Some Developments and Trends in Photogrammetry * *1946-1956-1966*

LYLE G. TROREY, *Ph.D.* (*Eng.*),
P.Eng., Consulting Engineer, Vancouver, B. C.

THE QUESTION: "*Would it not be possible to make use of the light—which paints pictures of the outer world on a photographic plate in an incredibly short time—to reconstitute an image in orthogonal projection from two or more . . . pictures . . . that is to say, to produce maps and plans from photographs by a direct and optical method?* (1)"

INTRODUCTION

THE assigned topic is, "trends and new developments in photogrammetry" changes which have taken place in the last decade, and a look at what effects these trends may have on the shape of things to come in the next ten years. To this the word "some" has been added, because only a small number of developments in only a few parts of the broad field are touched upon, these being confined mainly to personal experience in this region. The warning is given that opinions expressed in this paper are entirely personal ones.

Martin Hotine recently addressed the Photogrammetric Society of Great Britain under the title, "Forty Years On." (2) He says he chose this period, because forty years ago he had never heard of photogrammetry, and because in another forty years it will no longer bother him. I am required to deal with a shorter period. This is unfortunate, since within, the next decade, some of you may remember what I say today about the future and will call upon me for an explanation or a justification.

Brigadier Hotine injects a strong and welcome dose of common sense into this field of science fiction, striking out at some of our cherished ideals. He even goes so far as to suggest the heresy that we may be wrong in thinking everything new is so obviously right and, that everything that went before is, automatically, half-witted.

I, of course, would not dream of subscribing to such a radical idea.

THE ARITHMETIC OF SCALE AND HEIGHT

Scale varies inversely as the height of aircraft; so do line-miles of photography required to cover a given area. Stereoscopic ground-coverage, and number of frames in a given area, vary inversely as the square. Table I shows the effect of height of aircraft upon scale and cover, for the stated conditions. Columns 6 and 7 show $2\frac{1}{2}$, and 5 times the contact scale respectively. The multiplex works well at the column 6 scale; other instruments work well at 5X—which some authorities consider as being about the useful maximum.

The data in the table are very well known, of course but it is convenient to have the figures in mind in understanding the driving forces behind some of the developments and trends.

AUTOMATIC INSTRUMENTS AND (H-h), THE MAPPING FUNCTION

Ten years ago, 200 feet to the inch close-interval topographic mapping was compiled from 500 foot photography exposed at 3,000 feet; the multiplex was in common use.

Under present conditions flight altitude is doubled, 5,000 or 6,000 feet, and compilation is at, say, five times photo-scale, and commonly the Kelsh plotter is employed.

Looking at Table 1 the reason is apparent. The multiplex is not now economic for 200 foot compilation of an *area*. However a case can still be made for using multiplex in mapping a *strip* half or three-quarters of a mile wide and such use may be preferred.

The trend is to work at larger magnifications for the larger scales, and for some medium-scale work. At the 5X magnifica-

* Paper read at meeting at Puget Sound Section, A.S.P., Victoria, B.C., 4 December 1956.

TABLE I

EFFECT OF HEIGHT OF AIRCRAFT (*H-h*) UPON SCALE AND COVER. BASED ON 6-IN. 9×9, AND 22 SQUARE INCHES NET GAIN

1	2	3	4	5	6	7
H-h	Gain, square miles	Per 1,000 Square Miles		Scale, Feet to the Inch		
		1/mi.	Frames	Contact	$2\frac{1}{2}\times$	5×
3,000	0.2	1,700	2,500	500	200	100
6,000	0.8	850	1,250	1,000	400	200
12,000	3.2	425	312	2,000	800	400
15,840	5.5	330	182	2,640	1,000	500
20,000	8.8	260	114	3,333	1,320	660
31,680	22	166	44	5,280	2,000	1,000

tion obtainable in the Kelsh and, of course, in the higher instruments, the model is large, being in excess of four square feet.

