*Significance of Photogrammetry in Highway Engineering**

WILLIAM T. PRYOR, *Chief of Aerial Surveys, Bureau of Public Roads, Washington, D. C.*

PHOTOGRAMMETRY is the modern "minute-man" in the New Highway Program, ready for performing survey services needed by highway engineers—ready to make it possible for these engineers to keep their surveys, designs, and preparation of plans on schedule so that highway construction may proceed as planned, and as made mandatory by the Federal-aid Highway Act of 1956.

For rapid accomplishment and for attainment of better results in highway engineering, photogrammetry has been placed in an important and significant position. By law, the Highway act gives recognition to this significance in Section 121, titled MAPPING, which stipulates "In carrying out the provisions of this title the Secretary of Commerce may, wherever practicable, authorize the use of photogrammetric methods in mapping, and the utilization of commercial enterprise for such service."

Not only has the Secretary of Commerce through the Bureau of Public Roads, done that which the law authorizes, but he has encouraged, and continues to encourage, the States to make the fullest use possible of photogrammetric methods in every stage of highway engineering. This encouragement is given because such methods are efficient, save time and manpower, and are sufficiently accurate and comprehensive, when properly used, for obtaining the qualitative information and the quantitative (dimensional) data needed in highway location and design, and in much of the other engineering work required for highways.

The Highway Act of 1956 went further than merely recognizing photogrammetry. It added to the definition of highway construction " . . . the establishment of temporary and permanent geodetic markers in accordance with specifications of the Coast and Geodetic Survey in the Department of Commerce." Also, the Act provides Federal funds to be matched by the States in the usual Federal-aid manner for making the basic control surveys to set geodetic markers along highway routes, and for mapping by photogrammetric methods. Thus the control surveys essential in all mapping by photogrammetric methods and the large-scale mapping necessary before any designs can be made and highway construction plans prepared, are amply provided for by the new highway law.

There should be no need for devoting a larger proportion of our efforts to persuasion than to performance in order to prove the usefulness and benefits of ample basic control and full use of photogrammetric methods in making surveys for highways. Our future efforts should be largely devoted to continuance of performance on schedule and in the scope and to the accuracies required, and also devoted to improvement of photogrammetric methods so that these methods will serve the highway engineering profession better than ever before.

We all realize that much of the progress made throughout the history of mankind has been accomplished in consequence of our outside pressures and our internal urges. In both the photogrammetric and highway engineering professions there are no exceptions to this principle. This is especially so with the two professions working together. And the present stepped-up highway construction program, the existing engineering manpower shortages,

* Introductory paper for Panel on Photogrammetry in the New Federal Highway Program at the 23rd Annual Meeting of the American Society of Photogrammetry, Shoreham Hotel, Washington, D. C., March 4, 1957.

and the constant urge to continue making progress are the combination of forces which have contributed to the recent rapid acceptance and use of aerial photogrammetry in highway engineering.

Now that its use in this field has become a reality, it is appropriate to consider the significance of photogrammetry in highway engineering. This can be done by making comparisons in a parallel manner.

Aerial photographs are perspective views. Examination and interpretation of aerial photographs provide the qualitative information, and photogrammetric measurement provides the quantitative data which are always required in highway engineering work. The type and quantity of information and data transmitted by the aerial camera for recording on photographic negatives is restricted only by scale and ground obscuring limitations.

Maps made from aerial photographs by photogrammetric methods are orthographic projections. They are accurate dimensional representations, containing whatever is placed on them.

As there are two general types of aerial photographs, vertical and oblique, there are also two general types of maps, topographic and planimetric.

Whereas planimetric maps contain only two dimensional representations, (length and breadth), of the earth's surface, topographic maps contain, in addition, a representation of relief, usually by contours.

With certain advantages and limitations, assemblies of vertical photographs to form photographic mosaics may be used as substitutes for planimetric maps or the planimetric features of topographic maps. Maps orthographically indicate accurate position of features; whereas photographic mosaics indicate only approximate position, as they contain image displacements caused by ground relief and the perspective characteristics of the aerial photographs used to compile them.

