*Photogrammetry Aids the Engineer**

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ABSTRACT: *The availability of new equipment and new methods has expanded the use of photogrammetric techniques. From the recent expansion of highway construction through many non-topographic uses, photogrammetry comes into wider recognition every day. The future of the "measurements from photographs" appears unlimited.*

THE science of Photogrammetry is providing the engineer with a rapid, economic and accurate means of obtaining reliable measurements for a wide variety of engineering projects. Through the use of aerial and terrestrial photography and the application of basic mathematical principles, the photogrammetric engineer is providing a wide variety of maps which are used in the design and construction of major engineer projects. In addition, the engineering profession has discovered that photogrammetric techniques and methods can be used in solving many other engineering problems where reliable measurements are required.

In the mapping applications, large and small-scale planimetric and topographic maps are prepared for the preliminary and final design of engineering projects which require a knowledge of terrain conditions or involve earth movement. In the non-mapping field, extensive investigations of soils, drainage, geologic structures and other basic engineering data may be secured by interpretation and measurement of features appearing on photographs. Considerable research has been conducted into the use of photogrammetric methods to measure deformations of engineering materials and the deflection of engineering structures. While the largest volume of applications of photogrammetry at the present is in the preparation of topographic and special purpose maps, nevertheless, the uses of photo-interpretation and other photo measurements are well established.

The work of the photogrammetrist involves the making of measurements upon photographs. The degree of precision with which these measurements may be taken is a function of the materials and equipment used to obtain the photographs, the acuity of the persons and instruments making the measurements, and the planning of the engineer assigned to the project to achieve the desired results. For these reasons, the photogrammetric approach to problems of mensuration requires careful and deliberate planning. The inherent properties of film, camera lenses (involving both distortion and resolution characteristics), identification of ground-control points, and the design, construction and operation of photogrammetric instruments must be studied and their values precisely established, if reliable photogrammetric measurements are to be achieved.

A photograph produces a flat record of the terrain or object which is viewed through the camera lens. Since engineering problems rarely deal with only two dimensions, a depth or height usually is an essential element. For example, the hills and valleys appearing on an aerial photograph are shown as if they were a flat unbroken surface. This is not an objectionable feature, and indeed this phenomenon leads to solving the third-dimension problem, through the medium of stereo-

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NOTE by Chairman of Publications Committee: With the objective of stimulating interest in photogrammetric applications to various scientific disciplines, especially those that are non-engineering, the Society presented a two-session symposium under the title "Photogrammetry in Science" at the 125th meeting of the American Association for the Advancement of Science in Washington, D. C. Mr. Quinn's paper and those which follow composed part of this symposium. Because many of the future applications of photographic measurements are expected to be in non-engineering fields, there is a continuing need to bring photogrammetric methods to the attention of other scientific disciplines and to bring the problems of those disciplines to the attention of the photogrammetrist. The Society continues to welcome the opportunity to publish scientific papers involving photogrammetry in the various sciences.

scopic vision. Man's ability to fuse into a single impression, two photographic views of a specific object or of the terrain taken from different exposure stations, enables him to see stereoscopically; that is, in the third dimension. In addition to this ability, the engineer has developed viewing instruments which permit making highly precise measurements, and converting the perpective images shown on a photograph to a true orthographic projection. Stereophotogrammetric instruments such as the Wild Autographs A-7 and A-8 and the Zeiss Stereoplanigraph C-8 provide the highest order of viewing and measuring accuracies. These precision instruments are calibrated to make measurements to one one-hundredth of a millimeter in both the horizontal and vertical planes.

Time does not permit a complete treatment of the fundamental principles of the photogrammetric problem. Perhaps it is sufficient to say that photogrammetry is concerned with the solution of problems of spatial geometry which determine the orientation and position of photographs and enable the engineer to extract a wide variety of data using a combination of analytical, optical, mechanical and electronic methods.

Measurements are made to and from identifiable images on the photographs, using either monoscopic or stereoscopic devices. Recently an electronic instrument has been developed which will scan overlapping photographs and provide measurements to common images, with an amazing degree of reliability. Unquestionably, many research projects now in progress will produce superior methods to obtain data from photographs rapidly and accurately. Completely automatic scanning and measuring instruments will be available within the next few years, and the solution of many photogrammetric problems will be handled by electronic computing machines. Increasing attention to films and photographic emulsions is essential to provide a highly stable and reliable base for recording photographic information. Cronar film recently developed by the DuPont Company provides a film base with characteristics almost equal to glass, and some of the new photographic emulsions and camera lenses make possible obtaining a high resolution of images. Color photography promises many interesting developments in photogrammetric techniques and uses.