To produce topography of standard accuracy at the higher *C*-factors, the model must have a base which is flat within close limits and improved air camera optics. Metrogon and similar lenses are being displaced by the Planigon and the very high-grade European lenses. These lenses are of low radial-distortion and, what is perhaps even more important, the manufacturing tolerances are closer. Accordingly lenses of the same family may be expected not to differ from one another by amounts commensurate with the precision of the plotter. Too, the resolution, particularly at the edges, is much improved. Also we may expect that the better lenses will completely displace the older ones in topographic work.

Ten years ago the choice was virtually between the multiplex or the very expensive high-order European instruments. The decade just passed has seen the development, and wide acceptance, of the Kelsh plotter. The Kelsh can work at 5X, and nicely at *C* factor of 1,200. Unless something of the same price class with better operational and performance characteristics is developed, the Kelsh plotter will be in increasingly wider use wherever compilation at 4 or 5X is economic. While it can be used for bridging, the plotter is a mapping tool and should be so used.

We have now, and will continue to get 3,333 feet to the inch, and inch to the mile, ordinary vertical photography. Much of this will be compiled at $2\frac{1}{2}$x contact scale and the use of multiplex will be continued. Modifications of the genus multiplex, with associated aerial photographic techniques, will be in wider use—particularly by Governments.

However excellent or costly a photogrammetric instrument may be and, however well the optical and scientific principles may be reduced to practice, it is the economic considerations which will determine whether or not that instrument will continue to be found in general use. The criterion is *cost*—cost per unit of area to produce standard accuracy manuscript by the instrument and the associated methodology, unit air and ground costs, plus man-hours per square foot of manuscript, plus machine-rate in dollars per hour. One seldom sees such figures published, and it is not proposed to release examples now. Sometimes such data are surprising to protagonists of a particular instrument or class of instrument.

CONTACT SCALE AND OTHER TECHNIQUES

Templet, sketchmaster, radial plotter, and the like. Ten years ago there was a great deal of such work being done with them. Now there is less; in ten years there will be still less.

There is in present use certain kinds of contact-scale planimetry, e.g. forest-type maps. With a 4-inch, or even 2-inch, publication scale, it is difficult to justify this procedure on economic grounds, except as an expedient, or in special cases. If the whole project is properly designed and executed, 4-inch base maps of altogether higher order may be obtained more cheaply by other means.

For very small-scale compilation, we used to use, or contemplate the use, of trimet. Now small-scale verticals are used.