Aerial photographs are taken by instruments and are registered by the effect of light on chemicals. If the laws of instrumentation and chemical reaction are fully complied with, reliable records are obtained. Thus, aerial photographs provide the user of them with an adequate concept of the topography, its characteristics and condition, and the ground cover, drainage, and all types of land use.

Maps are compiled and reproduced by trained and experienced people, using special equipment. Results of their work are comparable in detail to the work of artists who make still-life representations with the pen or paint brush. Like an artist's landscape, maps reflect the intent and ability of the mapper who makes them; their completeness is dependent upon the type and amount of information he has at hand and chooses to see and use.

In their intricacies and scope maps, both topographic and planimetric, provide their users with only the details selected by the map compiler from the photographs and placed on the maps. If the compiler omits something, then the map users do not have it available unless they go to the source—aerial photographs or the ground—to fill in missing information. On the other hand, aerial photographs are pictures obtained in consequence of the extent to which light is available and used, and to the extent its impression is fully and reliably transmitted by a lens and captured by a photographic emulsion. Thus, aerial photographs are nearly all-inclusive, and maps are not.

When examined stereoscopically, aerial photographs provide a true concept of the three dimensional features of the ground. Topographic maps give a representation of relief. And only an experienced user of such maps can get any concept approaching that which is made possible by stereoscopic examination of photographs. The maps and photographs together, however, are companions which will provide complete qualitative information and quantitative data.

From small-scale photographs, broad and large topographic and land-use characteristics are easily determined and represented on small-scale maps with contours at large intervals. Finite details can be obtained only through taking large-scale photographs and preparing large-scale topographic maps with contours at small intervals. As a substitute for topographic maps, however, large-scale planimetric maps can be prepared; the third dimension required in highway design can be measured photogrammetrically and recorded and plotted as the vertical dimension of profile and cross sections of the route zone or band along which large-scale three-dimensional data are required.

Aerial photographs have adaptableness. They serve in times of need and where speed and reliability in attaining results

are of the essence. They will substitute for maps, and can be used with little or no equipment for attainment from them of most of the qualitative information which they will supply through stereoscopic examination and interpretation. They alleviate many of the difficulties of access and permit unrestricted traversing of any area to the extent required.

Maps are accurate to the extent precision is attained in compiling and reproducing them for use. The preparation of maps requires time, training, special experience and equipment, and knowledge of details needed in maps according to the purpose for which they are to be used. Many of the difficulties encountered in compiling and using maps cannot be circumvented except by going on the ground to verify conditions, or by examining aerial photographs which are the reliable comprehensive source of qualitative information and dimensional data lacking on maps.

Aerial photographs are not an end in themselves, but indirectly, when properly used, they are an exact means to an end. Maps, both planimetric and topographic, can be thought of as dimensional data only —ascertained to an exactness by either ground or photogrammetric surveys but having practical limitations—limitations caused by lack of understanding on the part of the map compiler of the purposes for which the maps are required, and will be used, and caused by the inadequacies of photogrammetric equipment and inaccuracies of ground surveys.

Maps of the earth and the things on it can be made from photographs through employment of proper techniques. But photographs of the earth and the things on it cannot be made from maps.

Aerial photographs, especially those taken in sequential periods of time, are an accurate record of conditions at the times taken, representable by shadows or lack of shadows, foliage, form and composition of the ground and land use, season of the year and climate, and photographic characteristics, patterns, and texture.

Maps are only relative measures of time periods and changes occurring as time passes. Changes in topography by the forces of nature are slow and limited. Changes in cultural features (land use) are varied and often fast—always occurring because of improvements or retrogression and decay. Topographic changes are natural. Land use changes are caused by the activities of man and nature.

