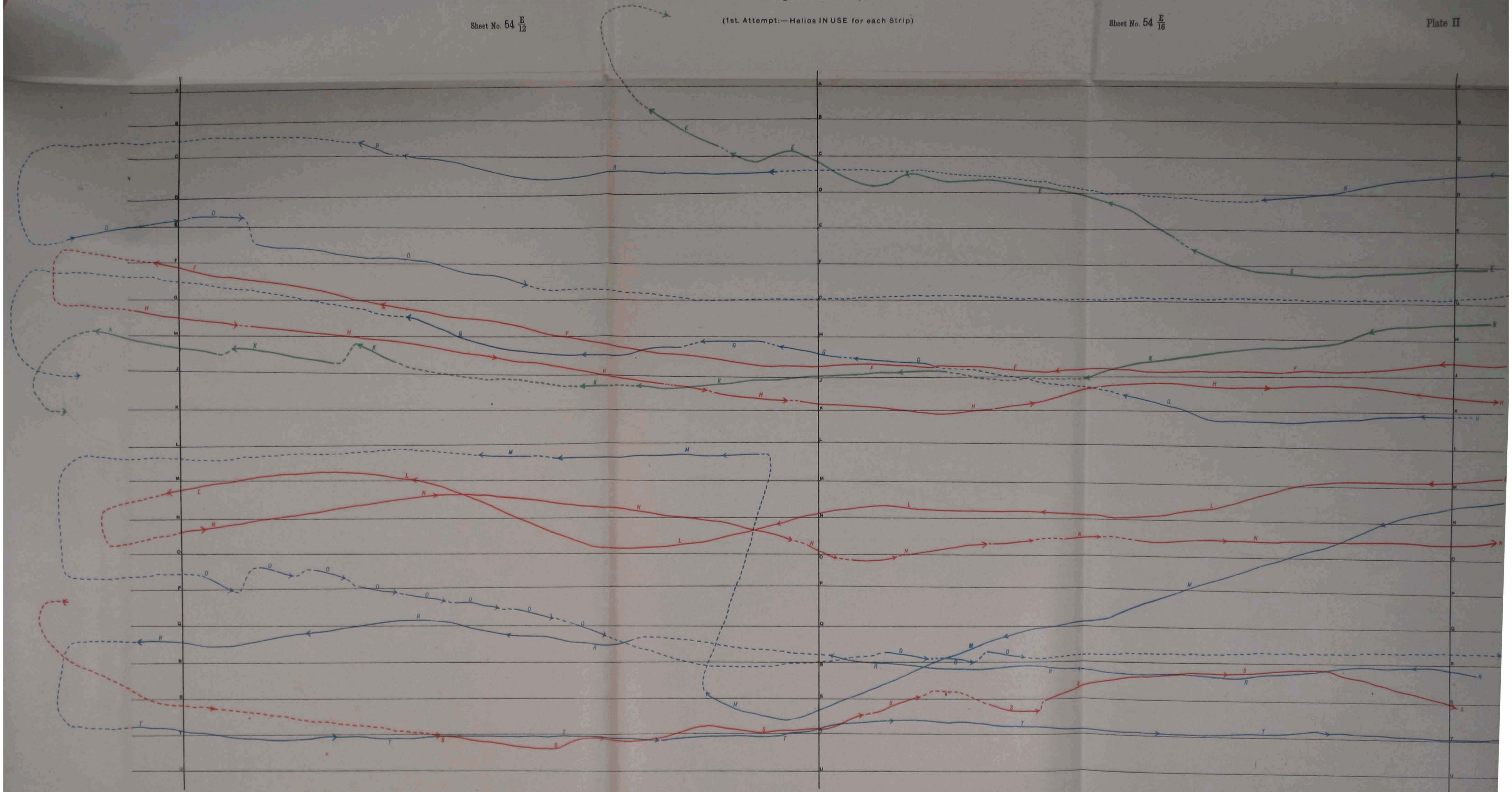
Showing Courses of Aeroplanes

(1st. Attempt:—Helios IN USE for each Strip)

Sheet No. 54 $\frac{E}{12}$

Sheet No. 54 $\frac{E}{16}$

Plate II



Courses not shown :—

A and C......................All photos were double exposures.

B and D......................Several camera jambs.

G and J......................No J owing to jambs.

P.................................All photos under-exposed.

Q and S......................Had to be repeated.

U.................................Pilot unable to locate position.

Scale 1 Inch = 2 Miles or 1:126,720.

Furlongs 8 4 0 1 2 3 4 5 6 7 Miles

Fine black lines and letters represent the courses that should have been followed.

Thick coloured lines and corresponding letters represent actual courses.