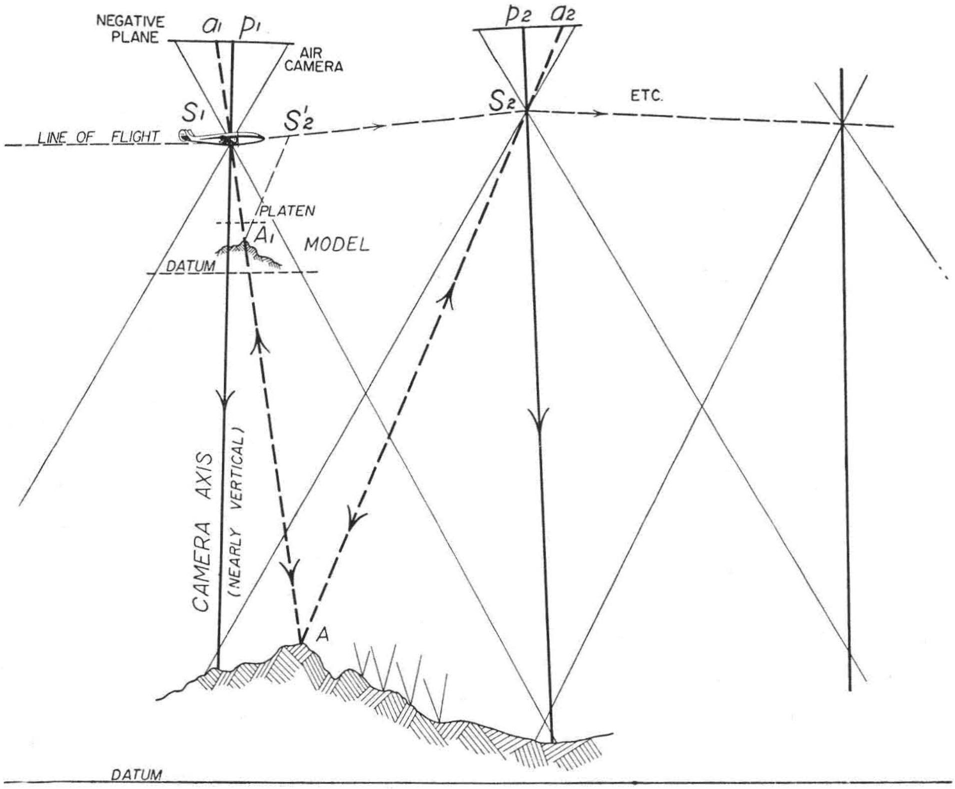

FIG. 1

Compilation is not instrumental. Contact-scale techniques with even some aid from simple parallax instruments and with strong assists from radar and photogrammetric control, are the trend. This trend may be expected to continue.

Rather low altitude horizon obliques were once widely used. Well known early operational techniques (e.g. the perspective grid) were developed at Ottawa and elsewhere. As the terrain of certain parts of Canada was particularly suited to the method, many areas were mapped at small-scale—mapped well and cheaply—from obliques.

A number of instruments were developed; mention will be made of only one, the Burns high-oblique plotter.* This early automatic instrument consists of a phototheodolite of more or less conventional form, at the perspective center, and a space rod mechanism and tracing pencil. By means of suitable handwheels, the cross-hair of the telescope can be made to scan detail of the oblique, and to cause the tracing pencil to produce (from obliques of suitable terrain) sensibly an orthogonal projection of that detail.

* The Burns responsible for this instrument, and for other important contributions in the science of photogrammetry, is General E. L. M. Burns, recently much in the public eye as Commander of the UN Forces in Egypt.

While the mapping use has virtually disappeared, there was in War II extensive military use in NWE of very low-altitude obliques exposed from fast aircraft, for such specialized purposes as measurement of height and slope of banks. (3) It is hoped, that these techniques will not again be required within the next decade. But they are ready if needed.

CONTROL

To go into first principles briefly, Figure 1, representing a line of aerial photography should be examined. The figure is a triangulation, the camera measures *angles*, nothing else. It is an automatic self-recording theodolite giving information on a piece of photographic film in the negative plane.

To solve triangulation, a distance or distances *must* be determined. The familiar means is measured on the ground with traverse triangulation and level.

But the distance from *S1*, etc., vertically to the ground can, in certain circumstances, be measured by radar to within a few feet. This may be used for horizontal control in substitution for traverse and triangulation on the ground.

Continuous measurement of ground clearance also gives, almost painlessly, a profile which is substantially a ground profile—to a datum of constant barometric pressure, in the absence of ground control.

Quite different are Shoran and other means of fixing the position of the aircraft at the instant of exposure. Triangulations —"trilaterations" is a better word—approaching first-order may thus be made.

The basis of these methods was developed during War II, and operational techniques were evolved. The post-war years have seen great strides, and certainly that progress will continue.

Going back to Figure 1, the strength of the triangulation shown (with given camera angle, e.g. 6-inch 9×9) depends only upon the precision at which the angles are recorded on the film, and the accuracy with which they may be recovered. Hence the further importance of the better lenses.

Mechanical solution may be by multiplex. Horizontally it is very good, within graphical limits, and not nearly enough advantage is taken of this. Vertically it is not as good, particularly off the center line.

The higher order European instruments come into their own on triangulation, and are capable of remarkable results. Here, too, the full possibilities are not nearly well-enough exploited. One notable exception is in the Dominion of New Zealand where, with geography not unlike that of the Pacific Coast Region, the practice in this respect is well advanced.