The photogrammetric problem requires the recreation of geometric properties of the spatial model in the plotting or viewing instrument. However, if a mathematical solution is to be obtained, the analytical conditions of orientation must form a part of the computations. Displacements caused by camera tilt, topographic relief, accidental and systematic errors must be analyzed and corrected.

Engineering uses of photogrammetric maps encompass a tremendous range. The basic requirements for maps—planimetric, topographic and special purpose—call for reconnaissance and precise types of map data, and in many projects a combination of both is required. Varying aerial and ground procedures must be used to achieve the accuracies and requirements of each individual project. Since horizontal and vertical map accuracy, the scale, contour interval and content of the final maps are a function of flying altitudes, different aircraft and cameras are used from various heights. Field surveys are needed to establish ground-control points which are identifiable on the photographs. These points are used by the photogrammetrist in the solution of the spatial orientation of the aerial photographs.

As an example of the multiple requirements of an engineering project which can be solved by photogrammetric mapping techniques, Aero Service was called upon to provide basic surveys and maps for the construction of a 200-mile railroad through exceedingly rough and remote terrain in the Province of Quebec in Northern Canada. This railroad is to be used to transport concentrated iron ore to a water shipping point on the St. Lawrence River. The client established general engineering requirements for grade, curvature, speed, length of trains, etc. The original ore body had been located by an airborne magnetometer survey; while this is not a photogrammetric device, it is an important application of aerial techniques in exploration work.

Initial investigations consisted of photo-interpretation studies to determine a preliminary route. Existing reconnaissance-type photographs at a scale of 1:40,000 were found which covered a block area between the mine site and the possible port sites. These photo interpretation studies rapidly reduced the possible routes to four, and valuable information concerning the basic geology, soils, drainage and topography was secured from the photographs. At the same time, extensive photographic studies supplemented by field investigations were made to determine possible port sites.

Next, aerial photographs were obtained, using a precision camera at a scale of 1:60,000 along the four routes. Field parties working in sub-zero temperatures measured distances along the frozen lakes and established a number of elevations using altimeters. From these data reconnaissance maps at a scale of 1:12,000 showing 25 foot contours were prepared. Additional engineering studies were made using these photographs and maps and a limited number of actual field visits to the area. From this information it was possible to prepare preliminary cost estimates and to provide a valid means for evaluating each of the four routes. Estimates of earth qualities for cut and fill, together with studies for bridges, tunnels and other railroad structures were made. Then it was possible to select a general route for the railway.

The selected route was flown at a low altitude from which topographic maps at a scale of 1″=200′, showing 5 foot contours, were prepared. Horizontal and vertical-control for these maps was provided from a traverse and level line which was run generally parallel to the chosen route. The story of this field survey project and the surveys required in the final route location and construction would thrill the most ardent explorer—supplies were provided by airdrops, and the crews encountered almost unbelievable conditions of rain, snow and droves of flies and mosquitoes. However, they were in an area of most beautiful scenery complete with excellent hunting and fishing.

Because of the heavy coniferous tree cover in a portion of the mapped route, high standards of map accuracy were not possible throughout the length of the job. Nevertheless, these maps were used to make a closer determination of the final railway line. A preliminary or *P* line was established on the maps, and once again field crews were sent to the area to stake the *P* line on the ground, to check the 5 foot contours along the line, and to establish survey monuments and bench marks for the clearing, grubbing and construction operations. The revised and supplemented maps, together with detailed photo studies of soils, overburden and problem areas from the low altitude aerial photography, were used to make further refinements and adjustments of the final location.

Now construction work is underway, and as clearing and grubbing operations are completed, new low altitude aerial photographs are being taken. From these photos, cross-sections will be taken by photogrammetric methods. From these data, earth quantities will be determined; progress will be measured; and slope-stake locations, and other construction survey data will be processed by electronic computers. It is estimated that this method will afford substantial savings in both time and money, and will reduce the number of field survey crews required to handle the usual construction surveys and computations.

