How Accurate Is Aerial Survey? *

H. G. DAWE, *Manager,*
Survey and Production
Hunting Aerosurveys Ltd.,
London, England

THE speed with which modern development programmes can be executed today calls for a corresponding speed in the preliminary stages of survey and planning work. To carry out accurate surveys using ground methods alone is a costly and lengthy procedure involving large amounts of men and equipment. The answer to this need for speed in the preparation of maps and plans is the use of aerial survey techniques.

Many people tend to regard aerial survey as insufficiently accurate, particularly where large-scale plans are called for. The fact is, however, that the precision of modern photogrammetric equipment makes it possible today to set up aerial photographs in stereoscopic plotting machines with such exactitude that they may be observed and their details recorded entirely free from any form of distortion. The article on the opposite page[1] gives an indication of the precision of the modern survey camera—a precision which is fully maintained throughout every stage of the photogrammetric process.

In many cases photogrammetry has considerable advantages over ground survey methods, since it can provide a far truer representation of the actual shape of the ground. The smallest detail can be closely followed in the three-dimensional photographic "model" and contours can be observed at every point along their path. The accuracy of these contours can normally be guaranteed to within one-half of the interval; thus a specification calling for one foot contours implies (if it does not actually state) that the tolerance is plus or minus six inches. In other words, no contour deviates from its true path by more than half the interval. Ground surveyed contours, on the other hand, must be interpolations of a grid of spot levels, so that they cannot follow the exact shape of the terrain.

Variations in elevation, even violent ones, present no problem to the aerial surveyor, since differences in scale are automatically accounted for. The relationship between detail, say, on top of a cliff and at the bottom is recorded with the same precision as if they were on one horizontal plane. Furthermore, in the plotting instrument it is not necessary to follow a circuitous path to go from one point to another; where access to a site is difficult or dangerous, across electric railway lines, for example, the major part of the survey may be completed in complete safety.

Broadly speaking, surface levels on clear ground can be measured from aerial photographs to an accuracy of between 1/5,000th and 1/8,000th of the height from which they were taken. This means that photographs taken from an aircraft flying almost a mile above the ground will yield measurements in the plotting machine accurate to within one foot. From lower flying heights the accuracies will be proportionately increased, until the stage is reached where the photographic and photogrammetric aspects are no longer the limiting factors.

At this point, although plotting instruments are capable of finer measurements, they can be used only to record what the operator can actually see. For example, in conditions that permit measurements to a ± 2–$3''$ accuracy, the subject may be a stubbly field or an ill-kept front garden and observations must of necessity be made on the top of these features. In practice, an allowance may be made but under such conditions it is not possible to guarantee all heights to the accuracy of ± 2–$3''$. Only on clear hard surfaces can such an accuracy apply.

A further point concerns the scale at which the height data is presented. In a case where heights are required along a given line indicated on, say, an Ordnance Survey 1/2,500 plan, the ground surveyor can record heights to $\frac{1}{4}''$ accuracy-precision which the air surveyor could not hope to achieve. However, the leveller's stave could easily be moved by an amount not plottable at that scale to show differences in readings of as much as three to

[1] "Camera Calibration" by R. Hall, Research Officer, Hunting Aerosurveys Limited.

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six inches. In fact, then, a specification calling for $\frac{1}{4}''$ accuracy at that scale becomes meaningless.

Photogrammetry can always provide detail to within the plottable limits of the publication scale and complexity in detail-shape can be dealt with as easily as regularly laid out features. In large-scale surveys exhaustive field examination follows the photogrammetric plotting. Very often details which are required to be shown on large-scale plans are obscured in the vertical view from the air and in some cases are too small to register on the photographs. 1/480 railway plans, for example, include such details as signals, mile and gradient posts, telegraph poles, lamp posts, manhole covers, inspection pits, watercocks and notice boards, all of which are plotted to an accuracy of three inches. Where this type of detail is obscured it can be readily supplied on the ground by simple offset measurements. Normally, however, for 1/500 plans 80 to 85 per cent of the detail is plottable by photogrammetric methods.

It is well known that aerial survey depends in the first instance upon a network of ground surveyed control points so that overall rigidity of the survey is ensured by the precision of the field control rather than by any photogrammetric process. In the case of a strip road survey, for example, the accuracy of the total distance from end to end is a reflection of the accuracy of the basic field work. It has been found from experience that detail plotted from aerial photographs is in general at least as good as can be represented by field measurement and in many cases much better for scales up to 1/500 or 40′ to one inch.

It might be mentioned that there have been several occasions when the plotting instruments have detected errors in ground control for, within fairly close limits, the instruments will not accept faulty data and soon locate any anomalies. The photogrammetric process is, therefore, a check in itself carried out in the terms of the scale specified.