For a good many years analytical bridging techniques have been known. That is, triangulations calculated from photo-coordinate measurements. The great advantage is the possibility of cheap (comparatively cheap, that is) and simple instrumentation. The disadvantage *was* complexity of the computations, and this disadvantage sharply restricted its use. If my memory serves me, rightly, a competent trained team with mechanical computers would require some 16 man hours per overlap, with perhaps an additional 8 hours for checking.

There was recently published in Britain *Professional Paper* No. 20 (new series), "A Stereocomparator Technique for Aerial Triangulation," D. W. G. Arthur.(4) It is a complete methodology for analytical aerial triangulation programmed for high-speed computers, and has been described as the most important single piece of photogrammetric literature in many years.

At the moment the weak link is a suitable instrument capable of coordinate measurement commensurate with the precision of the new lenses. When this is at hand—it is well on the way now or said to be—we will have formidable bridging means. It is not necessary to spend an astronomical sum for a computer—this part of the work even now can be farmed out cheaply. The system—very simple operationally and well suited to production-line work—could displace the high-order instruments in the field of aerial triangulation.

Perhaps it will, even before 1966.

Analysis and Interpretation

FORESTRY

There is much to be said but I will not add to the remarks of Dr. Smith, Professor Moessner, and Mr. Swantje.

ENGINEERING

The field of engineering applications of photo-analysis and interpretation techniques is growing rapidly with applications to such as soil-mapping, surveys for engineering purposes, surveys for reservoir and damsite selection, and so on. Dr. Mollard has written an authoritative report on such uses.(5) His figures show a growth in seven years of ten times in the number of such studies carried out. Growth will continue but not for a long time at such a high rate. In ten years time, I believe there will be no thought of initiating a major engineering project without such a survey.

PHOTOGEOLOGY

This field is much older than the field of engineering-geology, and the present discussion is confined to a quick glance at some of the newer work. Table II shows the divisions of photogeophysical survey, according to Blanchet. The methods on the left hand side of the Table, under the main subdivision photogeomorphological survey, are mainly conventional and well known to most geologists. Quantitative photogeological survey (6) has reference to quantitative measurements such as strike and dip, and bedding thickness, directly on a multiplex or Kelsh model, and, of course, to contact print techniques of narrower application. Geologists and geological engineers generally, strangely enough, seem to have been slow in taking advantage of the simple instrumental techniques which have been available for a good many years. Expensive field time can thus be conserved, and of course, in certain cases photogrammetric data may be taken over parts of the area which could only be reached, on the ground, with the greatest difficulty and expense. Within the last year or two there has been a considerable increase in work of this kind, both by Government agencies, and by consulting geologists and the exploration departments of the major companies.

TABLE II

SUBDIVISIONS OF PHOTOGEOPHYSICAL SURVEY, AFTER BLANCHET IN (7)

Photogeophysical Survey						
Photogeomorphological Survey			Quantitative Photogeological		Fracture Analysis	
Drainage pattern analysis	Topographic analysis	Iso-compaction	Contact print techniques	Quantitative measurement on instrumental model	Structure intensity surveys	Fracture incidence surveys

We come now to fracture analysis photogeological techniques. The method is described in some detail in the reference given (7) and it is understood that a similar description will be included in the next edition of the MANUAL OF PHOTOGRAMMETRY. Very briefly, the analysis consists of tracing the minute fracture pattern (not always minute, of course) by stereoscopic examination of suitable photographs, semigraphical analysis and integration, to end up with fracture intensity contours, and other information, which—broadly—in certain circumstances gives information analogous to that obtained by seismic survey. So, in effect, we may have something like seismic survey from the air, as well as magnetometer and scintillometer survey.

The qualitative techniques of photogeological analysis and interpretation have been widely used for a long time—this of course is one of the major fields of application of the photogrammetric science. In the past the photogeophysical end has been neglected, at least insofar as the quantitative methods of Table II are concerned. Within the next ten years we may look to see the qualitative uses continue, and the quantitative uses increase.