Most of the topographic and land-use changes are not easily represented on, or interpreted from, maps of the usual sequential dates of preparation. This is so because of the time interval between separate map compilations, whereas the time interval between sequentially taken sets of aerial photographs is short or long as convenient, with inconsequential expense involved. The only requirement is proper planning and execution of photography. Consequently, aerial photographs are the means of accurately and conveniently measuring changes in a small interval or a large interval of time, but maps usually measure changes only at large intervals of time. Sequentially taken then, separate sets of aerial photographs are reliable substitutes for both place and time interval, either large or small.

Nature, in her processes of composition and in forming the shape and characteristics of the world, has provided an infinite number of patterns and forms. There are no symbols. Natural patterns are plentiful. Together, these patterns and forms constitute a universal language which must be understood and read to obtain all the information aerial photographs make available. This is equally true with regard to man's land-use developments and changes. An experience gained by diligent photographic interpretation will gradually and surely span differences in patterns caused by nature and man in their various processes of development and change.

In contrast, maps are only symbolizations of nature's forms and patterns, and of the various land uses of men. Maps with their symbols are the best representations devised by men to substitute for the universal language of forms and patterns. Map symbols are only indicative of nature's works and man's land use, and such symbols are as limited as man is limited in portraying all intricacies in the natural forms and patterns.

The amount and kind of qualitative information and the dimensional data obtainable from aerial photographs are comprehensive, that which is actually obtained from them is restricted only by the ability, methods, and desires of the user of the photographs. His ability to glean the information and data from the photographs is usually no greater than his interest,

training, experience, and conscientiousness. The amount and kind of information that can be obtained from maps, however, is restricted by the impossibility of representing on maps everything which is contained on photographs; by the purpose for which the maps were prepared; and by the abilities of those who contribute to preparation of the maps (surveyors, map compilers and cartographers) and users of the maps. Thus, there are many sources of variables in maps which means there are omissions and uncertainties in true representation and interpretation.

Aerial photographs, both oblique and vertical, are excellent illustrative mediums, particularly the obliques, because they provide a comprehensive view in perspective of the land and the things on it—the view to which we are all accustomed. Maps, even though they may contain contours to outline the shape of the ground at intervals to represent its successive levels, are still flat and unrealistic to most people. They only convey proper concepts to the experienced user.

With such comparisons in mind, it is possible for all of us to agree today that in the highway engineering field, photogrammetric methods of using aerial photographs, and of using maps compiled and measurements made photogrammetrically by use of the photographs are inseparable companions for supplying highway engineers with nearly all the information and data they require. And, to attain this full use of photogrammetry, highway engineers and photogrammetric engineers must have full mutual understanding of requirements, possibilities, and limitations in each profession.

I am sure that the panel members are well qualified to amplify these comparisons and give specific applications in many, if not all, of the specialites in highway engineering where photogrammetry and aerial surveys will serve efficiently, save time and manpower, and comprehensively provide, to the accuracies required, what is needed for the engineering of highways.

*Photogrammetric Engineering Firms' Contribution to the New Highway Program**

KENDALL B. WOOD,
K. B. Wood & Associates, Inc.,
Portland, Oregon

THIS paper will be somewhat provocative. I did not travel 3,000 miles merely to relate statistical data available to anyone in Journals and recorded legal documents. Such statistical material as I have is largely taken from the Federal Aid Highway Act of 1956, and from a paper by C. L. Miller, entitled "A Study of the Private Photogrammetric Mapping Activity in the United States."† Also I have made some slide-rule calculations and have drawn some conclusions. The prevailing context, however, will be largely the personal opinion of a practicing engineer—a man who has spent the last twelve years in pioneering, financing, undertaking, and completing some two-and-a-half million dollars worth of engineering project mapping by photogrammetric methods. This opinion *may* be representative of the professionally-staffed, medium-sized, photogrammetric engineering firm in the United States. I *am sure* it represents opinions of

† PHOTOGRAMMETRIC ENGINEERING, March, 1957, vol. XXIII, no. 1.

* Presented at 23rd Annual Meeting of the Society, Shoreham Hotel, Washington, D. C., March 3, 1957. This paper is a part of the Panel on Photogrammetry in the New Federal Highway Program.