PHOTOGRAMMETRY AIDS HIGHWAY ENGINEERS*

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PHOTOGRAMMETRY, the science of making reliable measurements on photographs, has advanced from a preliminary and experimental medium to an accomplished and reliable scientific tool that is proving invaluable to engineers for planning purposes. Prior to World War I, this country was slow to recognize the importance of the practical applications of photography being used in Germany, France, Italy and Switzerland. But our military intelligence experts foresaw reconnaissance possibilities, and following the war a number of pilots ventured their capital in search of additional ways to utilize aircraft in peacetime operations.

A few of these organizations survived the crash of 1929, but the period between World Wars I and II was rough on the development of new ideas. Financial crises always produce wary and skeptical businessmen. The small aerial companies existed by carrying mail, taking inquisitive people for Sunday rides and occasionally snapping pictures for industrialists and government agencies. In 1933 the Tennessee Valley Authority, staffed by an outstanding group of engineers and scientists, entered into a large aerial photographic and mapping program. The success of this work prompted other agencies to study the methods used and to marvel at the speed and accuracy of results.

The global requirements in World War II for mapping, charting and intelligence completely removed any doubts as to validity of aerial photographic methods. Since the war we have entered into a phase of tremendous development and use of photogrammetry.

Production of maps which can be used by engineers has required a vast amount of research in photographic equipment, mapping instruments and cartographic techniques. For example, the aerial camera used in mapping work now has become a highly precise instrument. The essential parts of the aerial camera are the same as in your own camera—lens, shutter, film and winding mechanism. However, in aerial mapping the slightest distortion of the camera lens becomes a troublesome source of error, and the research of the past few years has produced a far better lens in which all distortion values are known. In fact, a virtually distortion-free lens is now being produced, and it is hoped that this new development will be available in the very near future. The seating of the lens must be very precise in order to maintain a constant focal length. The photographic medium was originally glass plates; however, the development of the roll film in 1890 was a great help in simplifying aerial photographic problems. The big disadvantage of film has been unequal distortion, but research has kept pace with the requirements and a more stable film base has been produced to keep film shrinkage problems at a minimum. The aerial camera also must have the means for keeping the film absolutely flat at the instant of exposure, and collimation marks which appear on each photograph must be precisely placed. Auxiliary equipment to level the camera, a view finder and occasionally an automatic exposure device are also incorporated into the camera. The net result is a precision instrument which, when properly used, will produce aerial photographs which can be used in present day photogrammetric mapping instruments

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We point to the aerial camera, because of the importance of aerial photography in the production of your maps. The aerial photograph is the foundation of all subsequent mapping work. Unless the photograph is produced by a calibrated and tested camera in the hands of a thoroughly competent photographic crew, it cannot be used successfully for precision mapping. Do not underestimate the importance of an experienced photographer and pilot. The best instruments cannot be expected to perform properly unless they are handled by experts.

The transformation of the immense amount of information contained on the photograph into a map is accomplished by means of a combination of analytical and mechanical solutions of a spatial geometry problem. Aerial photographs are exposed so that a portion of the area of each photograph is also included within the field of view of each successive photograph in a strip. In fact, the forward overlap is usually approximately 60%, and between adjacent flight lines, the side-lap is about 25%. Overlap is secured in order to achieve the phenomenon known as "stereoscopic vision." This is the ability to see a third dimension. Our eyes provide this effect by viewing an object from two slightly different points of view, and images of the two impressions are transmitted to our brain. There a fusion of the images takes place, and we receive an impression of depth—a third dimension. In photogrammetry we temporarily substitute aerial photographs taken several thousand feet apart for our eyes, and when the photographs are oriented properly we see the hills and valleys in their relative heights and depths.

The stereoscopic plotting instrument combines our ability to see stereoscopically with a precise method of measuring the third dimension. In the plotting instrument it is necessary to orient the aerial photographs in exactly the positions they occupied at the instant of their exposure in the airplane. This is accomplished by referring to established ground control—both horizontal positions, which control scale relationships, and elevations, which assist in recovering the exact tilt of each photograph. The ground survey points must be identified on the photographs and are known as "photo-control points." This identification requires the services of highly skilled surveyors who are especially trained for this type of survey work.

The operator of present-day, precision stereoscopic mapping instruments is a highly trained and skilled person. He must have a thorough knowledge of his equipment, topographic mapping, and the technical ability to solve the problems of photogrammetry. His ocular acuity must be far above average (this can be achieved in a large measure by training). He must be a fair draftsman, a photo interpreter and a mechanic (for even the best instruments occasionally do not function properly).

The mapping instruments range in cost from $6,000 to $50,000. The more costly instruments are used in the most precise work; they establish control by photogrammetric means rather than strictly ground survey methods.