FOREST MAPPING

A quarter of a century ago, early type maps were being compiled in Victoria, in the then Forest Surveys Division, under Fred Mulholland. There were available $8\frac{1}{4}$-inch, and some longer focal-length photography, much of which was quite close to optimum interpretation scale, as it happens. Photo-scale radial-line plots between control, direct tracing of planimetric and forest type detail, pantographic reduction to common scale: All of this in the office. Then the map went to the field where $1\frac{1}{4}\%$ sampling of productive areas was carried out. Looking back in the perspective of time, it is seen what an advance this was—and how much better the end product was—than that based upon extensive ground examination alone.

Planimetric type maps are still made by the direct descendant of this photogrammetric method—the slotted templet, radial plotter, and some form of reflecting instrument. This use may be expected to decrease, for reasons which have been given above.

LARGE SCALE TOPOGRAPHIC MAPPING UNDER DENSE FOREST COVER OF THE PACIFIC COAST FOREST REGION

The techniques have been developed primarily in connection with 400 feet to the inch, 25 foot V. I., for logging purposes.

On highway location, the problems are not the exclusive property of the logging engineer.

Work of this kind was done in British Columbia just after the war, at first from rather low-altitude photography, 8,000 to 10,000 feet. A great deal of trouble was experienced. Then from 12,000 to 14,000 feet, or even somewhat higher. This is little different from the present practice in this region and is not far from optimum. It was at this time that dual photography, simultaneous 6-in. and 12-in., was introduced. This photographic technique has met with continuing favor and is unlikely to change radically. The 12-inch at 1,000 to 1,200 feet to the inch for interpretation, and the 6-inch for the topographic base. The resultant 12-inch scale is close to optimum.

Then came the Kelsh. This gave the large scales we were trying to get with the original low-altitude photography—but with much less difficulty from relief as is to be expected. This procedure was stabilized for a number of years, with gradual improvement from experience, and with growing acceptance of the fact that, to attain optimum results, the operator must have knowledge of the ground being mapped.

There has been an important advance recently.

The method starts with changes in the aerial photographic system and pattern, and ends with instrumental use both of the 12-inch and the 6-inch. By these means there are obtained 12-inch photo centers and ground recognition points plotted in mutual sympathy, and in sympathy with finer topography, together with forest-type information, too accurately in sympathy with detail.

While it is out of place in this paper to describe the new technique in further detail, it may be reported that operational tests indicate that such technique will give better accuracy and improved rendition of minor detail, than heretofore. Like many developments of the last ten years, this for its father had War II operational techniques—but it seems to have taken the full ten years to grow to its present form.

My opinion is that this system will displace single-instrument compilation in applications where a higher standard of mapping is required under dense forest cover.

Conclusion

Perhaps the most striking postwar development in all parts of the field is—growth. As many of you know, the work of B. C. Air Survey Division started from nothing at the end of the war and its present size was reached within the last decade. This is perhaps an exaggeration and a misleading way of putting it, because "from nothing" does not take into account the pioneering and development work done by Col. Andrews before the war. All of the present air-survey development, both in the Air Survey Division itself and in the Forest Branch, stems directly from the work of those early days.

This growth is parallelled by that of the private companies since the end of the war, and by vastly augmented federal government services.

To go back somewhat further than the ten years under review, to 1865 in fact, we find Pujo and Fourcade asking the question at the beginning of this paper. The answer, as Scheimpflug so ably set about to prove thirty years later, is —

"*Yes, it is indeed possible to produce maps and plans from (air) photographs by direct optical methods.*"

References

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(3) Trorey, Lyle G. *Handbook of Aerial Mapping and Photogrammetry*, Cambridge University Press, New York, Chap. IV, 2nd Edition, 1952.

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(5) Mollard, John D. "Airphoto Analysis and Interpretation in Engineering-Geology Investigations," Parts I and II, *Engineering Digest*, Toronto, July and August 1956.

(6) Trorey, Lyle G., and Blanchet, P. H. "Quantitative Photogeology, Parts I and II," *Journal of the Alberta Society of Petroleum Geologists*, February and March 1955.

(7) Blanchet, P. H. Paper read to the C.I.M.M. at Vancouver, November 1956, for early publication.