Perhaps the main difference between ground and air survey techniques—and one that on occasion has led to misunderstanding—is that the latter is normally designed right from the start to fit a given specification. The aerial surveyor must take into account the purpose for which the map is required and the accuracy specified, so arranging each stage of the survey—the flight altitude, type of camera and plotting process—to ensure the best possible results.

Planned for presentation at a specific scale, and based on a framework of sound ground control, there is no reason why aerial survey should not attain any normal standard of accuracy required. Each stage of the survey is carried out by extremely precise instruments and supplementary field checks provide any detail which may be in doubt. Where contours are required there is no doubt that it is superior to ground methods and in addition it has the considerable advantages of speed and economy of manpower.

The three basic advantages can be summarised as:

SPEED—*Once the photography is acquired plotting can proceed rapidly, utilising a number of machines if necessary.*

ACCURACY—*Maps prepared from aerial photographs can be as accurate as those prepared entirely by ground methods, and superior when true contour positioning is essential.*

ECONOMY—*The need for large teams of surveyors is eliminated. Costs are comparable with ground surveys and can on occasion be less.*

"How Accurate Is Aerial Survey?" An Explanation[2]

This article was originally published in the *Aerial Survey Review* earlier this year. Its purpose was to emphasise the accuracy of modern photogrammetric techniques and it was in no way intended as a reflection on the classical methods of surveying. To avoid any possible misunderstanding we would like to amplify some of the author's remarks:

(1) Mapping from air photographs is still dependent (and is likely to remain so for a very long time to come) on the control framework supplied by the field surveyor on the ground.

(2) For mapping at scales of say 1/5,000 and smaller there can be very few cases indeed where modern photogrammetric methods have not entirely supplanted those of the conventional "topographer." One exception to this rule is the use of ground levelling rather than photogrammetric contouring for areas of "flat" ground such as in an irrigation

[2] In a letter of June 15, Lord Pentland of Hunting Technical Services, Ltd. stated that a ground survey organization had complained that Mr. Dawe's paper was unfair to ground survey techniques and said that they felt very strongly about this. Lord Pentland stated that it was not Mr. Dawe's intention to make any direct comparison with ground techniques. However in view of the complaint it was requested that the herein-given explanation follow the reprint of the original paper. PHOTOGRAMMETRIC ENGINEERING is very pleased to take the suggested action—ED.

survey where the amount of levelling required to control the photogrammetric survey is almost equal to that required to provide a grid of spot levels dense enough to permit the interpolation of contours by eye.

(3) Again ground survey is essential for small-scale mapping of dense areas of forest or bush where trails, drainage, and even small villages may often be screened entirely from the aerial view and can only be supplied by running a traverse on the ground.

(4) As the scale of the plan becomes large so the work of the ground surveyor becomes increasingly important. At very large scales, say in excess of 30 ft. to the inch, it is usually advisable to do the whole survey on the ground, for the sake of both accuracy and economy.

(5) Ground survey is also preferred for the preparation of large-scale plans of very small areas where the cost of aerial photography is disproportionately high to the size of the job. The undisputed field of the ground surveyor must lie however in practically all work which involves setting out, including the running of lines of precise engineering levels.

(6) As regards the reference to $\frac{1}{4}$ inch accuracy becoming "meaningless" this does not, of course, refer to the many cases where levels are referred to precise ground marks, but to level information read off a plan and of which the accuracy is dependent on the scale of the plan. For instance, the nearest one can re-establish a given point on the ground from measurements taken on a 1/2,500 plan is $\pm$3–4 feet. Within this circle of location on uneven or sloping ground it is possible for the level to vary by an amount far in excess of the precision with which it is surveyed and its value marked on the plan.

*Considerations for the Design of a Projection Plotter**

J. A. EDEN,
Directorate of Overseas Surveys,
Kingston Bye-Pass,
Tolworth, Surbiton, Surrey, England

THE advantage of the projection plotter compared with the more complicated binocular instruments is its extreme simplicity.

Having examined a number of projection plotters of different makes, I am convinced that a cheap projection plotter could be built for plotting individual models with better performance and facilities than any existing projection plotters and with a working accuracy as good, if not better than any existing first-order plotter, except of course, the instrument would not measure machine coordinates or be convenient for air triangulation.

The design should feature the following points:

(1) Rotating shutter viewing should be employed. Compared with anaglyph viewing this system presents enormous advantages with regard to model clarity and definition, and obviates the necessity for spectacles.

(2) The instrument should be nominally distortion free and utilise full size 9″×9″ diapositives. Optimum projection should be between ×5 and ×6. The working table should be large enough to accommodate the whole of a ×6 projection. Allowing margins at front and back to accommodate the tracing table supports when working close to the model edge, the table width would need to be 62 inches. This is not too large to be conveniently worked from both sides.

(3) The projectors should be mounted so that the diapositives are held in an approximately vertical plane, and prisms should be provided in front of each lens to reflect the projections down vertically onto the horizontal working table. The advantage of this

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