So it is that a topographic map is produced by photogrammetric methods. The accuracy of the map is a function of a great many factors: the altitude of the aircraft, the camera, the ground survey, the plotting instruments, and above all the experience and knowledge of the personnel used to operate the equipment. The National Map Accuracy Standards which have been adopted by our various government agencies require that 90% of the contours on a map should be accurate within one-half the contour interval. For example, on a map showing 5′ contours, 90% of the contours should be within $2\frac{1}{2}$ feet. For horizontal positions, they require that 90% of the well-defined map features should be correct

within 1/40 of an inch at the final map scale. For example, if the 5 foot contour map mentioned above is at a scale of 1 inch equals 200 feet, 90% of the points should be correct to 5 feet. These accuracies can be obtained in areas which can be clearly viewed on aerial photographs, but in places obscured by trees or heavy shadows, the accuracy requirements must be modified. You will be interested to know that topographic maps with a contour interval of one foot, at a scale of 1 inch equals 40 feet, have been prepared recently for one eastern State Highway Commission. The accuracy required was that 90% of the contours be dependable within $\frac{1}{2}$ foot! The Highway Commission rigidly checked the maps and accepted them as complying with the specifications. Usually highway maps are prepared for 2 foot contour intervals at a scale of 1 inch equals 100 feet, and at 5 foot contour intervals at a scale of 1 inch equals 200 feet.

Before ordering a topographic map, it is helpful to consult with representatives from reputable mapping organizations in order to review the problems to be encountered, the costs, and the relative accuracies required for a particular job. We feel that photogrammetric mapping is a professional engineering service. The map should be planned to fit the exact requirements, and acceptable results are best obtained through the services of highly trained and thoroughly experienced specialists in the problems of photogrammetric engineering. The entire mapping program must be planned. Just any old photographs cannot be used. The contour interval to be mapped largely determines the altitude of the photography, and photographs planned to produce 25 foot contours cannot, in general, be used for 5 foot contours. Good planning with the photogrammetric engineer can save time and substantial amounts of money.

Highway design engineers throughout the country are discovering that aerial mapping methods can produce topographic maps covering far larger areas than would be possible from ground surveys. Aerial maps are compiled at relatively low cost (approximately \$800–\$1,200 per mile for 5 foot contours at $1'' = 200'$) and within a short period of time. Now it is possible to study economically a number of alternate routes. Drainage and run-off investigations can be made through the use of wider bands of topographic maps and aerial photographs, and minute route research through congested areas can be made without disturbing entire communities. You are all familiar with the problems of the land speculators along a proposed route, and you know of the successful aerial mapping operations for our major turnpikes and various state highways. The continuing research and development of photogrammetric instruments and techniques is working in favor of even lower costs and greater speed of map production.

In addition to the production of topographic maps which are used to prepare highway location without extra field investigation, aerial photographs can assist the highway designer in many other ways. In preliminary investigations for possible routes between two terminals, high altitude (relatively small-scale) photographs should be obtained. A stereoscopic review of these photographs together with a topographic map having a large contour interval will enable the designer to select one or two rather restricted routes for further detailed studies. These studies can be made from lower altitude photographs and topographic maps prepared by photogrammetric methods.

Recently, extensive investigations prompted by military photo-intelligence experts have made it possible to investigate soil and rock conditions from photographs. Thus, in the preliminary aerial studies, it is possible to make very reliable determinations of all conditions to be encountered along a proposed route. These studies should not be neglected in highway planning of new routes.

Very low altitude photographs taken by a special type of camera known as the Sonne camera have been used to study the wear and tear on highways between stated time intervals. Traffic investigations involving traffic counts, movability, and urban and suburban parking can best be handled through the accurate medium of a permanent aerial photographic record. Construction progress and the preparation of releases for public relations and legislative reviews can be easily and graphically handled by aerial photographs. A well annotated aerial mosaic of a proposed route can show law makers in a simple and understandable terms the salient facts which often are lost in an involved engineering report.

These are only a few of the many, many practical applications of aerial photographs for your work. No doubt you can think of other problems that can be solved the easy way—by using photographs.

Photogrammetry has arrived and is available to assist you in the solution of your highway problems. It is now a highly specialized science which is being successfully used for the production of thoroughly reliable topographic maps for a multitude of engineering purposes. By coordinating your requirements with photogrammetric engineers you can obtain even more assistance in your problems than you may now envision. We welcome your suggestions and comments.

ANNOUNCEMENT

Inauguration of Bausch and Lomb Photogrammetric Award

THE Society takes great pleasure in announcing the establishment of an annual award to be known as The Bausch and Lomb Photogrammetric Award. The purpose of the award is "*to stimulate an interest in photogrammetry in college students in the United States and to recognize meritorious students who display outstanding ability and interest in photogrammetry.*" This is the first award of the Society for which students alone complete.

This preliminary announcement of the award is being made so that faculty members can call attention of their students to this award. Any regular student (undergraduate or graduate) in a recognized college or university in the United States is eligible for competition. The awards are to be made on the basis of papers of not more than 4,000 words in length submitted to the Society by the contestants. Such papers are to describe a new use of photogrammetry or of photogrammetric equipment, or an adaptation or improvement in the use of photogrammetry or of photogrammetric equipment to any field of study.

The papers submitted by the contestants will be judged 40 per cent on the basis of originality, 40 per cent on the basis of a demonstration of adequate comprehension of the photogrammetric principles involved in the equipment or process described, and 20 per cent on the basis of the organization and English used.

The award consists of a first prize of $100 cash and a three year paid-up membership in the Society, and two second prizes of $50 each plus one year memberships in the Society. The awards will be made annually.

The deadline for submission of papers each year is to be October 31. Further details concerning the award will be announced later. The preliminary announcement of the award in this issue of Photogrammetric Engineering is to give sufficient notice so students who may be graduating in June 1953 will have time to prepare papers for the competition.