Dotted coloured lines represent gaps in the sequence of photographs.

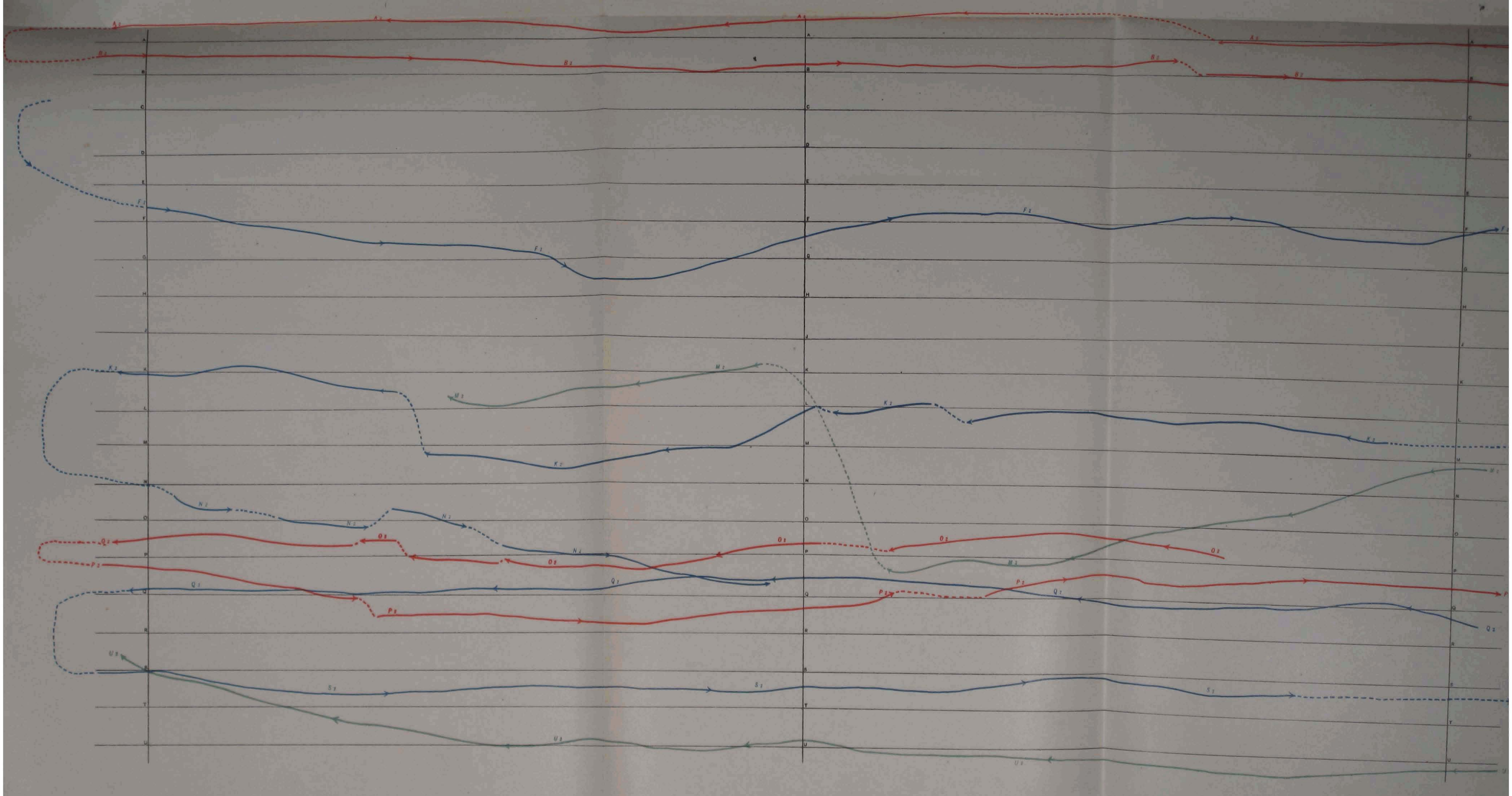
DIAGRAM

Showing Courses of Aeroplanes

(2nd Attempt:— Helios NOT IN USE)

Sheet No. 54 $\frac{E}{12}$

Sheet No. 54 $\frac{E}{16}$



Dotted coloured lines represent gaps in the sequence of photographs.

Courses A2, B2, Q2, S2 & U2 WITHOUT Helios were taken by the same pilot who took courses R and T in Plate II, i. e., With Helios.

Scale 1 Inch = 2 Miles or 1:126,720.

Furlongs 8 4 0 1 2 3 4 5 6 7 Miles

Fine black lines and letters represent the courses that should have been followed.

Thick coloured lines and corresponding letters represent actual courses.