Variations of these methods are being used in the location of highways, pipelines and transmission lines. However, of basic importance is the increasingly important role of photogrammetry in speeding the solution of design and construction surveying and mapping problems. Many old-time engineers and surveyors are reluctant to accept the new methods; however, field checks of maps, comparisons of earthwork volumes as obtained by ground-survey and photogrammetric methods, and the usefulness of the basic-control established for photogrammetric mapping have softened the hearts of the most skeptical engineers.

Other engineering uses of aerial photogrammetric mapping techniques include the measurement of the volumes of coal and pulp wood piles for inventory, tax and operational purposes. In addition, similar data can be obtained for open pit mines and gravel pits. Maps are an essential part of the engineering profession, and the solution of the many and varied map requirements presents a continuous challenge to photogrammetrist.

Early European texts and articles have contained reports concerning non-topographic uses of photogrammetry. These applications range from problems in sculpturing to astronomy and encompass many interesting and complex situations. In general, the non-topographic work can be conducted under laboratory conditions whereby the problems of camera tilt, atmospheric conditions and the establishment of field control are eliminated. This has led to the development of special photogrammetric measuring instruments and techniques. Von Gruber* reported the invention and use of the Stereoplast by Bauersfeld in 1912. This instrument was manufactured for the sculptor, Selke, to reproduce statues and busts by stereophotogrammetric methods. Experiments and developments by Bauersfeld, Pulfrich, Von Gruber and others led to the solution of various non-mapping problems under laboratory conditions, and were the forerunners of the original first-order plotters that are in use today for aerial mapping projects.

The application of photogrammetric prin-

* Photogrammetry—Collected Lectures and Essays edited by O. Von Gruber—1942.

ciples to non-mapping projects does not require any change in fundamental approach. The fact that photographs may be taken under controlled conditions does provide the photogrammetrist with uniformly good pictures, and enables him to have predetermined camera tilt conditions.

Papers describing the recent developments of instruments and uses of non-topographic techniques and methods have been an important part of meetings of the American Society of Photogrammetry. The March, 1955, issue of "PHOTOGRAMMETRIC ENGINEERING" published by the American Society of Photogrammetry contains many papers presented at the 1955 Annual Meeting which record the recent progress in this most interesting field.

Professor K. B. Jackson of the University of Toronto has performed some valuable experiments in structural research in which he was able to compare the performance of curved plates subjected to axial loads, with the predictions of various mathematical solutions. The details of this work are recorded in Report No. NRC-ARI of the National Research Council, Ottawa, Canada. Other experiments in the structural field were reported by Dr. Bertil Hallert, under the title of "Some Experiences from Deformation Measurements by Photogrammetric Methods," published in PHOTOGRAMMETRIC ENGINEERING, December, 1954.

Successful work has been conducted in the measurement of the deflection, or yield, of highway pavements under various loads,* and terrestrial photogrammetric methods have been used in the study of glaciers in Greenland.† Studies of waves and wave action in changing shorelines and in the measurement of water depths were conducted during the war in an attempt to predict reliable landing beaches for invasion troops and military operations. The measurement of tree crowns to determine volumes has proven to be a reliable way of cruising timber.

In astronomy, photogrammetry has played an important role for a long time in determining stellar distances and in problems relating to the position and figure of the moon and other bodies. Unquestionably, photogrammetry will play an increasingly important part in the space and land measurements to be made from missiles and satellites.

European engineers have been able to reconstruct historic buildings destroyed by wartime bombs through the use of existing photographs. Recently an Egyptian engineer was given the task of reconstructing the old tombs to be flooded by the Aswan Dam. He solved these problems by taking a series of terrestrial photographs in the tombs to prepare engineering drawings, and to provide a permanent photographic record of each feature of these historic tombs.

These are but a few of the many useful applications of photogrammetric methods to various scientific problems. Unquestionably, the field for further uses and the development of new equipment and techniques is unlimited. To supply the demand for reliable measurements, research in the fields of optics, basic photographic materials and instruments, and photogrammetry must continue. The members of the American Society of Photogrammetry provide the nucleus for further research and development in these fields, and through the exchange of ideas with other scientists, we are confident that in addition to many and highly varied uses and values, photogrammetry will be an important tool in solving the space problems of the future.

* Turpin, Dr. Robert D., PHOTOGRAMMETRIC ENGINEERING, September, 1958.

† Jury, Harold—Graduate thesis, "An Application of Terrestrial Photogrammetry to Glaciology in Greenland."